INTERNATIONAL STANDARDS FOR THE PRACTICE OF ECOLOGICAL RESTORATION – INCLUDING PRINCIPLES AND KEY CONCEPTS

FIRST EDITION: December 2016

Tein McDonald, George D. Gann, Justin Jonson, Kingsley W. Dixon

SER
SOCIETY FOR ECOLOGICAL RESTORATION

SER in collaboration with SER Australasia

ABOUT THE SOCIETY FOR ECOLOGICAL RESTORATION

ABOUT OUR ORGANIZATION

The Society for Ecological Restoration is an international non-profit organization with members in 70 countries. SER advances the science, practice and policy of ecological restoration to benefit – and to create a healthy relationship among – people, biodiversity, ecosystems, and climate. SER is a dynamic global network, linking researchers, practitioners, land managers, community leaders and decision-makers to restore ecosystems and the human communities that depend on them. Via our members, publications, conferences, policy work, and outreach, SER defines and delivers excellence in the field of ecological restoration.

CONTACT INFORMATION

Society for Ecological Restoration
1133 15th St. NW Suite 300
Washington, DC 20005 USA

www.SER.org

REPORT PARTICIPANTS

Little Gecko Media

Bazany Design

CITATION

McDonald T, Gann GD, Jonson J, and Dixon KW (2016) International standards for the practice of ecological restoration – including principles and key concepts. Society for Ecological Restoration, Washington, D.C.

Front cover photo credits: ©Marcel Huijser, Errol Douwes, ©Marcel Huijser
Back cover photo credits: ©Marcel Huijser, Soil-Tec, Inc.,©Marcel Huijser, Bethanie Walder

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

International Standards for the Practice of Ecological Restoration represents the outcome of consultation across many professionals and practitioners within the Society for Ecological Restoration and their peers in the global scientific and conservation communities. However, as described in more detail below, it is intended as the First Edition of a *living document* that will improve and expand as the family of restoration practitioners makes use of and provides feedback on this and future editions.

DOCUMENTS

This document draws upon and joins SER's collection of foundation documents (see www.ser.org): including the SER International Primer on Ecological Restoration (SER 2004), Guidelines for Developing and Managing Restoration Projects (Clewell et al. 2005), Ecological Restoration – a Means of Conserving Biodiversity and Sustaining Livelihoods (Gann & Lamb 2006), and the IUCN's (International Union for Conservation of Nature) Ecological Restoration for Protected Areas: Principles, Guidelines and Best Practices (Keenleyside et. al. 2012). It also utilizes the editorial Ecosystem Restoration is Now a Global Priority (Aronson & Alexander 2013), the book Ecological Restoration: Principles, Values and Structure of an Emerging Profession (Clewell & Aronson 2013) and specifically draws on interpretations contained within the National Standards for the Practice of Ecological Restoration in Australia (McDonald et al. 2016). Many other documents have influenced the development of this document, and the authors acknowledge a debt to scores of published and unpublished documents that have influenced our thinking.

CONTRIBUTORS

Members of the Society for Ecological Restoration Science and Policy Committee and Executive Staff made significant conceptual and text contributions to this document: James Aronson, Kris Decleer, James Hallett, Karen Keenleyside, Cara Nelson, Bethanie Walder and Levi Wickwire. Contributors to the National Standards for the Practice of Ecological Restoration in Australia included David Lamb, David Freudenberger, Peter Erskine, Vern Newton, James Fitzsimons, Ben Carr, Simon Branigan, Scott Meier, Jen Ford, Zoe Metherill, Anne Cochrane, Martin Driver, Lucy Sutherland, Peter Cuneo, David Merritt, Jim Radford, Angela Sanders, Matt Appleby, Keith Bradby, Paula Deegan, Paul Gibson-Roy, Bindi Vanzella, Brian Bainbridge, Amelia Hurren, Nathan Wong, Robyn Edwards, Louise Duff, Hanna Kogelman and Timothy Mouton. Andre Clewell contributed inspiration and ideas that led to the attributes list and circle template shown in Figure 2 and Appendix 2.

REVIEWERS

We thank the following international reviewers: Paul Adam, Mariam Akhtar-Schuster, Sasha Alexander, Pedro Brancalion, Hamid Custovic, David Boshier, Aïda Farag, Alexis Gibson, Manuel Guariguata, Jim Harris, Kay Havens, Eric Higgs, Klaus Kellner, Susan Kennedy, Sam Lake, Robert Marrs, Joyce Maschinski, Tanya McGregor, David Polster, Karel Prach, Nancy Shaw, Junko Shimura, Brad St. Claire, Evert Thomas, Rudy van Diggelen, Steve Whisenant and Joan Yoshioka.

Community participants in an "Indigenous Trees for Life" restoration project in eThekwini Municipality, South Africa. This project was part of a restoration offset associated with the 2010 World Cup in Durban.

Photo credit: Errol Douwes

ABOUT THIS DOCUMENT

This document, International Standards for the Practice of Ecological Restoration – including Principles and Key Concepts (hereafter, the Standards), provides standards to guide practitioners, operational personnel, planners, managers, regulators and funding agencies involved in restoring degraded ecosystems anywhere in the world – whether terrestrial, freshwater, coastal or marine. It places ecological restoration into a global context, including its role in conserving biodiversity and improving human wellbeing.

The key principles and concepts underpinning the Standards further develop definitions, principles and concepts contained in the *SER Primer* (www.ser.org), other SER foundation documents (including Keenleyside et al. 2012), and the SER Australasia-developed standards (McDonald et al. 2016). The Standards expand these conceptual frameworks to clarify the degree of recovery represented by 'ecological restoration' in times of global changes including anthropogenic climate change and other rapid environmental changes. This document also recognizes the value of other types of environmental repair efforts (e.g., rehabilitation, remediation and reclamation) where they represent the highest quality of recovery possible or are appropriate to the circumstances. In addition, the Standards document explores restoration principles, discusses the values that restoration aims to satisfy, and highlights six key concepts **essential** for achieving high levels of recovery.

The Standards reaffirm the use of a reference ecosystem **as a model, or target, for the local native** ecosystem being restored. The reference model, **derived from multiple sources of information,** aims to characterize the condition of the ecosystem as it would be had it not been degraded, adjusted as necessary to accommodate changed or predicted biotic or environmental conditions. The use of such reference models in ecological restoration does not signify in any way an attempt to immobilize an ecological community at some point in time, but rather to optimize potential for local species and communities to recover and continue to reassemble, adapt, and evolve. The Standards provide a specific procedure for developing targets and evaluating the recovery of six key ecosystem attributes. These attributes represent broad functional and structural categories of ecosystems around which more specific and measurable goals and objectives can be defined by the project manager. The Standards also acknowledge additional project-related characteristics including scale, strategic importance and social engagement in order to highlight key factors that can improve the influence of a restoration project on overall sustainability of ecosystems in a rapidly changing world.

I

SECTION I - INTRODUCTION

This document, International Standards for the Practice of Ecological Restoration – including Principles and Key Concepts (hereafter, the Standards) has been developed to provide support for the technical application of ecological restoration treatments across all geographic and ecological areas – whether terrestrial, freshwater, coastal or marine – to improve biodiversity conservation outcomes for all ecosystems, secure the delivery of ecosystem services, ensure projects are integrated with socio-cultural needs and realities, and contribute to the 2030 Agenda for Sustainable Development.

ECOLOGICAL RESTORATION AS A MEANS OF CONSERVING BIODIVERSITY AND IMPROVING HUMAN WELLBEING

The planet's local native ecosystems (whether natural, semi-natural or restored) are globally recognized as having high biological, societal and economic value. Ecosystem services include, for example, provision of clean water, healthy soils, clean air, and food/fiber/medicines that are essential for human health, wellbeing, and livelihoods. Functioning ecosystems also play important roles in reducing the effects of natural disasters and mitigating climate change. As degradation, damage and destruction (collectively referred to in this document as 'degradation') diminish the extent of ecosystems, biological diversity, function and ability to respond to disturbance is also reduced. Although protecting remaining intact ecosystems is vital to conserving our natural and cultural heritage, protection alone is now insufficient given the extent to which degradation has proceeded and continues to expand. To ensure the sustainable flow of ecosystem services and products, **the world must work to secure a net gain in the extent and functionality of native ecosystems by investing in environmental repair activities including ecological restoration.** This repair must be implemented at large enough scales to make a difference whether the goals include carbon sequestration, livelihoods, ecosystem services or biodiversity. Ecological restoration therefore seeks the highest and best recovery outcomes practicable to both compensate for past damage and to progressively effect an increase in the extent and healthy functionality of the planet's imperiled ecosystems.

Ecological restoration efforts are being ramped up globally. For example, the Bonn Challenge aspires to restore 150 million hectares of degraded or deforested lands by 2020 and 350 million hectares by 2030. The Convention on Biological Diversity has a restoration target of 15% of degraded ecosystems by 2020 to mitigate the impacts of climate change and to combat desertification (Aichi Biodiversity Target 15). In addition, the CBD also views ecological restoration as key to delivering essential ecosystem services (Aichi Biodiversity Target 14). More recently, the United Nations adopted its 2030 Agenda for Sustainable Development, including Sustainable Development Goal 15 to "protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss." The success of these activities will depend on our capacity to effectively and efficiently implement ecological restoration around the world.

RESTORATION DOES NOT JUSTIFY DESTRUCTION OF ECOSYSTEMS

Ecological restoration should never be considered a substitute for sustainably protecting and managing existing native ecosystems. Most natural and semi-natural ecosystems are not readily transportable or easily rebuilt once damaged. Moreover, restoration science and technologies for many ecosystems are still far from achieving 100% recovery of biodiversity, ecosystem functioning, or delivery of ecosystem services. This means that the promise of restoration should never be invoked as a justification for destroying or damaging existing ecosystems. Similarly, the potential to translocate rare species into a restored or created habitat cannot and should not predicate the destruction of existing intact habitat for that purpose.

