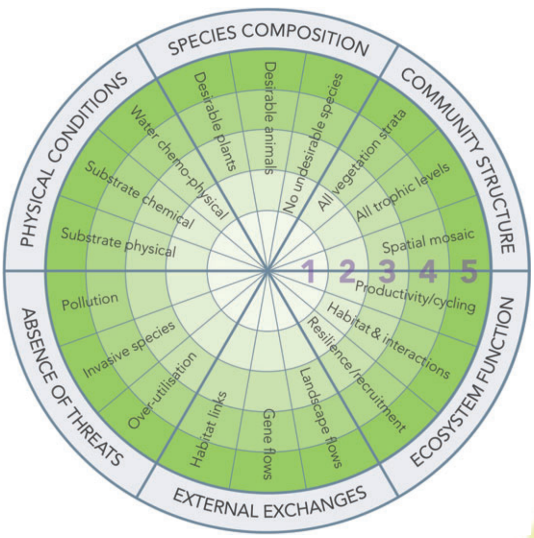
NATIONAL STANDARDS FOR THE PRACTICE OF ECOLOGICAL RESTORATION IN AUSTRALIA



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In consultation with key partners. March 2016

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

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We acknowledge the contributions of many agencies, researchers, industry bodies, contractors, and individuals whose comments on earlier versions improved the relevance and rigor of the Standards. While these people and organizations are too many to mention by name we particularly acknowledge the following people who contributed substantial information on genetics or environmental change: Andre Clewell, Linda Broadhurst, Nola Hancock, Lesley Hughes, Suzanne Prober, Margaret Byrne, Martin Breed, Andy Lowe, Nick Gellie, Siegy Krauss, Maurizio Rossetto, Ary Hoffman, Rebecca Jordan, Nigel Tucker, Trevor Booth and George Gann. Andre Clewell additionally contributed inspiration and ideas that led to the attributes list and recovery wheel shown in Figs 2 and 5; and the final draft was further improved by valuable comments from George Gann and Andre Clewell.

This Special Issue is sponsored by Curtin University and The University of Western Australia.

MINISTER'S FOREWORD

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

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

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

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

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

Restoration Ecology
THE JOURNAL OF THE SOCIETY FOR ECOLOGICAL RESTORATION

POLICY ARTICLE

National standards for the practice of ecological restoration in Australia

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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 means the continent possesses ancient soils and exceptionally diverse and unique biota—yet its terrestrial and marine ecosystems carry a more recent legacy of extensive and continuing environmental degradation, particularly in urban, industrial, and production landscapes and aquatic environments. Anthropogenic climate change is superimposing further pressure on ecosystems, whose vulnerability to climate change is exacerbated by other causal factors including land clearing, overharvesting, fragmentation, inappropriate management, disease, and invasive species. Degradation is so severe in most cases that it will not be overcome without active and ecologically appropriate intervention including mitigation of these causal factors and reinstatement of indigenous biodiversity.

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

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

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

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[This Special Issue is sponsored by Curtin University and The University of Western Australia.]

doi: 10.1111/rec.12359

SECTION 1 - INTRODUCTION

Definitions

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed (SER 2004[2]).

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

The Standards recognize that the same term "ecological restoration" can be used to describe not only a *process* (i.e. the activity undertaken) but also 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*—is interpreted here as meaning that all projects that aim to ultimately achieve **full recovery** relative to an appropriate local indigenous **reference ecosystem** can be considered ecological restoration *projects* regardless of the period of time required to achieve that state. Full recovery is defined as the state whereby all **ecosystem attributes** closely resemble those of the reference ecosystem. (For definitions of all terms, see the Glossary.)

The restored state can therefore only be considered achieved when the ecosystem's **attributes** are on a secure trajectory (pathway) to highly resemble those of the reference ecosystem without further restoration-phase interventions being needed. After the completion of the restoration phase, ongoing management interventions would be viewed as a form of ecosystem maintenance. 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, applying appropriate processes can help us to arrive at satisfactory outcomes.

Projects based on a local indigenous reference ecosystem but unable to adopt the target of full recovery are considered **rehabilitation** that, as described in Appendix 1, is especially encouraged and valued where it: (i) improves ecological condition or function and ii is the highest standard that can be applied. The Standards can be applied to rehabilitation to optimize outcomes. Only projects that are based on an appropriate local indigenous reference ecosystem are covered by the Standards.

The Ethic of Ecological Restoration

The ethic of ecological restoration is one of conservation, repair, and renewal (Appendix 2). There is a global recognition that local indigenous ecosystems are of high intrinsic biological, societal, and economic value but are diminishing in extent and condition. While protecting remaining ecosystems is vital to conserving our natural heritage, protection alone is not sufficient. Human societies are increasingly recognizing that we need to achieve a net gain in the extent and function of indigenous ecosystems through supplementing conservation with environmental repair.

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

Ecological Restoration in Australia—The Need for Standards

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

Important foundation documents exist that inform and guide ecological restoration, namely the SER International Primer on Ecological Restoration (SER 2004)—expanded upon in Clewell and Aronson (2013)—and the IUCN (International Union for Conservation of Nature) guidelines (Keenleyside 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 rich in unique species and ecosystems of extraordinary diversity and ecological complexity.

What Are the Standards and For Whom Are They Designed?

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

The Standards will be updated periodically or on a 5-year cycle as required. They are designed to be generic in nature and thereby compatible with more detailed guidelines and standards that may already exist or which are yet to be prepared for a specific aspect of restoration or a geographically distinct biome.

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

SECTION 2 - SIX KEY PRINCIPLES OF ECOLOGICAL RESTORATION PRACTICE

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

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

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

Australia's landmass, waterways, and marine areas contain many intact or remnant indigenous ecosystems. The site's pre-degradation ecosystems are used as starting points for

Box 1. Reference ecosystems in cases of irreversible human-mediated environmental change

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

1. *Irreversible physical (soil and water) and biological changes*. In cases where insurmountable environmental change has occurred to the site and the pre-degradation ecosystem cannot be reinstated, an appropriate solution would be to establish an alternative, locally occurring ecosystem better suited to the changed conditions. (Examples include sites where hydrology has changed irreversibly from saline to freshwater or vice versa, traditional fire regimes cannot be reinstated, or where erosion has produced a rocky platform.) This approach has in the past been called "creation" or "fabrication" but is more usefully labelled 'conversion'. Whether a particular conversion would be considered ecological restoration or rehabilitation depends on there being a reasonable likelihood of achieving a viable local indigenous ecosystem; the magnitude of the change; and social perceptions of compensation for loss or damage. That is, shifting to an alternative ecosystem would not be considered restoration or rehabilitation if it were used to sidestep addressing the physical conditions of a site—and is likely to be considered rehabilitation rather than restoration where irreversible change to an ecosystem is contemporary and deliberate (e.g. associated with a current industrial or urban development).