NEED FOR STANDARDS

Practitioners, operational personnel, planners, managers, funders, and regulators need standards to help them develop high quality plans and achieve acceptable ecosystem recovery outcomes. This applies to both mandatory restoration (i.e., restoration required as part of consent conditions for current or planned disturbances) and non-mandatory restoration (i.e., the voluntary repair of damage).

Additionally, though many projects are successful, ecological restoration outcomes often fall short of expectations, further elevating the need for standards. Challenges can occur due to ecologically or socially inappropriate planning and implementation, a lack of appropriate effort or resources, or insufficient or inappropriate knowledge and skill. Standards can assist with optimizing the success of ecological restoration efforts, whether they are used to guide agencies and community members engaged in non-mandatory restoration, or to guide regulators in their development of consent criteria for mandatory restoration and to evaluate whether those criteria have been attained.

This document clarifies what constitutes a restoration project, elaborates on the principles that underpin current best practice for ecological restoration (Appendix 1) and lists the actions required for the successful planning, implementation and monitoring of ecological restoration projects (Section 3). The Standards are applicable to any ecosystem, whether terrestrial, freshwater, coastal, or marine, anywhere in the world. Any sector that performs ecological restoration, whether private or public, mandatory or non-mandatory, can apply these Standards. They can be used by any person or organization to develop restoration plans, contracts, consent conditions and closure criteria.

This first edition of the International Standards for the Practice of Ecological Restoration is based on a wealth of field-based experience and contemporary science. Over time these Standards will evolve through formal feedback from the global community of restoration practitioners and restoration scientists. Future advances in restoration science and practice will lead to periodic updates of the Standards to ensure they provide the most relevant and effective guidance. As such, this Standards document should be viewed as a living document, which will be revised and improved as we receive and incorporate additional knowledge and perspectives from the global restoration community. SER's website – www.ser.org – hosts a community forum that allows readers and users of the Standards to comment on their utility and how the document might be improved. Finally, the Standards are designed to be generic in nature and to provide a framework for those developing more detailed guidelines and standards for the ecological restoration of specific ecosystems, ecosystem types or regions.

THREE UNDERPINNING PRINCIPLES

To be successful, ecological restoration practice should be effective, efficient and engaging (Keenleyside et. al. 2012):

(a) EFFECTIVE ecological restoration establishes and maintains an ecosystem's values.

(b) EFFICIENT ecological restoration maximizes beneficial outcomes while minimizing costs in time, resources and effort.

(c) ENGAGING ecological restoration collaborates with partners and stakeholders, promotes participation and enhances experience of ecosystems.

DEFINITIONS

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

(For definitions of all terms not defined here and given in bold face, see Glossary, Section 5.)

A fundamental distinction between ecological restoration and other forms of ecosystem repair is that ecological restoration seeks to 'assist recovery' of a natural or semi-natural ecosystem rather than impose a new direction or form upon it. That is, the activity of restoration places an ecosystem on a trajectory of recovery so that it can persist and its species can adapt and evolve.

The Standards recognize that the same term 'ecological restoration' is commonly used to describe not only a *process* (i.e., an activity undertaken for a given set of goals), but also the outcome sought for an ecosystem (i.e., its recovery). Favoring the term **recovery** for the latter, these Standards define as an ecological restoration activity any activity whose aim it is to ultimately achieve ecosystem recovery, insofar as possible and relative to an appropriate local native model (termed here a **reference ecosystem**), regardless of the period of time required to achieve the recovery outcome.

A reference ecosystem is a model representing the approximate restoration target (see also Key Concept 1 below). In the absence of suitable intact ecosystems of the same type surviving close to the targeted site, the reference model can be derived from multiple sources of information about past and present biota and conditions occurring on or near the site; supplemented by information on anticipated changes in environmental conditions that may lead to altered biological assemblages. Levels of recovery sought and achieved should be identified in a restoration project's plans and reports, respectively. **Full recovery** is defined as the state or condition whereby all the **key ecosystem attribute categories** closely resemble those of the reference model. Where only lower levels of recovery are possible despite best efforts, the recovery would be referred to as **partial recovery,** although it is reasonable to expect that any project would need to aspire to substantial recovery of the native biota of the reference ecosystem for it to qualify as an ecological restoration project. When full recovery is the target, an important benchmark is when the ecosystem demonstrates a condition of **self-organization** and is on a trajectory to reach full recovery as defined above. If and when the self-organizing stage is reached, ongoing monitoring and, potentially, some further intervention may be required to ensure that the trajectory of recovery ultimately converges with full recovery and is not deflected off course by unexpected factors. If full recovery has been achieved but ongoing interventions (e.g., removal of invasive species, or application of disturbance regimes) are needed to ensure desirable states are maintained, these interventions would be considered **ecosystem maintenance.**

The *process* of ecological restoration and its *outcome* of recovery are synergistically linked. That is, if the desired restoration *outcomes* are identified from the start (using processes described in Section 3 including collaboration with stakeholders) then they can help identify and direct the optimal restoration *process.* The reference ecosystem, in particular, will help in planning, monitoring and evaluating ecological restoration work. Similarly, where outcomes are uncertain, applying appropriate processes through adaptive management and ongoing stakeholder interaction will help the project team arrive at satisfactory outcomes.

Projects that focus on the recovery of single species (e.g., threatened species or highly mobile faunal species with large minimum range sizes) are

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

generally considered highly valued components of larger ecological restoration projects or programs. Projects that focus solely on reinstating some form of ecosystem functionality without seeking to also recover a substantial proportion of the native biota found in an appropriate native reference ecosystem would be best described as **rehabilitation.**

Importantly, if such a project were to improve the state of the environment without compromising potential for future ecological restoration it would also be considered a **restorative** project – i.e., part of a continuum of activities improving potential for ecological recovery at larger scales (see Section 4).

Photo 1

Photo 2

Photo 3

Milltown Dam removal on the Clark Fork River in Montana, USA. The dam trapped 6.6 million cubic yards of mining-contaminated sediment in a 540 acre reservoir (photo 1). This multi-year project rerouted the river, removed the contaminated sediment (photo 1), removed the Milltown Dam (photo 2 - first breach of temporary coffer dam to drain reservoir/remove full dam) and ultimately restored the river channel (photo 3) and the natural confluence of the Clark Fork and Blackfoot Rivers.

Photo credits: Photos 1 and 2: ©Marcel Huijser; photo 3: Watershed Restoration Group

II

SECTION II - SIX KEY CONCEPTS UNDERPINNING BEST PRACTICE

Current best practice ecological restoration is underpinned by a range of concepts and principles which build upon ideas first developed in SER's foundation documents. (Also see Appendix 1.) The following Key Concepts are highlighted here to provide a framework to more concisely explain, define and measure the activities and outcomes of ecological restoration practice.

KEY CONCEPT 1. ECOLOGICAL RESTORATION PRACTICE IS BASED ON AN APPROPRIATE LOCAL NATIVE REFERENCE ECOSYSTEM, TAKING ENVIRONMENTAL CHANGE INTO ACCOUNT

A fundamental principle of ecological restoration is the identification of an appropriate reference model, commonly referred to as a **reference ecosystem.** While existing **reference sites** that act as analogues may be selected for this role, in practice the reference ecosystem often needs to be assembled from diverse sources of information on local native plants, animals, other biota and abiotic conditions. These sources may include multiple extant reference sites, field indicators, historical records (including human use) and predictive data. The resulting model helps identify and communicate a shared vision of project targets and specific ecological attributes, which then provides a basis for setting goals and objectives and monitoring and assessing restoration outcomes over time.

Wherever possible, the reference ecosystem is assembled to represent the site's ecosystem as it would be had degradation not occurred, while incorporating capacity for the ecosystem to adapt to existing and anticipated environmental change. That is, recognition is required that ecosystems are dynamic and adapt and evolve over time in response to changing environmental conditions and human pressures including climate change (see Box 1 and definition of 'local native ecosystem' in glossary). Where local information is incomplete, regional information can help inform the characteristics of likely local native ecosystems (SER 2004).

> A REFERENCE ECOSYSTEM is a model characteristic of the particular ecosystem that informs the **target** of the restoration project. This involves describing the specific compositional, structural, and functional ecosystem attributes requiring reinstatement to a self-organising state leading to full recovery. This model is synthesized from information about past, present and anticipated future conditions at the site and similar sites in the region, in consultation with stakeholders.

In cases where uncertainty and

potential for unforseen outcomes is high, assembling a reference ecosystem may not be a one-phase operation. Indeed, a reference ecosystem often functions as a working hypothesis, particularly initially, and is adjusted in light of new information discovered about the site. As more confidence about the reference ecosystem develops with greater feedback from the site itself, details and targets may become more specific (Clewell & Aronson 2013).

In summary, adopting a reference ecosystem should not be viewed as an attempt to immobilize an ecological community at some point in time, or to 'turn back the clock'. Rather the purpose of selecting or synthesizing a reference ecosystem (or multiple, sequential references to reflect anticipated changes over time) is to optimize the potential for local species and communities to recover through well-targeted restoration actions and continue to reassemble and evolve in the face of change. For this reason, the reference model primarily involves consideration of contemporary examples or analogues of the pre-degradation ecosystem where they exist. Otherwise historical information is used as a starting point for identifying restoration targets, considering natural variation and anticipated future environmental change. In this way restoration reconnects the states and conditions of an ecosystem's historic past to those that develop in the future.