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

2. *Accelerated and irreversible climate change*. A changing climate means that all local ecosystems are likely to be changing at faster rates than in the past, in ways that are difficult to anticipate. Some entire ecosystems will be destroyed (e.g. many marine, coastal, alpine, and cool temperate communities) where no suitable migration habitats exist; while in other ecosystems, species may have a capacity to adapt by genetic selection or migration, options that are less likely under conditions of fragmentation (Appendix 3). Climate change is recognized as an anthropogenic degradation pressure that requires urgent and unfaltering mitigation of its causes, mitigation that needs to be embraced by the whole of society. Even with optimal mitigation, however, much of this change is irreversible and therefore becomes part of the environmental background conditions to which species need to adapt or be lost. To assist potential adaptation, target-setting needs to be informed by research into the anticipated effects of climate change on species and ecosystems so that reference ecosystems and restoration targets can be modified as required (Appendix 3).

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

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

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

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

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

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

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

Skillful assessment of capacity for natural recovery should be done prior to prescribing whether regeneration-based or reconstruction-based approaches are needed (Box 2). This is essential to optimise success but is also important to assist

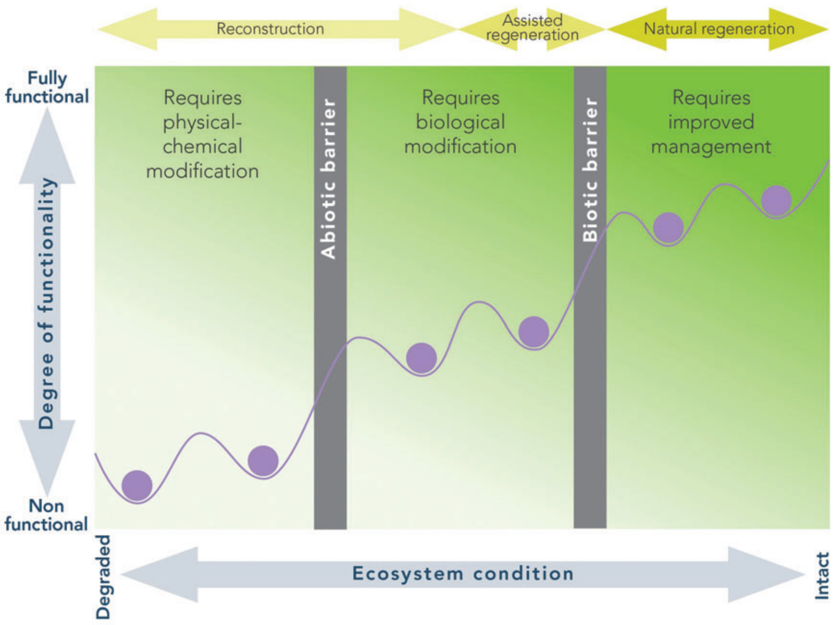

Figure 1. Conceptual model of ecosystem degradation and restoration (Adapted from Keenleyside et al. 2012, after Whisenant 1999, and Hobbs & Harris 2001). The troughs in the diagram represent basins of stability in which an ecosystem can remain in a steady state prior to being shifted by a restoration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

prioritization. That is, variation in the resilience of sites (and the higher cost of assisting recovery where the potential is lower) highlights the strategic advantage that can be gained by investing scarce resources into areas where resilience and potential for connectivity is higher.

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

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

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

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

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

Box 2. Identifying the appropriate ecological restoration approach

Correctly assessing the capacity of various parts of a site to recover facilitates the selection of appropriate approaches and treatments—avoiding inefficient use of natural resources or restoration inputs. A useful initial rule of thumb is to identify any potential for harnessing the natural regeneration capacity of a species (plant, animal or other biota) 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 relatively low, preexisting biota should be able to recover after cessation of the degrading practices. (Examples of degrading practices include removal of native vegetation, over-grazing, over-fishing, restriction of water flows, or inappropriate fire regimes etc.) Animal species may be able to migrate back to the site if connectivity is in place. Plant species may recover through resprouting or germination from remnant soil seeds banks or seed that naturally disperse from nearby sites.
2. **Assisted regeneration** approach. Recovery at sites of intermediate (or even high) degradation needs both the removal of causes of degradation *and* further active interventions to correct abiotic damage and trigger biotic recovery. (Examples of lower level abiotic interventions include reinstating environmental flows and fish passage, applying artificial disturbances to break seed dormancy, or installing habitat features such as hollow logs, rocks, woody debris piles, and perch trees. Examples of higher level abiotic interventions include remediating pollution or substrate chemistry, reshaping watercourses and landforms, building habitat features such as shell reefs, and controlling invasive plants and animals.)
3. **Reconstruction** approach. Where damage is high, not only do all causes of degradation need to be removed or reversed and all biotic and abiotic damage corrected to suit the identified local indigenous ecosystem, but also all or a major proportion of its desirable biota need to be reintroduced.