WHAT NEEDS TO BE CONSIDERED WHEN DEVELOPING A REFERENCE ECOSYSTEM?

Abiotic conditions including substrates, hydrology, energy flows, nutrient cycles, disturbance cycles and **triggers** characteristic of a reference ecosystem are considered along with the biota at the stage the reference ecosystem is being characterized. Thus the formulation of a reference ecosystem involves analysis of the **composition** (species), **structure** (complexity and configuration of species) and **functionality** (underlying abiotic and biophysical processes and community dynamics of organisms) of the ecosystem to be restored on the site. The reference ecosystem should also include descriptions of successional or developmental states that may be characteristic of the ecosystem's decline or recovery and descriptions of **ecological stressors** and disturbance regimes that need to be reinstated.

WHAT ABOUT CULTURAL ECOSYSTEMS?

Many ecosystems around the world have been shaped to a greater or lesser extent by human utilization. Well known examples include Indigenous peoples' burning of forests to create and maintain the grassy openings found in woodlands and savannas. Because these were modified prior to industrialization and so exhibit states very similar to those occurring in unmodified areas, they are universally accepted as native ecosystems, with the continuation of traditional management practices unequivocally encouraged as a necessary part of their continued functioning. In a similar way, other ecosystems that are more recently modified (e.g. many of the mown hay meadows of central Europe, and agrosilvopastoral savannas in the Mediterranean region and the Sahel) are considered high quality examples of native ecosystems and legitimate reference models in an ecological restoration context. In cases where modifications from cultural ecosystems produce dissimilar states and substantially different species composition to native ecosystem, the sites may not be appropriate reference models for ecological restoration but may still warrant management (and repair as required) as valued, semi-natural / cultural ecosystems.

BOX 1. REFERENCE ECOSYSTEMS IN CASES OF IRREVERSIBLE ENVIRONMENTAL CHANGE.

Many local sites, intact or degraded, are subject to naturally occurring irreversible change; with many being increasingly threatened by irreversible change arising from human activities. Reinstating local native ecosystems in such cases requires anticipation and, if necessary, mimicry of natural adaptive processes.

1. Irreversible physical changes. In cases where substantial and insurmountable environmental change has occurred but the changed physical conditions now resemble those that occur in other local areas, project managers may consider adopting (as the reference ecosystem) an alternative, locally occurring ecosystem that would be expected to naturally occur under the changed conditions. Examples of such conversion include sites where (i) hydrology has changed irreversibly from saline to freshwater or vice versa, (ii) stormwater has produced intermittent streams, (ii) traditional fire regimes have been irreversibly altered and (iv) erosion has produced a rocky platform. Whether such activities function as ecological restoration, a complementary restorative activity or simply a reallocation (e.g., the creation of a designer ecosystem) will be highly dependent on the local historic occurrence of such shifts due to natural dynamic processes, the strength of the case for irreversibility, and the degree to which the project is primarily focused on establishing the full complement of key ecosystem attributes as distinct from ecosystem services alone.

2. Anthropogenic climate change. Worldwide, many ecosystems are changing due to relatively rapid anthropogenic climate change. While this change is generally recognized as undesirable and requiring urgent attention by the whole of society (Section 4), much of this change is likely to be irreversible for the foreseeable future. This means that climate change needs also to be recognized as part of the environmental background conditions to which species need to adapt or go extinct.

   The reality of anthropogenic climate change means that target-setting needs to be informed by data and ongoing research into its anticipated effects on species' ranges and ecosystems, to the extent that these can be documented or predicted. While a high degree of uncertainty exists, we do know that some entire ecosystems are likely to be lost in specific geographic areas (e.g., many marine, coastal, alpine, and cool temperate communities) where no suitable migration areas or corridors exist or can be created. We also know that in other ecosystems the **climate envelopes** of individual species will be shifting, resulting in progressive – often dramatic - range changes. Some species may be lost while others may have inherent climate-adapted plasticity, or an ability to migrate.

   As migration will be severely constrained under conditions of fragmentation, practical steps are likely to be needed to optimize potential for adaptation. The favoured option is to retain and enhance genetically diverse representatives of as many current local species as possible – and to ensure these exist in configurations that increase linkages and optimize **gene flow** where appropriate. Potential for experimentally introducing more diverse genetic material of the same species from other parts of a species' range, however, may also be considered in some areas.

In summary, as the role of restoration is to 'assist recovery', we recommend that practitioners design restoration projects based on local native reference ecosystems, and be ready to adapt these in light of observed or likely changes occurring within these ecosystems, as informed by appropriate research and practice.

KEY CONCEPT 2. IDENTIFYING THE TARGET ECOSYSTEM'S KEY ATTRIBUTES IS REQUIRED PRIOR TO DEVELOPING LONGER TERM GOALS AND SHORTER-TERM OBJECTIVES

Six **key ecosystem attribute categories** are listed in Table 1. Given the very large range of ecosystem types for which ecological restoration is needed, these categories are, by necessity, broad and may only be measurable when subdivided into more detailed sub-categories that are specific enough to inform a given project's **goals** and **objectives.** Site-specific attributes or sub-attributes that are specific to the ecosystem being restored are thus identified as part of the reference ecosystem phase at the early planning stage of a project (Box 2).

Specific and measurable **indicators** (examples in Box 2) are then selected to help evaluate whether the project's ecological and socio-economic targets, goals and objectives are being met as a result of the interventions. In order to evaluate success, it is critical that each restoration objective clearly articulates: 1) the attribute or sub-attribute that is being manipulated, 2) the desired outcome (e.g., increase, decrease, maintain), 3) the magnitude of effect (e.g., 40% increase in plant cover) and 4) the time frame.

Projects that include indicators linked to specific goals and objectives not only ensure that the project can be evaluated over time, but also ensure that the project will have greater transparency, manageability, and that its results will be transferable. This approach is most effective if set within an adaptive management context (Box 3).

Table 1. Key ecosystem attribute categories and examples of broad goals likely to be interpreted for each attribute category in a restoration project.

ATTRIBUTE	Examples of broad goals - for which more specific goals and objectives appropriate to the project would be developed
Absence of threats	Cessation of threats such as overutilization and contamination; elimination or control of invasive species.
Physical conditions	Reinstatement of hydrological and substrate conditions.
Species composition	Presence of desirable plant and animal species and absence of undesirable species.
Structural diversity	Reinstatement of layers, faunal food webs, and spatial habitat diversity.
Ecosystem functionality	Appropriate levels of growth and productivity, reinstatement of nutrient cycling, decomposition, habitat elements, plant-animal interactions, normal stressors, on-going reproduction and regeneration of the ecosystem's species.
External exchanges	Reinstatement of linkages and connectivity for migration and gene flow; and for flows including hydrology, fire, or other landscape-scale processes.

BOX 2. 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 treatments are well matched to the desired ultimate outcomes.

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

Objectives need to be specific, measurable, achievable, reasonable and time-bound. This is achieved by the use of specific, quantifiable indicators that directly connect the (longer-term) goals and (shorter-term) objectives to key attributes of the target ecosystem.

HYPOTHETICAL EXAMPLE:

1. **Target.** The target of a project can be interpreted as the specific reference ecosystem to which the restoration project is being directed (e.g., *'Quercus/Pseudotsuga* Oak Woodland') and will include a description of the key ecosystem attributes selected for monitoring and evaluation.
2. **Goals.** The goal or goals provide a finer level of focus in the planning process compared to the target. They describe the status of the target that you are aiming to achieve in the medium to long term and, broadly, how it will be achieved. For example:

   Hypothetical examples of ecological goals in a project where the target is a *Quercus/ Pseudotsuga* Oak Woodland in a cleared landscape with some remnants may be to achieve:

   i. An intact and recovering composition, structure, and functionality of remnants A and B within 5* years; and,

   ii. Effective revegetated linkages between the remnants within 10 years.

   Hypothetical examples of socio-economic goals of the same project may be to achieve:

   i. Improved water quality for clean drinking water, local swimming and sustainable fishing activities within 5 years;

   ii. An outdoor environmental education classroom for local schools within 5 years; and,

   iii. Renewed social cohesion within the community, focused on improved sense of place within 5 years.
3. **Objectives** (ecological and social). These are the changes and intermediate outcomes needed to attain the goals. In a hypothetical *Quercus/Pseudotsuga* Oak Woodland case, for example, preliminary ecological objectives may be to achieve:

   i. Reduced abundance of invasive plants to less than 1% cover within 2 years in both remnants A and B;

   ii. Increased rates of recruitment of native shrubs for at least two species within 2 years in both remnants A and B;

   iii. Increased native woody plant density to at least 100 stems/ha of trees and 100 stems/ha of shrubs within 3 years and increase in vertebrate fauna sightings;

   iv. Increased richness of at least six grass and 10 forb species / $10m^2$ and a coarse woody debris load of <5 m^3/ha in the reconstructed linkages within 3 years;

   v. Cessation of livestock grazing and weed dumping within 1 year;

   vi. Reduced E-coli count in waterways to within health department standards for swimming within 5 years and for drinking within 10 years;

   vii. Field visits by 50% of local schools by 5 years; and,

   viii. Formation of a 'friends' group representing >50% of neighbours within 2 years and increasing to 80% within 5 years.

* Note that these numbers are all hypothetical examples and not a guide.

BOX 3. RESTORATION MONITORING AND ADAPTIVE MANAGEMENT

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

1. provide evidence to stakeholders that specific goals are being achieved according to plan;
2. identify whether the actions are working or need to be modified (i.e., adaptive management); and
3. answer specific questions (e.g., to evaluate particular treatments or which organisms or processes are returning to the ecosystem).

Resources for appropriate monitoring need to be allocated, alongside resources for all other elements of a restoration project, prior to the planning phase. Monitoring plans should be included in project plans to ensure that goals are clearly considered and objectives are measurable. Information on the 'starting' condition of a project must be collected prior to any changes triggered by restoration activities.

Adaptive management is based on clear goals and an assumed set of operating objectives that may need to be adjusted by 'trial and error'. Using the best available knowledge, skills and technology, actions are implemented according to these identified goals and objectives and records are made of success, failures, and potential for improvement. These lessons then form a basis for the next round of 'improvements'. Adaptive management can and should be a standard approach for any ecological restoration project irrespective of how well-funded that project may be. This can be supported by formal or informal monitoring.

1. A useful, if minimal way to provide visual **evidence to stakeholders and regulators that goals are being achieved** is to use time-series photography – i.e., securing an image of the site from precisely the same photo points, prior to and at intervals after treatment to show changes over time. At small sites, fixed photo-points on the ground can be established, while at larger sites, remotely sensed imagery (including drones) or imagery derived from other detection systems may provide useful before and after imagery. Because such imagery only provides a visualisation of changes occurring, funded projects (particularly those under regulatory controls) are usually expected to undertake formal quantitative plot-based monitoring. This usually involves professionals and is based on a monitoring plan that identifies, among other things, monitoring design, timeframes, who is responsible, the planned analysis, and frameworks for response and communication to regulators, funding bodies or other stakeholders. Not only are 'before' and 'after' data required in such monitoring but, ideally, untreated (control) sites should also be included; allowing for a 'Before, After, Control and Impact' (BACI) design. Where appropriate, monitoring can also be simultaneously carried out in Reference sites, allowing a BARCI design.
2. A basic process necessary to **identify whether restoration actions are working or need to be modified** is to inspect the site routinely, and record observations of site responses. Such inspections are undertaken by a project supervisor to identify any need for a rapid response and to ensure appropriate treatments can be scheduled before a problem becomes entrenched. More formal monitoring using descriptive methods such as condition classification systems, however, is necessary to reliably monitor progress toward goals.

   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 and objectives. Care should be taken to ensure that the sampling begins prior to the commencement of restoration treatments. Where possible, control sites should be included in the design. Such design must be carried out by experienced and skilled people. As such, if the necessary skills are unavailable 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.

   Experimentally comparing techniques requires a further level of formality. Formal experimentation needs to observe the conventions of sufficient sample size, replication and the use of untreated controls in order to interpret the results with any certainty. 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 as surrogates throughout the life of the restoration project to track recovery of functional diversity in the soil microbial communities.
3. Monitoring can be used **to answer questions** (i.e., formal 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. Rigorous recording of specific restoration treatments and any other conditions that might affect the results is also needed. A standard practice in such a situation would be for the initiator of the research to ensure appropriate partnerships between practitioners and scientists to ensure the project receives the appropriate level of scientific and practical advice and assistance to optimize both its success and relevance. Where new treatments are being considered or where the nature of the site is uncertain, treatments are first piloted in smaller areas prior to application over larger areas.

KEY CONCEPT 3. THE MOST RELIABLE WAY TO ACHIEVE RECOVERY IS TO ASSIST NATURAL RECOVERY PROCESSES, SUPPLEMENTING THEM TO THE EXTENT NATURAL RECOVERY POTENTIAL IS IMPAIRED

An essential underpinning concept of restoration is that we do not, as practitioners, actually carry out the work of recovery of an ecosystem. We can create the conditions and assemble components, but the work of recovery is carried out by the biota themselves through germination or birth/hatching, growth, reproduction, recruitment, and interaction with other organisms and their environment over time. Restoration can facilitate this by assisting the return of appropriate cycles, flows, productivity levels and specific habitat structures and niches. This suggests that restoration interventions should be focused on reinstating components and conditions suitable for these processes to recommence and the degraded ecosystem regain its pre-degradation attributes, including its capacity for self-organization and **resilience** to future stresses. The most reliable and cost effective way to achieve this is to harness any remaining potential of species to regenerate and undertake more intensive intervention only to the extent that **regeneration** potential has been depleted. This is not to advocate regeneration approaches over **reconstruction** approaches (see Box 4) but to emphasize that the effectiveness and efficiency of restoration can be improved by correctly estimating recovery capacity and prescribing treatments accordingly. An assessment is therefore needed at the **baseline inventory** stage of a restoration project to consider (1) any remaining potential for regeneration after modification of conditions including dynamics or (2) any need to reinstate missing biotic and abiotic elements. This assessment should be informed by knowledge of such things as the recovery mechanisms of individual species likely to occur on the site and predictive indicators of their propagule flows and stores. Where this potential or limitation is unclear due to lack of knowledge or indicators, it is accepted practice to test the recovery response in smaller areas prior to application in large areas.

This assessment of recovery potential, with or without assistance, is not only essential to optimize recovery but is also important to help identify which areas should be prioritized for treatment. Advantage can be gained, for example, by preferentially investing scarce resources into areas where regeneration capacity has not yet been fully depleted (e.g., remnants and their margins, terrestrial or aquatic, whatever their condition) and placing lower on the priority list areas of lower potential unless they are of strategic or other importance. In this way, recovering areas can expand in size to strategically enlarge and link native ecosystems to allow them to coalesce into bigger, more functional wholes and provide more functional habitat for fauna.

Precise outcomes of restoration interventions are unpredictable; thus, practitioners need to be prepared to undertake additional treatments to overcome unexpected limitations or meet opportunities that arise. Disturbances designed to stimulate recovery of native species, for example, may also stimulate a response from undesirable species that may be present in the propagule bank, often requiring multiple follow-up interventions until the project's goals have been achieved.

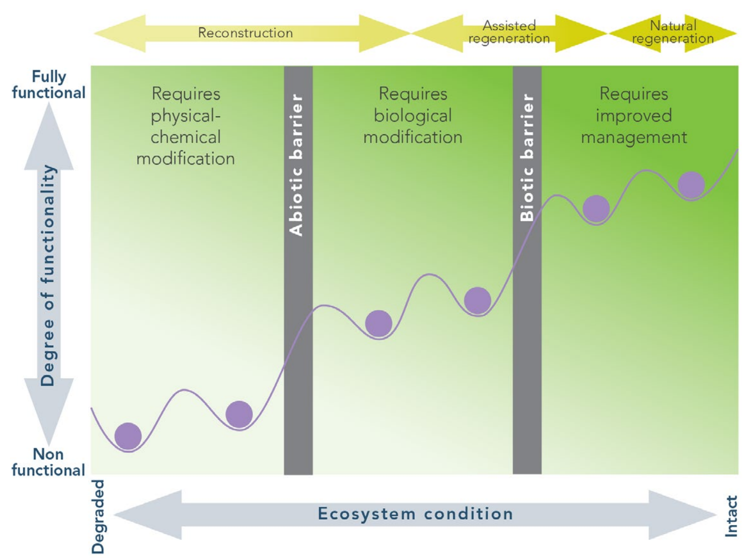


Figure 1. Conceptual model of ecosystem degradation and responses to it through restoration (Adapted from Keenleyside et al. 2012 and Whisenant 1999; cf. Hobbs & Harris 2001). The troughs in the diagram represent points of stability in which an ecosystem can remain in a steady state prior to being shifted (by a restoration or a degradation event or process) over a barrier (represented by peaks in the diagram) towards a higher or a lower degree of functionality. [Note: sites in need of physical/ chemical amendment but with high colonization potential may progress quickly along the recovery trajectory without a need for interventions involving biological modification.]

BOX 4. IDENTIFYING APPROPRIATE ECOLOGICAL RESTORATION APPROACHES

Native species have a capacity to recover after natural disturbances or stresses to which they have adapted over evolutionary timeframes. This capacity may be harnessed to assist with recovery after human-induced impacts to the extent the impacts resemble (in nature and degree) the disturbances or stresses to which the species are adapted. Correctly assessing the capacity of species at a given site to regenerate facilitates the selection of appropriate approaches and treatments, thus avoiding inefficient use of natural or financial resources or other restoration inputs.

A useful initial process is to identify more resilient (less damaged) areas of a site and to use 'regeneration' approaches in those areas. These are sometimes collectively referred to as 'passive' restoration (although this term can be misleading as regeneration approaches are often far from passive). Reintroductions or augmentations, sometimes referred to as 'active' restoration, can then be applied to areas (or for species) where potential for regeneration is deemed to be low or non-existent.

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

1. **Natural (or spontaneous) regeneration** approach. Where damage is relatively low (or where sufficient time frames and nearby populations exist to allow recolonization), plants and animals may be able to recover cessation of the degrading practices alone, including removal of native vegetation, inappropriate grazing, over-fishing, restriction of water flows, and inappropriate fire regimes. Animal species may be able to migrate back to the site if connectivity is in place. Plant species may recover through resprouting or germination from remnant soil seed banks or seeds that naturally disperse from nearby sites
2. **Assisted regeneration** approach. Recovery at sites of intermediate (or even high) degradation need both 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 in estuaries and rivers, applying artificial disturbances to break seed dormancy, and installing habitat features such as hollow logs, rocks, woody debris piles and perch trees. Examples of higher level abiotic interventions include remediating contamination or substrate chemistry, reshaping watercourses and landforms, building habitat features such as shellfish 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 native reference ecosystem, but also all or a major proportion of its desirable biota need to be reintroduced wherever possible. These will then interact with abiotic components to drive recovery of attributes.

Combinations of the three approaches are sometimes warranted. Varying responses by individual native 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 is insufficient.