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

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

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

Box 3. Restoration monitoring and adaptive management

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

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

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

1. The most direct and critical form of monitoring for adaptive management is routinely inspecting the site to **identify whether restoration actions are working or need to be modified**. Such monitoring is undertaken by the project supervisor to identify any need for a rapid response and to ensure appropriate treatments can be scheduled before problems become entrenched. Additional inspections are also needed after episodic events such as storms, floods, fire, severe frost, and droughts.
2. The minimum formal monitoring required for adaptive management—and to provide **evidence to stakeholders and regulators that goals are being achieved**—is to maintain a photo monitoring record of the site being treated, using a fixed photopoint. All monitoring—even time-series photographs—needs to have evidence of "before" condition. This is because, once the whole site is treated, a photograph may be the only evidence that change has occurred. Photo monitoring at control (untreated) sites is also recommended, where possible. For larger sites, aerial photography may also provide useful before and after imagery.
   Well-funded projects (or projects under regulatory controls e.g. mine site restoration) are expected to undertake formal comprehensive monitoring for adaptive management and reporting to stakeholders. This usually involves professionals or skilled advisors and is based on a monitoring plan that identifies, among other things, monitoring design, time frames, who is responsible, the planned analysis, and frameworks for response and communication to regulators, funding bodies, or other stakeholders.
   The monitoring design of projects may involve development or adaptation of a condition assessment system or formal sampling system to track the progress of specific indicators, whether they be abiotic or biotic. In some cases, individual species or groups of species can function as surrogates for suitable abiotic conditions. For soil microorganisms, one or more quantitative determinants are used consistently throughout the life of the restoration project to ensure that the functional diversity of the microbial communities is restored in soils. Formal sampling of plant and animal populations can involve a range of faunal trapping and tracking methods or vegetation sampling using randomly located quadrats or transects. Design of such monitoring schemes should occur at the planning stage of the project to ensure that the project's goals, objectives, and their selected indicators are measurable and that the monitoring aligns with these goals. Care should be taken to ensure that the sampling commences prior to the commencement of restoration treatments, and where possible, control sites should be included in the design. If the necessary skills are not available in-house, advice should be sought from relevant professionals with experience in designing site-appropriate monitoring, documenting and storing data, and carrying out appropriate analysis.
3. Monitoring can be used **to answer questions** (hypotheses) about new treatments or the return of organisms or processes—but only if the data collected are well matched to the particular question and an appropriate experimental design is employed. A restoration project that is comparing or doing trials of techniques needs to observe the conventions of replication and include untreated controls in order to interpret the results with any certainty. Rigorous recording is also needed of specific restoration treatments and any other conditions that might affect the results. A standard practice in such a situation would be for the practitioner to partner with an ecologist or relevant scientist to ensure the project receives the appropriate level of advice and assistance. Where new treatments are being considered or where the nature of the site is uncertain, treatments first undergo trials in smaller areas prior to application over larger areas.

evaluate whether these targets, goals, and objectives are being met as a result of the interventions (Boxes 3 and 4, Appendix 4).

Principle 4. Full recovery is the goal of ecological restoration even if outcomes take long time frames

Qualification of a project as an ecological restoration activity is not determined by the duration of the project but by the intent to achieve full recovery relative to a reference ecosystem. In some cases this outcome may be achieveable in relatively short timeframes, while in other cases—even though restoration may be desirable and attainable—the outcome may take long timeframes. This can be because sufficient time has not yet elapsed for recovery processes to run their course; sufficient restoration resources or knowledge are not yet available to overcome recovery barriers; or, mitigating impacts originating from outside the site may require lengthy negotiation. To help managers track progress toward project goals over time, the Standards offer a tool (five-levels or "stars") for progressively assessing and ranking degree of *recovery* over time. This tool is summarized in Table 1 and more fully described, relative to the six attributes of ecological restoration, in Table 2.

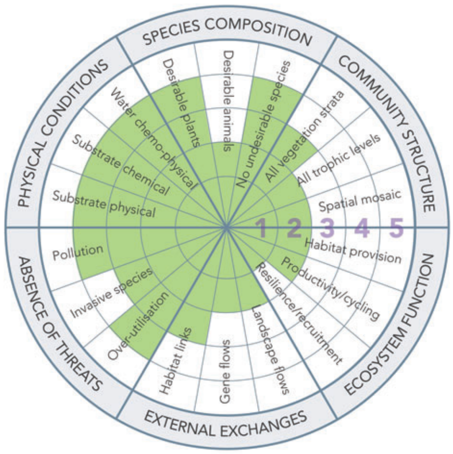

Figure 2. Progress evaluation 'recovery wheel'. This template allows a manager to illustrate the degree to which the project is achieving its ecosystem goals over time (in this case a hypothetical 1-year-old reconstruction site on its way to a four-star condition). A practitioner with a high level of familiarity with the goals and achievements of the project can shade the segments for each subattribute after formal or informal evaluation. (Blank templates for this diagram and its accompanying proforma are available in Appendix 5.) Notes: Subattribute labels can be adjusted or more added to better represent a particular ecosystem. The scores must be based on informal or formal monitoring indicators for the project. These should be identified at the outset of the project to provide ecologically meaningful information about the subattributes and attributes being finally evaluated.

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 five-star recovery in the long term, even if loosely based on an appropriate local occurring reference ecosystem, are better referred to as **rehabilitation** (Appendix 1). Such rehabilitation projects can, nonetheless, employ the five-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.

Notes for interpreting the five-star evaluation system.

1. **The five-star system has been designed to evaluate the progression of an ecosystem along its recovery trajectory.** It is not a tool for evaluating the quality of the work carried out by practitioners.
2. **The five-star system represents a conceptual gradient, providing a framework that can be interpreted by managers, practitioners, and regulators in more quantitative terms to suit a specific ecosystem**. The indicators described here are generic and provided as a guide only. This means that the indicators or metrics used to specifically describe and interpret recovery at each ranking level for a specific ecosystem need to be interpreted for each project.
3. **Evaluation can only be as rigorous (and therefore as reliable) as the monitoring that informs it.** As some projects

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

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

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

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

Hypothetical example:

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

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

i. An intact and recovering composition, structure, and function of remnants A and B within 5 years;
ii. 20 ha of revegetated linkages between the remnants within 10 years; and,
iii. 100% support of all stakeholders and neighbors within 5 years.

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

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

For other examples of some detailed indicators, see Appendix 4.

Table 1. Summary of generic standards for recovery levels 1–5.

Number of stars	*RECOVERY OUTCOME* (*Note:* Modeled on an appropriate local indigenous reference ecosystem)
1	Ongoing deterioration prevented. Substrates remediated (physically and chemically). Some level of indigenous biota present; future recruitment niches not negated by biotic or abiotic characteristics. Future improvements for all attributes planned and future site management secured
2	Threats from adjacent areas starting to be managed or mitigated. Site has a small subset of characteristic indigenous species and there is little if any internal threat from undesirable species. Improved connectivity arranged with adjacent property holders
3	Adjacent threats being managed or mitigated. A moderate subset of characteristic indigenous species are established and some evidence of ecosystem functionality commencing. Improved connectivity commencing
4	A substantial subset of characteristic biota present (representing all species groupings), providing evidence of a developing community structure and commencement of ecosystem processes. Improved connectivity established and surrounding threats being managed or mitigated
5	Establishment of a characteristic assemblage of biota to a point where structural and trophic complexity is likely to develop without further intervention. 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

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.