A mosaic of the three approaches can be warranted where there is a range of different degrees of degradation across a site. This is particularly required at larger scales. That is, some parts of a site may require a natural regeneration approach, others may require an assisted regeneration approach, and still other areas may require a reconstruction approach, or combinations as appropriate.

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

KEY CONCEPT 4. RESTORATION SEEKS 'HIGHEST AND BEST EFFORT' PROGRESSION TOWARDS FULL RECOVERY

An ecological restoration project plan adopts the goal of achieving, insofar as possible, a secure trajectory to full recovery relative to an appropriate local native reference ecosystem. Full recovery is not possible or appropriate everywhere, however; and even where it is possible, it may take decades or possibly centuries because of the long-term nature of some recovery processes; an insufficiency of restoration resources, technology, or knowledge; or the presence of drivers outside the site that require lengthy negotiation to resolve.

The recognition that full recovery may be slow provides encouragement for managers to adopt a policy of continuous improvement. Strategies for continuous improvement can include re-treating or applying new interventions at sites previously treated when new knowledge, technologies or resources become available – or through adopting standard adaptive management processes. Taking a longer-term view can thus encourage managers who believe they can only aim for partial recovery, to consider upgrading their goals to more ambitious full recovery over the longer term. This suggests that (i) a focus on recovery level and (ii) valuing all 'highest and best' level of recovery (i.e., highest and best performance possible in the individual project) can be a useful way to view goals and outcomes for any restoration project.

FIVE-STAR RECOVERY SYSTEM - FOCUS ON *RECOVERY LEVEL*

To help managers, practitioners and regulatory authorities track progress towards project goals over time, the Standards provide a tool (5-levels or 'stars') for progressively assessing and ranking degree of *recovery* over time. This tool is both summarized (Table 2) and more fully described relative to the six key ecosystem attributes of ecological restoration (Table 3). A template to visually communicate the progress of recovery at a site over time is provided (Figure 2).

Five-star recovery - that is, a status where the ecosystem is on a self-organizing trajectory to full recovery (based on an appropriate local native reference ecosystem) - is the 'gold standard' to which all ecological restoration projects aim, insofar as is possible. Projects that aim for lesser goals are encouraged to use the 5-star ranking system to identify the level to which their project goals are being achieved and to foster increased ambition for the future. Projects that do not include a focus on reinstating biota characteristic of an appropriate local native reference ecosystem would be considered rehabilitation rather than restoration. Such rehabilitation projects, however, may still benefit from using the 5-star system with respect to recovery of functional attributes.

IS IT POSSIBLE TO IDENTIFY IN ADVANCE WHETHER RESTORATION IS POSSIBLE?

Experience shows us that the appearance of a site is not always a reliable indicator of restoration potential. In many cases where restoration has been assumed by some to be impossible, recovery has been achieved after the application of skilled and informed approaches. Where a site's potential for recovery is in doubt, but its recovery is highly desirable, a standard approach is to carry out trial interventions on a small area for a sufficient period to gain stronger evidence one way or the other. If even partial recovery proves to be impossible or not feasible, it would be sensible to modify the goal of the project from restoration to rehabilitation.

Table 2. Summary of generic standards for 1-5 star recovery levels

[**Note 1:** Each level is cumulative. **Note 2:** The different attributes will progress at different rates –see Table 3 that shows more detailed generic standards for each of the six key ecosystem attributes. **Note 3:** This system is applicable to any level of recovery where a reference ecosystem is used]

Number of stars	SUMMARY OF RECOVERY OUTCOME *(Note: Modelled on an appropriate local native reference ecosystem)*
★	Ongoing deterioration prevented. Substrates remediated (physically and chemically). Some level of native biota present; future recruitment niches not negated by biotic or abiotic characteristics. Future improvements for all attributes planned and future site management secured.
★★	Threats from adjacent areas starting to be managed or mitigated. Site has a small subset of characteristic native species and low threat from undesirable species onsite. Improved connectivity arranged with adjacent property holders.
★★★	Adjacent threats being managed or mitigated and very low threat from undesirable species onsite. A moderate subset of characteristic native species are established and some evidence of ecosystem functionality commencing. Improved connectivity in evidence.
★★★★	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.
★★★★★	Establishment of a characteristic assemblage of biota to a point where structural and trophic complexity is likely to develop without further intervention. Appropriate cross boundary flows are enabled and commencing and high levels of resilience is likely with return of appropriate disturbance regimes. Long term management arrangements in place.

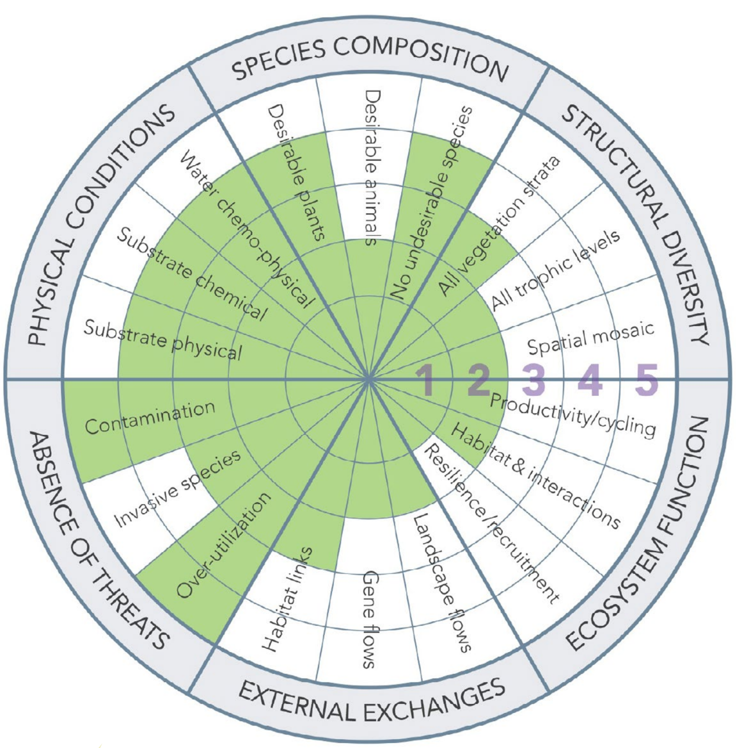


Figure 2. Progress evaluation 'recovery wheel' depicting a hypothetical 1-year old reconstruction project on its way to a 4-star condition. This template allows a manager to illustrate the degree to which the ecosystem under treatment is recovering over time. A practitioner with a high level of familiarity with the goals, objectives and site specific indicators set for the project and the recovery levels achieved to date can shade the segments for each sub-attribute after formal or informal evaluation. (Blank templates for the diagram and its accompanying proforma are available in Appendix 2.) Note: Sub-attribute labels can be adjusted or more added to better represent a particular ecosystem.

Table 3. Generic 1-5 star recovery scale interpreted in the context of the six key ecosystem attributes used to measure progress towards a self-organizing status. See interpretive notes, next page.

Note: This 5-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 the ecosystem and sub-attributes identified.

ATTRIBUTE	★	★★	★★★	★★★★	★★★★★
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 managed or mitigated to a low extent.	All adjacent threats managed or mitigated to an intermediate extent.	All threats managed or mitigated to high extent.
Physical conditions	Gross physical and chemical problems remediated (e.g., contamination, erosion, compaction).	Substrate chemical and physical properties (e.g., pH, salinity) on track to stabilize within natural range.	Substrate stabilized within natural range and supporting growth of characteristic biota.	Substrate securely maintaining conditions suitable for ongoing growth and recruitment of characteristic biota.	Substrate exhibiting physical and chemical characteristics highly similar to that of the reference ecosystem with evidence they can indefinitely sustain species and processes.
Species composition	Colonising native 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 native species establishing (e.g., ~10% of reference). Low onsite threat from exotic invasive or undesirable species.	A subset of key native species (e.g., ~25% of reference) establishing over substantial proportions of the site. Very low onsite 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 onsite threat from 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.
Structural diversity	One or fewer strata present and no spatial patterning or trophic complexity relative to reference ecosystem.	More strata present but low spatial patterning and trophic complexity, relative to reference ecosystem.	Most strata present and some spatial patterning and trophic complexity relative to reference site.	All strata present. Spatial patterning evident and substantial trophic complexity developing, relative to the reference ecosystem.	All strata present and spatial patterning and trophic complexity high. Further complexity and spatial pattering able to self-organize to highly resemble reference ecosystem.
Ecosystem functionality	Substrates and hydrology are at a foundational stage only, capable of future development of functions similar to the reference.	Substrates and hydrology show increased potential for a wider range of functions including nutrient cycling, and provision of habitats/resources for other species.	Evidence of functions commencing - e.g., nutrient cycling, water filtration and provision of habitat resources for a range of species.	Substantial evidence of key functions and processes commencing including reproduction, dispersal and recruitment of species.	Considerable evidence of functions and processes on a secure trajectory towards reference and evidence of ecosystem resilience likely after reinstatement of appropriate disturbance regimes.
External exchanges	Potential for exchanges (e.g. of species, genes, water, fire) with surrounding landscape or aquatic environment 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.

NOTES FOR INTERPRETING THE 5-STAR EVALUATION SYSTEM.