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

4. **Each restoration project does not necessarily start at a one-star ranking**. Sites that involve remnant biota and unaltered substrates will start at a higher ranking, while sites where substrates are impaired and/or biota are absent will start at a lower ranking. Whatever the entry point of a project, the aim will be to progress the ecosystem along the trajectory of recovery toward a five-star rated recovery.
5. **Though the aim is to achieve a five-star rating for all attributes in a restored system, full recovery of some attributes will be difficult to achieve at larger scales**. Complete removal of threats in a fragmented landscape or aquatic environment, for example, is usually beyond the scope of a site-specific restoration project but *mitigation* of these threats may be possible (e.g. pollution regulation, "no take" zoning, installation of nutrient filters ongoing control of pest species). Assessment of ongoing threat levels should be in place at the restoration site. If an attribute is not fully achievable, monitoring and reporting needs to indicate whether this is the result of external constraints and to what extent these are potentially resolvable.
6. **Evaluation using the five-star system and Figure 2 must be site- and scale-specific.** An evaluation will provide more detail when applied at the scale of an individual project or site. However, multiple evaluations can be aggregated to inform degree of recovery in larger programs. Where larger scale projects retain substantial areas of permanently converted industrial activity or urban development, scores will necessarily be lower. Nonetheless, in such situations additional detail in supplementary reporting can capture even low level gains at larger scales where these are important for some species or ecological processes. Similarly, in social-ecological systems, progress with important social outcomes of the project (such as increasing level of capacity and stewardship commitment by stakeholders) can be reported separately to capture social elements.

Principle 5. Restoration science and practice are synergistic

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

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

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

Table 2. Generic one- to five-star recovery scale interpreted in the context of the six attributes used to measure progress toward a restored state.

Attribute	*1-star*	*2-star*	*3-star*	*4-star*	*5-star*
Absence of threats	Further deterioration discontinued and site has tenure and management secured	Threats from adjacent areas beginning to be managed or mitigated	All adjacent threats being managed or mitigated	Larger scale threats starting to be managed or mitigated	All threats managed or mitigated to high extent
Physical conditions	Gross physical and chemical problems remediated (e.g. pollution, erosion, and compaction)	Substrate chemical and physical properties (e.g. pH and salinity) on track to stabilize within natural range	Substrate stabilized within natural range and supporting growth of characteristic biota	Substrate maintaining conditions suitable for ongoing growth and recruitment of characteristic biota	Substrate exhibiting physical and chemical characteristics highly similar to that of the reference ecosystem with evidence they can indefinitely sustain species and processes
Species composition	Colonizing indigenous species (e.g. ~2% of the species of reference ecosystem); no threat to regeneration niches or future successions	Genetic diversity of stock arranged and a small subset of characteristic indigenous species establishing (e.g. ~10% of reference); low threat from exotic invasive or undesirable species	A subset of key indigenous species (e.g. ~25% of reference) establishing over substantial proportions of the site, with nil to low threat from undesirable species	Substantial diversity of characteristic biota (e.g. ~60% of reference) present on the site and representing a wide diversity of species groups; no inhibition by undesirable species	High diversity of characteristic species (e.g. >80% of reference) across the site, with high similarity to the reference ecosystem; improved potential for colonization of more species over time
Community structure	One or fewer strata present and no spatial pattering or trophic complexity relative to reference ecosystem	More strata present but low spatial pattering and trophic complexity relative to reference ecosystem	Most strata present and some spatial pattering and trophic complexity relative to reference ecosystem	All strata present Spatial pattering evident and substantial trophic complexity developing, relative to the reference ecosystem	All strata present and spatial pattering and trophic complexity high Further complexity and spatial pattering able to self-organize to highly resemble reference ecosystem
Ecosystem function	Substrates and hydrology are at a foundational stage only, capable of future development of functions similar to the reference	Substrates and hydrology show increased potential for a wider range of functions including nutrient cycling, and provision of habitats/resources for other species	Evidence of functions commencing, e.g. nutrient cycling, water filtration and provision of habitat resources for a range of species	Substantial evidence of key functions and processes commencing including reproduction, dispersal, and recruitment of a species	Considerable evidence of functions and processes on a secure trajectory toward reference and evidence of ecosystem resilience likely after reinstatement of appropriate disturbance regimes
External exchanges	Potential for exchanges (e.g. of species, genes, water, and fire) with surrounding landscape or aquatic environments identified	Connectivity for enhanced positive (and minimized negative) exchanges arranged through cooperation with stakeholders and configuration of site	Connectivity increasing and exchanges between site and external environment starting to be evident (e.g. more species, flows, etc.)	High level of connectivity with other natural areas established, observing control of pest species and undesirable disturbances	Evidence that potential for external exchanges is highly similar to reference and long term integrated management arrangements with broader landscape in place and operative

Note: This five-star scale represents a cumulative 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 monitoring metric specific to their system and ecosystem type.

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

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

Principle 6. Social aspects are critical to successful ecological restoration

Restoration is carried out to satisfy not only conservation values but also socioeconomic values, including cultural ones. Without considering these values, particularly relationships between a site and its stakeholders, a restoration project may not gain the social support needed for success and may fail to deliver important benefits to ecosystems and to society.

Few ecosystems are without human influence—whether positive or negative. Some human-induced disturbance regimes are intrinsic to the structure and function of a local indigenous ecosystem (e.g. indigenous fire management regimes that have long exposed sites to fire or protected them from fire); while others can progressively erode ecosystems or shift them to cultural ecosystems. This means that values and behaviors of humans (whether positive or negative) will dictate the future of ecosystems. Conserving and restoring ecosystems therefore depends upon appreciation by society of the negative and positive effects of different behaviors, and involvement by all stakeholders in finding solutions to ensure that ecosystems and society mutually prosper.

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

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

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

SECTION 3. ACTIVITIES AND THEIR PERFORMANCE LEVELS REQUIRED IN PROFESSIONAL ECOLOGICAL RESTORATION

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

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

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

1. **PLANNING AND DESIGN**

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

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

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

1.2.2 Identify ways to align habitats at the restoration site to improve external ecological connectivity with the surrounding landscape or aquatic environment to optimize colonization and gene flow potential between sites.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1.5.1 Restoration **target**—reference ecosystem (including description of ecosystem attributes);
1.5.2 Restoration **goal**(s)—the condition or state of that ecosystem and attributes that are aimed to be achieved;
1.5.3 Restoration **objectives**—i.e. changes and immediate outcomes needed to achieve the target and goals relative to any distinct spatial zones within the site. Such objectives are stated in terms of measurable and quantifiable indicators to identify whether the project is reaching its objectives within identified time frames.

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

Plans should include:

1.6.1 Descriptions of actions to be undertaken for elimination and mitigation of (or adaptation to) causal problems.
1.6.2 Identification of (and brief rationale for) specific restoration approaches, descriptions of specific treatments for each zone, and prioritization of actions. Depending on the condition of the site, this includes identification of:

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

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

1.7.1 Security of tenure of the site to enable long-term restoration commitment and allow appropriate ongoing access and management.
1.7.2 Potential for adequate arrangements for ongoing prevention of impacts and maintenance on the site after completion of the project to ensure that the site does not regress into a degraded state.

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

1.8.1 Identifying funding, labor (including appropriate skill level), and other resourcing arrangements that will enable appropriate treatments (including follow-up treatments) until the site reaches a stabilized condition.
1.8.2 Undertaking a full risk assessment and identifying a risk management strategy for the project, particularly including contingency arrangements for unexpected changes in environmental conditions or resourcing.
1.8.3 A rationale for the duration of the project and means to maintain commitment to its aim, objectives, and targets over that period.
1.8.4 Permissions, permits, and legal constraints applying to the site and the project.

1.9 Review process scheduling. Plans include a schedule and time frame for:

1.9.1 Stakeholder and independent peer review as required.
1.9.2 Review of the plan in the light of new knowledge, changing environmental conditions, and lessons learned from the project.

2. **IMPLEMENTATION**. During the implementation phase, restoration projects are managed in such a way that:

2.1 **No further and lasting damage is caused by the restoration works** to any natural resources or elements of the landscape or waterscape that are being conserved, including physical damage (e.g. clearing, burying topsoil, trampling), chemical pollution (e.g. over-fertilizing, pesticide spills) or biological contamination (e.g. introduction of invasive species and pathogens, 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 are undertaken in a manner that is responsive to natural processes and fosters and protects natural recovery**. Primary treatments including substrate and hydrological amendments, pest species control, application of recovery triggers, and biotic reintroductions are adequately followed up by secondary treatments as required and appropriate aftercare is provided to any planted stock.

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

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

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. They regularly assess and analyze progress to adapt treatments (adaptive management) as required. Partnerships with research bodies are sought in cases where innovative treatments or treatments applied at a large scale are being trialled and to ensure all necessary research permits and ethical considerations are in place.

3.1 **Monitoring** begins at the planning stage with the development of a *monitoring plan* to identify success or otherwise of the treatments (see also Boxes 3 and 4).

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

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

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

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

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

3.2 **Adequate records of treatments and all monitoring are maintained** to enable future evaluation.

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

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

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

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

3.3.2 Results are used to inform ongoing management.

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

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

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

4. **POST-IMPLEMENTATION MAINTENANCE**

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

SECTION 4 - GLOSSARY OF TERMS

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

Abiotic: Nonliving materials and conditions within a given ecosystem, including soil, rock, deadwood, litter or aqueous substrate, the atmosphere, weather and climate, topographic relief and aspect, the nutrient regime, hydrological regime, fire regime, and salinity regime.

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

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

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

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

Barriers (to recovery): Factors impeding recovery of an ecosystem attribute.

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

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

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

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

Composition (of an ecosystem): The array of organisms within an ecosystem.

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

Conversion: Shift to an alternative local indigenous ecosystem (whether through construction or natural regeneration approaches) where current conditions are so degraded that they 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). Elsewhere, the terms 'creation' or 'fabrication' have been used to describe this.

Creation: See "Conversion".

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

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

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

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

Destruction (of an ecosystem): Complete removal or depletion of an ecosystem.

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

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

Ecosystem: Small- or large-scale assemblage of biotic and abiotic components in oceans, rivers, and on land in which the components interact to form complex food webs, nutrient cycles, and energy flows. The term ecosystem is used in the

Standards to describe an ecological community of any size or scale.

Ecosystem attributes: See Attributes.

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

Environmental repair: Any intentional activity—including mitigation, rehabilitation and ecological restoration—that improves ecosystem functionality, ecosystem services, or biodiversity.

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

Fabrication: See "Conversion".

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

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

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

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

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

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

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

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

Management (of an ecosystem): A broad categorization 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: Any activity of reducing impacts—in this Standards particularly referring to works to protect ecosystems from impacts arising from human settlement and production.

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

Nonmandatory restoration: Restoration that is voluntary rather than required (mandated) by a government, regulatory authority, or court of law.

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

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

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

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

Reconstruction: A restoration approach where the appropriate biota need to be entirely or almost entirely reintroduced as they cannot regenerate or recolonize within feasible time frames, 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.

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

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

Regeneration: See **natural regeneration** and **assisted regeneration.**

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

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

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

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

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

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

Seed production area: A site used for the production of bulk quantities of high-quality seed of known origin, quality, and appropriate genetic diversity for replanting or direct seeding onto restoration and rehabilitation sites.

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

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

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

Spatial patterning: See **spatial mosaic**.

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

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

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

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

Threat: A factor potentially or already causing degradation, damage, or destruction.

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

Trajectory (ecological): A course or pathway of recovery or adaptation of an ecosystem over time.

Transform: Shift to a different ecosystem, in this Standard, specifically referring to an agro-ecosystem or urban ecosystem.

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

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

Trophic levels: Levels in food webs, with greater complexity usually being characteristic of a more mature ecosystem.