- **The 5-star system serves to evaluate the progression of an ecosystem along a trajectory of recovery.** It is not a tool for evaluating sites per se, or for evaluating the individual performance of practitioners.
- **The 5-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 in Tables 2 and 3 are generic in nature and should be interpreted more specifically by managers to suit their specific ecosystem or project.
- **Evaluation can only be as rigorous (and therefore as reliable) as the monitoring that informs it.** An 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 is not to be used as evidence of restoration success without also citing the monitoring report on which it is based.
- **Each restoration project attribute does not necessarily start at a 1-star ranking.** Sites that involve remnant biota and unaltered substrates will start at higher rankings - while sites where substrates are impaired or biota are absent will start at lower rankings. Whatever the entry point of a project, the aim will be to assist the ecosystem to progress along the trajectory of recovery insofar as possible towards a 5-star recovery. (A nil recovery score would be noted in written reports or as a zero in spreadsheets and would be represented by an empty cell in the diagram.)
- **Evaluation using the 5-star system and Figure 2 must be site- and scale-specific.** The 5-star system is most informative when applied at the scale of an individual project or site rather than a landscape or aquatic area containing zones that are not subject to restoration or rehabilitation treatments. Nonetheless multiple subsites can be separately evaluated then aggregated to inform degree of recovery in larger programs. For programs that include restorative and social development elements, 5-star reporting should be accompanied by supplementary information to represent these gains.

KEY CONCEPT 5. SUCCESSFUL RESTORATION DRAWS ON ALL RELEVANT KNOWLEDGE

Long-term relationship to place by local peoples (including Indigenous peoples) builds extensive and detailed knowledge of sites and ecosystems; and, when integrated into restoration projects, provides outstanding opportunities for improving restoration outcomes and social benefits. Practitioners of restoration and a wide range of other disciplines also bring extensive and detailed knowledge to restoration, as do researchers. The practice of ecological restoration is distinguished by a high degree of acquired knowledge that integrates ecological knowledge (derived from science and traditional ecological knowledge) with practitioner knowledge and knowledge developed in the fields of restoration practice, agronomy and seed production, horticulture, botanical and zoological management, soil and water management, engineering, landscape design and management and conservation planning, among others. Restoration ecology is the field of science that focuses on questions relevant to the practice of ecological restoration, which in turn is also informed by basic and applied ecology, the specialist sciences of conservation biology, conservation genetics and landscape ecology, the social sciences and economics.

Scientific thinking is not the exclusive preserve of professional researchers. Rather it is a logical approach, based on testable ideas (hypotheses), that can be applied with varying degrees of formality. Informal processes of trial and error are characteristic of all ecological restoration. More formal monitoring informed by experimental design principles, however, is increasingly being incorporated into ecological restoration projects (Box 3). In many cases practitioners have sufficient knowledge and skills to employ a scientific approach and achieve the desirable level of monitoring. In the case of professional ecological restoration planning, implementation, and monitoring, however, substantial background knowledge of both restoration practice and underpinning ecology is needed, requiring the planner and practitioner to draw as fully as possible from all learning and knowhow achieved to date.

The benefits of formal monitoring can be enhanced by practitioner-researcher collaborations. Such collaborations (whether involving the natural sciences or social sciences) may also result in research that optimizes potential for innovative restoration approaches, provide robust guidance for future activities and provide replicable data that generates new knowledge.

For example, focused research can help practitioners overcome what can seem difficult-to-resolve barriers to recovery, particularly for larger scale projects where cost-effectiveness becomes paramount. These barriers might include hostile substrate conditions, problematic reproductive traits 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 solutions to meet performance criteria, it would be appropriate to downgrade the classification and devise alternative compensations.

Formal studies integrated into restoration projects can also improve our understanding of 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 scientific methodology to assist with assessing the potential of a plant or animal population to adapt effectively to anthropogenically-induced climate change. If little is known about a population, research may be needed to determine the degree of assistance required to improve climate-readiness (i.e., improve the potential adaptability of a population to anticipated climate scenarios).

USING ADAPTIVE MANAGEMENT TO BUILD KNOWLEDGE AND CAPACITY.

Lack of restoration success in the past does not mean that restoration is not technically, practically or economically feasible in the future. Where knowledge and technical competency gaps exist, the use of adaptive management, linked to focused, outcome-based science is a fundamental tenet of building the know-how for future improvements in restoration capability.

KEY CONCEPT 6. EARLY, GENUINE AND ACTIVE ENGAGEMENT WITH ALL STAKEHOLDERS UNDERPINS LONG-TERM RESTORATION SUCCESS

Restoration is undertaken not only to restore environmental values but also to satisfy socio-economic and cultural values, needs and expectations. Communities who live or work within natural and semi-natural ecosystems benefit from restoration that improves the quality of air, land, water and vegetation. Indigenous and local communities, in particular, also benefit where that restoration reinforces nature-based cultures and livelihoods. Urban communities also benefit from restoration that provides amenities, natural resources and opportunities for re-engaging with nature.

A range of relationships exists between humans and the living biota and landscapes of the world; and the values and behaviors of humans (whether positive or negative) will dictate the future health and condition of ecosystems. Restoration itself can provide a powerful vehicle for encouraging positive and restorative attitudes toward ecosystems and the natural world in general. However, conserving and restoring ecosystems depends upon recognition of the expectations and interests of stakeholders and involvement by all stakeholders in finding solutions to ensure that ecosystems and society mutually prosper.

In cases where a mandate for restoration is not already in place or where further engagement is desirable, restoration project managers should genuinely and actively engage with those who live or work within or near a restoration site, and those who have a stake in the area's biodiversity and intrinsic values, or in the ecosystem goods and services the site provides. It is particularly important to recognize the cultural importance of ecosystems and sites to individuals and communities, including those engaged in restoration. This engagement needs to occur at or soon after the outset of a project to help define ecological goals, objectives, and methods of implementation, and throughout a restoration project to ensure social needs are also being met. Not only will a restoration project be more secure if genuine dialogue occurs between managers and community stakeholders, but also this dialogue – coupled with sharing of information about the ecosystem – can increase the level of practical collaboration, thereby facilitating solutions best suited to local ecosystems and cultures.

Social engagement, interpretation and two-way learning regarding the benefits of restoration to community 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 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.

Arbor Day planting at Waiwhakareke Natural Heritage Park in Hamilton, New Zealand, June 2016. This urban restoration project provides ecological and community benefits.

Photo credit: Peter Drury for Hamilton City Council

III

SECTION III - STANDARD PRACTICES FOR PLANNING AND IMPLEMENTING ECOLOGICAL RESTORATION PROJECTS

The following activities are standard practices used in planning, implementing, monitoring and evaluating ecological restoration projects where professional staff or contractors are engaged. They can, however be relevant to any restoration project because the degree to which they are applied should be adapted to correspond to the size, complexity, degree of damage, regulatory status and budgets of the particular project.

1. PLANNING AND DESIGN

1.1. Stakeholder engagement. Meaningful engagement is undertaken at the planning stage of a restoration project, with all key stakeholders (including the land or water managers, industry interests, neighbors and local community 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 environment;

1.2.2. Identify ways to physically 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; and,

1.2.3. Specify mechanisms for the future management of the project to interface optimally with management of nearby native ecosystems.

1.3. Ecosystem baseline inventory. Plans identify the site's current ecosystem(s) and its/their condition, including:

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

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 or changing 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. This includes undertaking an inventory that includes:

- A list of native and non-native species presumed absent and those potentially persisting as propagules or occurring within colonization distance;
- A map of 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 drivers and threats that have caused degradation, damage or destruction on the site and ways to eliminate, mitigate or (in some cases) adapt to them. 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, contamination, altered disturbance regimes and other threats – and ways to manage, remove or adapt to them;
- Description of any need for supplementing genetic diversity for species reduced to non-viable population sizes due to fragmentation [e.g., to a standard described in Offord & Meagher 2009 (for flora); and IUCN/SSC 2013 (for fauna)]; and,
- Existing and anticipated effects of climate change (e.g. temperature, rainfall, sea level, marine acidity) on species and genotypes with respect to likely future viability.

1.4. Reference ecosystem identification. Plans identify and describe (to the level needed to assist project design) the appropriate local native reference ecosystem(s), optimally derived from multiple sites and sources of information (see above). (Generic information on benchmark characteristics and functions for the ecosystems may be available in environmental agency guidelines). The reference ecosystem will represent the composition and any notable structural or functional elements (reflecting the six key 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 extant ecosystems are being disturbed and then restored, the pre-existing intact ecosystems must be mapped in detail prior to site disturbance);

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

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

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

1.5.2. Restoration goal(s)—i.e., the condition or state of that ecosystem and attributes that the project is aiming to achieve;

1.5.3. Restoration objectives—i.e., changes and immediate outcomes needed to achieve the target and goals relative to any distinct spatial zones within the site. Such objectives are stated in terms of measurable and quantifiable indicators to identify whether or not the project is reaching its objectives within identified 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 likely appropriate prescription, will be necessary. (Without certainty, the precautionary principle should be applied in a manner that results in least environmental risk.)

Plans should include:

1.6.1. Descriptions of actions to be undertaken for elimination and mitigation of (or adaptation to) causal problems; and,

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 condition of abiotic elements to render them amenable to the recovery of target biota and ecosystem structure and functionality;
- 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;
- Identification of ecologically appropriate strategies (such as leaving gaps for in-fill reintroductions in subsequent seasons) for addressing circumstances where the ideal species or genetic stock is not immediately available; and,
- Specifications for appropriate species selection and genetic sourcing of biota to be reintroduced. [In the case of fauna, a strategy for sourcing and re-introduction should comply with IUCN/SSC (2013). In the case of plant species, a strategy for sustainable seed supply and a timetable for collection and supply of seed should be prepared that complies with guidelines in 'Plant germplasm conservation in Australia' (Offord & Meagher 2009) or the U.S. document 'National Seed Strategy for Rehabilitation and Restoration' (www.blm.gov/ut/st/en/prog/more/CPNPP/0/seedstrategy.html), or similar relevant national or regional document.].