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Appendix 1. Relationship of ecological restoration to other environmental repair activities

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

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

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

Ecological restoration is the appropriate means of repairing damage in natural areas wherever it is attainable and desirable, irrespective of zone. In production and urban zones however, many areas have undergone extreme and extensive past modification and the lands and waters within them may be of high economic or cultural value. This can make ecological restoration undesirable or unattainable in such cases. Here the next "highest and best" level of repair should be aspired to—termed here as **rehabilitation**. Improved environmental management activities in already transformed production and urban areas (termed here as **mitigation**) are critical to the success of all ecological restoration and rehabilitation, as even intact ecosystems are affected by how we live and work. That is, substantial improvements in the ecological sustainability of urban and production zones are needed to reduce society's impacts on biodiversity, soils, water, air quality, and climate—thereby securing long-term rehabilitation and ecological restoration.

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

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

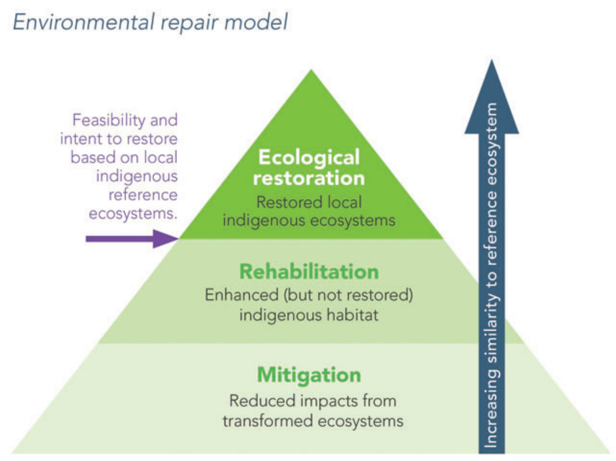

Figure 3. Broader context of "environmental repair." Ecological restoration fits within a range of complementary activities undertaken by various sectors of society to repair damage to the broader environment, with the broader context referred to in the Standards as "environmental repair." The pyramid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

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 a highly significant ecological 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 five-star system of recovery.)

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

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 what would be defined here as 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 what would be defined here as ecological restoration, with many adopting and aspiring to this goal voluntarily.

Ready-made, off-the-shelf post-mining restoration solutions 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 on remade substrates and landscapes. 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 process. 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 is provided of the capacity of the company to deliver timely restoration that includes understanding landform, soil creation (where topsoil is limited), topsoil protection (to enhance biological and seed preservation), propagation needs, recalcitrant biota, seed supply and storage requirements, seed dormancy alleviation and “germination on demand,” precision seeding, hydrological support for establishment plants, weed and feral animal controls, and nutritional and pollination needs of plants.
- 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.]
- Safeguards are in place to ensure that industry economic down-turns or defaults by development companies do not result in a failure to restore a site to the agreed closure standard.

Where mining is undertaken in natural areas, the highest standard of ecological restoration is expected by society as exemplified in the regulatory process. In seminatural 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 three-star recovery condition. Where mining occurs on converted landscapes, there is an expectation that mine site rehabilitation achieves a safe, stable, and ecologically sustainable utilitarian condition which provides ecosystem services and lowers rather than raises impacts on natural systems (i.e. “rehabilitation” as defined in this document).

Reforestation for timber production or carbon storage

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

Forestry should consider using local indigenous species and higher diversity models wherever feasible. Carbon farming adjacent to natural habitats should be encouraged to adopt a five-star recovery goal, using the natural habitat as a reference ecosystem. Where this is not possible, as high a recovery ranking as practicable should be the goal. If lower goals are applied for good reason, the revegetation should be undertaken in a manner that enhances ecosystem services and has no deleterious effect on the adjacent natural areas and does not preempt potential for further recovery if it is possible in the future.

Agricultural lands

Agricultural lands occupy large areas of Australia with many farms and rangelands containing substantial indigenous habitats. Over recent decades, many landholders have been restoring and rehabilitating remnant habitats on farmlands and in rangelands, particularly through Landcare and often with coinvestment from governments through regional natural resource management (NRM) organizations. 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 four-star or five-star recovery on a range of attributes. Many others, particularly larger projects, however, have only achieved three-star recovery and may or may not be able to progress further due to resource constraints and the irreversibility of some causal factors including fragmentation. Whether the *latter projects can be considered ecological restoration or rehabilitation depends on whether the landholder (with or without support from an agency/organization) can make the necessary commitment to contribute land for linkages to allow comprehensive recovery (five-stars) in the medium to long term.*

Whatever the case, landholders, Landcare groups, regional NRM organizations, 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 prioritization of more resilient and strategically important areas.

Aquatic ecosystem management

Restoration and rehabilitation of freshwater, estuarine, and marine habitats is underway in Australia, yet more is needed. Such activities protect aquatic species, habitats, and carbon stores (e.g. within rivers, lakes wetlands, kelp forests, sea grass meadows, mudflats, salt marshes, and mangroves); improve fish breeding for conservation and commercial and recreational fisheries; and, provide cultural and recreational values that highlight compatibility between these interests.

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

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

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 five-star restoration has been achieved in water catchment areas and adjacent to utilities, while at other sites only rehabilitation is possible.

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

Urban green space

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

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

Many urban bushland projects are committed to restoration and commonly achieve at least four-star or higher outcomes. Where this is not possible (but where parks and gardens can include indigenous plantings that enhance conservation genetics and provide faunal habitats) rehabilitation 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, particularly in transformed zones, to maintain potential for conservation of biodiversity while pursuing both production and lifestyles that are ecologically sustainable.*

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

(a) Ecologically sustainable production

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

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

(b) Ecologically sustainable lifestyles

The lifestyle and purchasing choices made by all Australians dictate the degree to which our industries can be sustainable and engage in 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.

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

Appendix 2. Values and principles underpinning Ecological Restoration

FIRST-ORDER

Ecological restoration:

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

SECOND-ORDER

Successful ecological restoration depends upon:

ECOLOGICAL

- **Addressing causes at multiple scales to the extent possible.** Degradation will continue to undermine restoration inputs unless the causes of degradation are addressed or mitigated. The range of anthropogenic threats includes over-utilization, clearing, erosion and sedimentation, pollution, altered disturbance regimes, reduction and fragmentation of habitats and invasive species. All these threats are capable of causing ecosystem decline in their own right, and can be exacerbated when combined, particularly over long time frames. Habitat loss and fragmentation, in particular, exacerbates the threats to biodiversity from climate change.
- **Recognizing that restoration initiates a process of natural recovery**. Reassembling species and habitat features on a site invariably provides just the starting point for ecological recovery; the longer term process is performed by the organisms themselves. The speed of this process can sometimes be increased with greater levels of resourcing.

- **Recognizing that undesirable species can also be highly resilient to the disturbances that accompany restoration,** with sometimes unpredictable results as competition and predator–prey relationships change. Invasive species, for example, can intensify or be replaced with other invasives without comprehensive, consistent, and repeated treatment.
- **Taking account of the landscape/aquatic context and prioritizing resilient areas.** Sites must be assessed in their broader context to adequately assess complex threats and opportunities. Greatest ecological and economic efficiency arises from improving and coalescing larger and better condition patches and progressively doing this at increasingly larger scales. Position in the landscape/aquatic environment and degree of degradation will influence the scale of investment required.
- **Applying approaches best suited to the degree of impairment.** Many areas may still have some capacity to naturally regenerate, at least given appropriate interventions, while highly damaged areas might need rebuilding "from scratch." It is critical to consider the inherent resilience of a site (and trial interventions that trigger and harness this resilience) prior to assuming full reconstruction is needed (Box 2).
- **Addressing all biotic components.** Terrestrial restoration commonly starts with reestablishing plant communities but must integrate all important groups of biota including plants and animals (particularly those that are habitat-forming) and other biota at all levels from micro- to macro-organisms. This is particularly important considering the role of plant–animal interactions and trophic complexity required to achieve the reinstatement of functions such as nutrient cycling, soil disturbance, pollination, and dispersal. Collaboration between fauna and plant specialists is required to identify appropriate scales for on-ground works and to ensure the appropriate level of assistance is applied to achieve recovery.
- **Addressing genetic issues**. Where habitats and populations have been fragmented and reduced below a threshold/minimum size, the genetic diversity of plant and animal species may be compromised and inbreeding depression may occur unless more diverse genetic material is reintroduced from larger populations, gene flow reinstated, and/or habitats expanded or connected.

LOGISTICAL

- **Knowing your ecosystems and being aware of past mistakes.** Success can increase with increased working knowledge of (1) the target ecosystem's biota and abiotic conditions and how they establish, function, interact, and reproduce under various conditions including anticipated climate change; and (2) responses of these species to specific restoration interventions tried elsewhere.
- **Gaining the support of stakeholders**. Successful restoration projects have strong engagement with stakeholders including local communities, particularly if they are involved from the planning stage. Prior to expending limited restoration resources, potential benefits of the restored ecosystem to the whole of society must be explicitly examined and recognized and it must be previously agreed that the restored ecosystem will be the preferred long-term use. This outcome is more secure when there are appreciable benefits or incentives available to the stakeholders, and where stakeholders are themselves engaged in the restoration effort.
- **Taking an adaptive (management) approach.** Ecosystems are often highly dynamic, particularly at the early stages of recovery and each site is different. This not only means that specific solutions will be necessary for specific ecosystems and sites but also that solutions may need to be arrived at after trial and error. It is therefore useful to plan and undertake restoration in a series of focused and monitored steps, guided by initial prescriptions that are capable of adaptation as the project develops.
- **Identifying clear and measurable targets, goals, and objectives**. In order to measure progress, it is necessary to identify at the outset how you will assess whether you have achieved your restoration outcomes. This will not only ensure a project collects the right information but it can also better attune the planning process to devise strategies and actions more likely to end in success (Box 3 and Appendix 4).
- **Adequate resourcing.** Budgeting strategies need to be identified at the outset of a project and budgets secured. When larger budgets exist (e.g. as part of mitigation associated with a development) restoration activities can be carried out over shorter time frames. Smaller budgets applied over long-time frames can be highly effective if works are limited to areas that can be adequately followed up within available budgets before expanding into new areas. Well-supported community volunteers can play a valuable role in improving outcomes when budgets are limited.
- **Adequate long-term management arrangements**. Secured tenure, property owner commitment, and long-term management will be required for most restored ecosystems, particularly where the causes of degradation cannot be fully addressed. Continued restoration interventions aid and support this process as interactions between species and their environment change over time. It can be helpful to identify likely changes in species, structure, and function over the short, medium, and longer term duration of the recovery process.

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

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

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

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

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

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

Species that have large, connected populations, a wide climatic range, naturally high dispersal characteristics and whose populations have many genes in common are likely to have a higher chance of genetically adapting to the new environments or migrating as their climate envelope moves. Conversely, species with low pollen and seed dispersal characteristics, that occur naturally in "islands" or "outliers" or that have been isolated through land clearing or river regulation, for example, may be less able to adapt or migrate in response to climate change (Box 5).

Implications for restoration and rehabilitation

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

Tools for assessing climate-readiness in relation to genetics

Some tools are available to help restoration planners undertake what could be called "climate-readiness" analysis at the planning stage. Firstly, restoration practitioners are encouraged to seek out predictions of locations where ecosystems are likely to be affected by climate change. Secondly, practitioners are encouraged to liaise with researchers to gain a better understanding of predicted responses of species to both

Box 5. Climate envelope

The climate range in which a species currently exists can be referred to as its "climate envelope." During climate change this climate envelope is likely to uncouple from the current location in which the species exists and, where conditions become hotter, move further poleward or to higher elevations. This means that the species may be lost from the more equatorial extreme of the range and need more help to adapt as it, or its genotypes, move poleward or to higher elevations.
However, as precipitation is likely to change in less predictable ways, it is likely that the displacement of climate envelopes will be more complex.