1.7. Assessing security of site tenure and of post treatment maintenance scheduling. Some indication of potential for long term conservation management of the site is required before investing in restoration. Restoration plans should thus identify:

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

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, financing or human resourcing;

1.8.3. An approximate timetable for the project and a rationale for the duration of the project and means to maintain commitment to its aim, objectives and targets over that period; and,

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

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

1.9.1. Stakeholder and independent peer review as required; and,

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

2. IMPLEMENTATION

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

2.1. No further or lasting damage is caused by the restoration works to any natural resources or elements of the landscape or aquatic area that are being conserved, including physical damage (e.g., clearing, burying topsoil, trampling), chemical contamination (e.g., over-fertilizing, pesticide spills) or biological contamination (e.g., introduction of invasive species including undesirable pathogens);

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 potential for natural and assisted recovery. Primary treatments including substrate and hydrological amendments, pest animal and plant control, application of recovery triggers and biotic reintroductions are adequately followed up by timely secondary treatments as required. Appropriate aftercare is provided to any planted stock;

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

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

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

3. MONITORING, DOCUMENTATION, EVALUATION AND REPORTING

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

3.1. Monitoring to evaluate restoration outcomes begins at the planning stage with the development of a monitoring plan to identify success or otherwise of the treatments (See also Boxes 2 and 3).

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

- Collecting baseline data prior to works to ensure a comparison for later data collection (to identify whether objectives, goals and targets are being attained);
- Collecting data at appropriate intervals after works (e.g., at higher frequency early in the recovery phase); and,
- Recording the details of restoration activities including numbers of 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 monitoring is undertaken before and after treatment and formal monitoring is ideally undertaken not only at the restored site but also at untreated areas and, ideally, any actual reference site).

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

3.1.4. For statistical analysis and publication of results, sampling units must be consistent with a rigorous sampling design, be an appropriate size for the attributes measured and should be replicated sufficiently within the site.

3.2. Adequate records of treatments are maintained to ensure adequate implementation, inform adaptive management and enable future evaluation of results relative to treatments. All treatment data, along with all evaluation monitoring records are maintained for future reference. In addition:

3.2.1. Consideration should be given to lodging data with open access facilities; and,

3.2.2. Secure storage should be arranged, ideally by the project managers, for records of the provenance (i.e., source) of any re-introduced plants or animals. 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/propagator's name.

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

3.3.1. Evaluation should adequately assess results from the monitoring.

3.3.2. Results should be 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 should convey the information in an accurate and accessible way, customized to the audience.

3.4.2. Reporting should specify the level and details of monitoring upon which any evaluation of success 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.

IV

SECTION IV - RESTORATION AND THE 'BIG PICTURE' ENVIRONMENTAL CHALLENGE

SCALING UP RESTORATION

Scale is an important consideration in ecological restoration as some ecosystem processes (such as gene flow, colonization, predation and ecological disturbances) function at larger scales (larger aquatic environment, landscape, watershed, etc.), as do degradation processes. In addition, some species may have large minimum habitat areas (or greater trophic complexity) than is provided by small scale projects unless these are linked within a larger program or to protected areas. Substantially increasing the scale of carbon sequestration through extensive additional plants and animal biomass (including biomass in soils) is also urgently needed. Thus, ecological restoration needs to be at scales (these may be at the hundreds to the thousands of hectares) that provide environmental and ecological benefits.

Aspiration to increase the scale of a project to make a substantial contribution to reversing degradation at larger scales is to be encouraged. Where the aim is to achieve a 5-star rating for all attributes in a restored system, full recovery of attributes will be difficult to achieve at larger scales and control or mitigation of threats will take longer to achieve if those threats occur at larger scales. Certainly, scaling up restoration can bring some economies of scale but it also brings increased risk of over-extension of financial and human resources, particularly where a high degree of unpredictability exists with respect to ecosystem responses to interventions. For scale-sensitive and time-sensitive issues, therefore, treatments are usually trialled at a small scale prior to application more broadly. In addition, some managers will see wisdom in investing scarce resources in more gradual, 'diluted' targeted improvements at larger scales for particular attributes, rather than adopting a comprehensive approach that limits the scale at which restoration can operate. Such larger-scale works carried out over longer time frames are generally referred to as restoration **programs,** which typically contain multiple smaller 'projects' that are ideally interlinked in multiple physical and biological ways.

When evaluating the benefits of the scale of a project it is important to recognize that size only confers an advantage where it represents an increase in the scale at which other values (e.g., increased abundance of native species, decreased pest species abundance or increased carbon store) are improved or anticipated to be improved. For this reason, and because over-valuing the importance of scale relative to other benefits (such as recovering threatened species or ecosystems) may lead to an undervaluing of smaller projects that may be of high ecological importance, scale should be evaluated only as a multiplier of the other values achieved. It is also important to bear in mind that success at larger scales is often conferred by cumulative success at smaller scales and that every small-scale project can be important in the larger picture.

Project characteristics that can help drive larger scale benefits. A range of contextual characteristics of a project (i.e., co-benefits beyond ecosystem recovery) should also be considered when predicting whether a project is likely to make a difference at larger scales (Table 4). These characteristics may include: a project's strategic location and timeliness; relative rarity of taxa or ecosystems to potentially benefit; the pervasive nature of threats to be managed; the degree of social support the project may attract; and, the potential security of its long-term management arrangements. Achievement of such characteristics should be included in project goals and measured (wherever possible) and reported during the life of a project to better evaluate and fine tune its potential to make a difference at larger scales.

RELATIONSHIP OF ECOLOGICAL RESTORATION TO OTHER 'RESTORATIVE' ACTIVITIES

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

More specifically, public agencies have adopted ecological restoration as a process for improving the condition of degraded biodiversity reserves - while also managing natural resources and public open space areas in a manner complementary to environmental repair activities. Many industries, community organizations and private citizens have responded to the current environmental challenges by seeking to reduce environmental impacts and improve the ecological sustainability of lifestyles and production systems.

All this work - whether actual ecological restoration or complementary activities that improve environmental conditions - can be termed 'restorative' where it is inspired by the values and principles underpinning ecological restoration and moves the trajectory of broad ecological recovery in a positive direction.

Ecological restoration - with its aspiration to achieve the highest level of recovery attainable (whether *full recovery* or partial recovery) and its emphasis on working with natural processes - is the most efficient and effective means of repairing damage to all intact, semi-natural or degraded local native ecosystems irrespective of land or water use zone.

At least some form of environmental repair is practiced, often alongside reduction of environmental impacts, in a broad range of industry sectors including protected areas management, forestry, fisheries agriculture, mining, utilities and urban green space management. While in some cases ecological restoration is already practiced and is increasing (Table 5), many other activities that are intended to be ameliorative or reduce environmental impacts might only be categorized as rehabilitation.

Whether works aim to reduce impacts or effect environmental repair, the principles, conceptual frameworks and best practices of ecological restoration conveyed in these Standards can inspire and inform all works so that ecosystem managers from all sectors can improve rather than reduce potential for recovery of ecosystems. Activities that aim to achieve such improvement in conditions for ecological recovery can be considered restorative.

Table 4. A range of project characteristics can add weight to a project's potential to make a difference

CHARACTERISTIC	EXAMPLES
1. Strategic location and timeliness	Restoration projects can deploy strategies and tactics that optimize spatial and temporal advantage, thus making the most of scarce resources and other leverage points for restoration. Projects, for example, are generally prioritized in terms of: (i) which goals are more urgent than others or can act as an accelerator for the achievement of other goals; and, (ii) which areas having greater 'holding' potential or higher influence on other parts of the site or broader environment.
2. Extinction risk status of the taxa or ecosystems potentially benefiting	Projects may have added value to the degree they may provide benefits for the conservation of threatened species, populations, or ecological communities. Mechanisms for listing threatened species and ecological communities are in place in many countries of the world, often consistent with (or linked to) the International Union for Conservation of Nature (IUCN) Red List of Threatened species and Red List of Ecosystems.
3. Pervasiveness of threats to be addressed	The degree to which the threats addressed by a project are pervasive across larger areas can add weight to a project's capacity to make a difference because its positive effects can influence a broader area than the site on which the works are carried out. For example, a project that achieves substantial storage of carbon through additional biomass of plants and animals, reduces contamination into waterways, or contributes substantially to the control of highly significant pest plants or animals contributes not only to improved outcomes at its own location but also contributes to improved outcomes elsewhere.
4. Degree project is informed by ecological knowledge	Restoration success can be improved when restoration planning and implementation is infused with an integration of ecological knowledge and other knowledge. In practical terms this is achieved through the knowledge and skills of the individual planner, researchers and/or restoration practitioners involved in the project and through their interaction with local knowledge holders. Success can also be enhanced by the degree to which difficult problems can be examined and resolved through research partnerships.
5. Project culturally embedded	While restoration is largely driven by ecological processes, the success and security of a restoration project will also depend on the degree to which the purpose, targets, goals and objectives of the project are endorsed by affected communities. This is best achieved by early and genuine consultation and participatory planning involving those communities, which will affect the degree to which the project is embedded in the culture of the stakeholder communities.
6. Secure institutional support	Long-term projects need long-term security both for the sake of their consistent implementation and to reassure participants that the benefits predicted to arise from the resources invested will persist over time, ideally in perpetuity. Formal protection of the site through legal tenure arrangements is ideal, as well as ensuring that long term commitment is made by the site's major public and private stakeholder institutions.

Table 5. Degrees of restorative activity currently or potentially applied in a range of sectors. All industry, government and community sectors are encouraged to adopt the practice of ecological restoration wherever feasible and appropriate. Where it is not appropriate, they can be encouraged to undertake restorative work of all kinds to the highest possible recovery level.