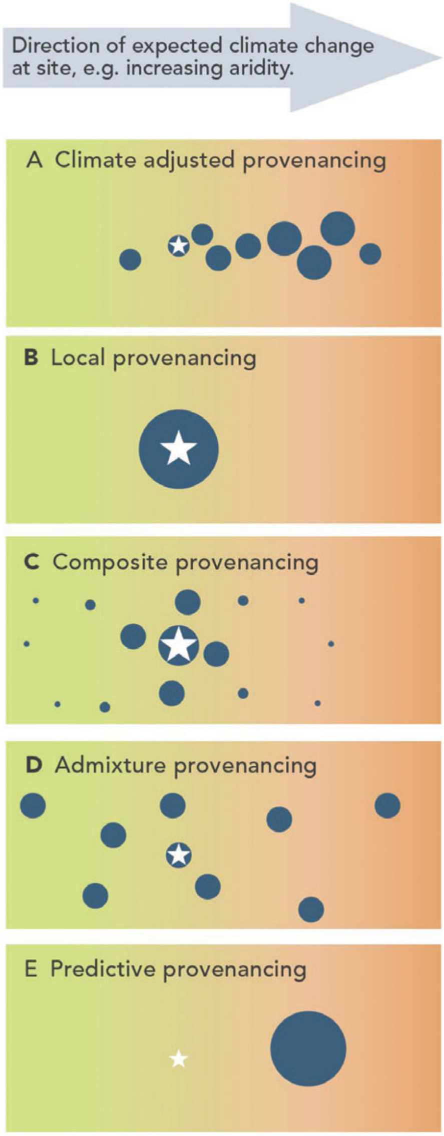

Figure 4. Provenancing strategies for revegetation (Reproduced here from Prober et al. 2015.) The star indicates the site to be revegetated, and the circles represent native populations used as germplasm sources. The size of the circles indicates the relative quantities of germplasm included from each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

fragmentation and climate change and to identify the relative risks of a range of options relating to the deliberate movement of genetic material in restoration projects. (Genetic analysis can be undertaken by a range of research institutions and is increasingly affordable for practitioners. This cost reduction is increasing the numbers of species being studied while rapid improvements in the effectiveness and efficiency of genetic testing tools are also occurring.)

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

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

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

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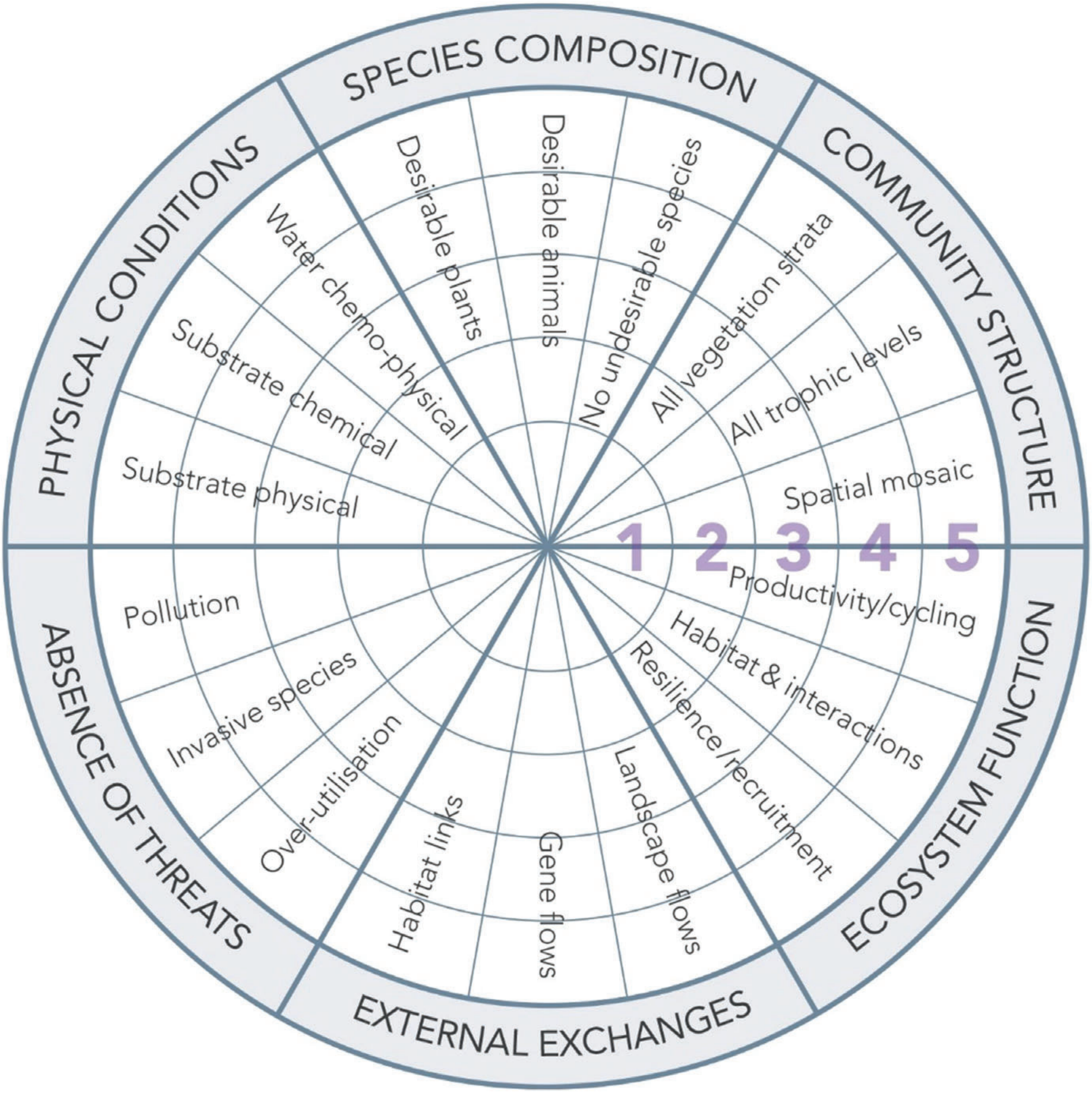
Appendix 4. Some examples of detailed objectives (using quantifiable indicators)

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

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

Appendix 5. Blank project evaluation templates (for practitioner use)



Evaluation of ecosystem recovery proforma Site …………………………………………………………………

Assessor……………………………………………………………………… Date……………………………………………

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

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:

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

Sponsors SER Australasia and its Partners also gratefully acknowledge the followin individuals and organizations whose financila contributions by the date of publictaion made the project possible:

The Nature Conservancy (through its Ecological Science Program, which is generously funded by The Thomas Foundation), Curtin University, The University of Western Australia, Australian Seed Bank Partnership, Indigenous Flora and Fauna Association, Australian Association of Bush Regenerators, Bush-It, Ecosure, Bushland and Rainforest Restoration & Consulting, and Little Gecko Media.

Coordinating Editor: Valter Amaral

Received: 16 December, 2015; First decision: 13 January, 2016; Revised: 29 February, 2016; Accepted: 2 March, 2016

Society for Ecological Restoration Australasia (SERA) www.seraustralasia.com Design: Little Gecko Media