INDUSTRY	STANDARDS RECOMMENDED
Protected area management	• Natural areas: 5-star • Semi-natural areas: ideally 5-star and at least a 3-star • Already converted landscapes: provide ecosystem services and lower rather than increase impacts on natural systems
Mining, quarrying and oil and gas drilling	• Natural areas: 5-star • Semi-natural areas: ideally 5-star and at least a 3-star • Already converted landscapes: provide ecosystem services and lower rather than increase impacts on natural systems
Forest management	• Native forest management: 5-star • Reforestation adjacent to natural habitats: ideally 5-star but at least 3-star • Reforestation for ecosystem services: no deleterious effect on natural areas
Agricultural lands	• Remnant management: ideally 5-star but at least 3-star • Reforestation adjacent to natural habitats: ideally 5-star but at least 3-star • Reforestation for ecosystem services: no deleterious effect on natural areas
Fisheries management	• Native habitat management: ideally 5-star but at least 3-star • Management adjacent to natural habitats: ideally 5-star but at least 3-star • General fisheries management: no deleterious effect on natural areas ecosystems and management on continuous improvement basis
Utilities and infrastructure	• Natural areas: 5-star • Semi-natural areas: ideally 5-star and at least a 3-star • Within utility areas: no deleterious impacts on adjacent natural areas
Urban green space	• Many natural areas: 5-star • Semi-natural areas: ideally 5-star and at least a 3-star • Converted parks and gardens: at least 2-star recovery is encouraged

EMPHASIZING OUR COMBINED EFFORTS ALONG THE 'RESTORATIVE CONTINUUM'

There are important potential synergies between all natural resource management fields and the growing field of ecological restoration, such that it is more beneficial to see these as an integrated whole rather than foster separation (Figure 4). The global imperative to reduce degradation and effect ecosystem repair across the board provides a strong incentive to use ecological principles to guide the reduction of impacts and to incorporate local native species in all industry sectors wherever mutual benefits can be realized.

Conceptualizing management interventions by means of this continuum (alongside becoming informed by restoration principles and standards) can assist governments, industries and communities to better achieve integrated 'net gain' improvements in condition that will accelerate positive change at larger scales. Indeed, continuous local improvements in reduction of degradation and environmental condition of ecosystems, waterways and the atmosphere will inevitably be cumulative at larger scales - even if only low level efforts are initially applied. As such, any small and continuous improvement can play an ecologically important role in reducing the pace of degradation and improving the adaptability – and therefore potential resilience - of ecosystems and individual species to rapid environmental change.

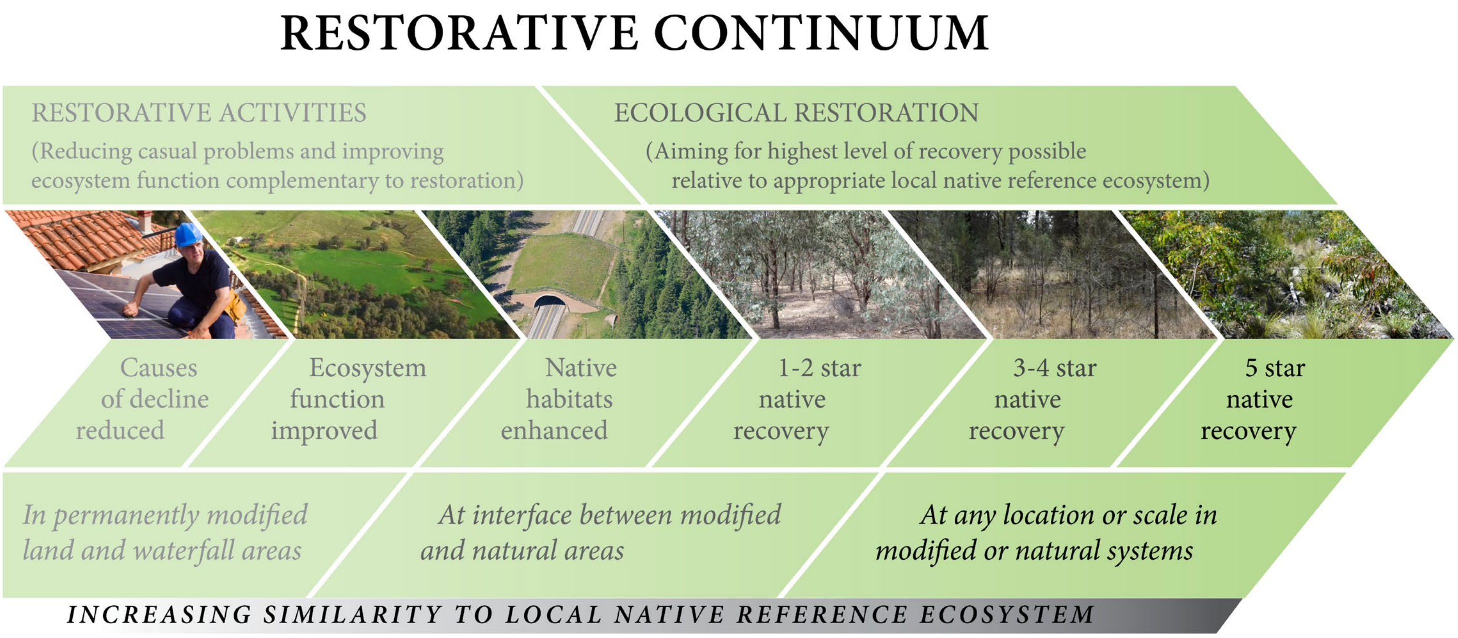


Photo credits: (from left): 1. Used under license from Shutterstock.com; 2: ©S. Triggs: Inglis Rural; 3: ©Marcel Huijser; 4 and 6: ©T. McDonald; 5: ©J. Jonson

Figure 3. Restorative continuum. Ecological restoration and restorative management can be seen to be aligned along a 'restorative continuum' where a broad range of activities undertaken by society to repair damage to the broader environment, complement ecological restoration and provide improved conditions for broad scale recovery.

Initial restorative activities such as single-species revegetation projects can be transformed over time into diverse 4-star to 5-star restoration projects. Left, Bethany Beach, Delaware, USA, ©ER&M/Biohabitats. Right, Delray Beach, Florida, USA ©George D. Gann.

V SECTION V - GLOSSARY OF TERMS

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

Adaptive Management – an ongoing process for improving management policies and practices by applying knowledge learned through assessment of previously employed policies and practices to future projects and programs (MA 2005). The practice of revisiting management decisions and revising them in the light of new information (Groom et al. 2006).

Approach (to restoration) – the generic category of treatment (i.e., natural or assisted regeneration or reconstruction) (McDonald et al. 2016).

Assisted regeneration – a particular approach to restoration that focuses on actively harnessing any natural regeneration capacity of biota remaining on site or nearby as distinct from reintroducing the biota to the site or leaving a site to regenerate naturally (Clewell & McDonald 2009). While this approach is typically applied to sites of low to intermediate degradation, even some very highly degraded sites have proven capable of assisted regeneration given appropriate treatment and sufficient time frames (Prach & Hobbs 2008). Interventions include removal of pest organisms, reapplying ecological disturbance regimes and installation of resources to prompt colonization.

Attributes – see Key ecosystem attribute categories

Barriers (to recovery) – factors impeding recovery of an ecosystem attribute (May 1977).

Baseline inventory – a description of current biotic and abiotic elements of site prior to restoration, including its structural, functional and compositional attributes and current condition (SER 2004). The inventory is implemented at the commencement of the restoration planning stage, along with the reference model, to inform planning including restoration goals, measurable objectives and treatment prescriptions.

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

Carbon storage – the capture and long-term storage of atmospheric carbon dioxide (typically in biomass accumulation by way of photosynthesis and vegetation growth). This may occur naturally or be the result of actions to reduce the impacts of climate change.

Climate envelope – the climatic range in which the population of a species is distributed (Pearson & Dawson 2003). With climate change, such envelopes are likely to shift.

Closure criteria – detailed description of the measurable outcomes required at a restored site before restoration or rehabilitation works can be considered by a regulator as completed.

Community structure – see definition under *Structural diversity.*

Composition – the array of organisms within an ecosystem. In a restoration or monitoring plan usually listed to species or genus (for plants and vertebrate fauna) or at least to order (for invertebrates and micro-organisms).

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

Creation (See also *Designer Ecosystem*) – intentional fabrication of an ecosystem (different from the one previously occurring on a site) for a useful purpose (such as the construction and assemblage of a desired habitat or providing a service such as water purification) without a focus on achieving a reference ecosystem (Clewell & Aronson 2013).

Cultural ecosystems – ecosystems that have developed under the joint influence of natural processes and human-imposed organization to provide structure, composition and functionality more useful to human exploitation (SER 2004). Where these remain well within the range of natural variation for the ecosystem (e.g. grassy openings and savannahs traditionally managed by pre-industrial age peoples), they may become the subject of ecological restoration (at least partial recovery). Where they exceed the range of natural variation they may be best managed as historical or production systems and their repair described as rehabilitation.

Cycling (ecological) – the transfer (between parts of an ecosystem) of resources such as water, carbon, nitrogen, and other elements that are fundamental to all other ecosystem functions.

Damage (to ecosystem) – an acute and obvious deleterious impact upon an ecosystem (SER 2004).

Degradation (of an ecosystem) – a level of deleterious human impact to ecosystems that results in the loss of biodiversity and simplification or disruption in their structure, composition, and functionality, and generally leads to reduction in the flow of ecosystem goods and services (MA 2005, Alexander et al. 2011).

Designer Ecosystem (see also Creation) – an ecosystem that is primarily created to achieve mitigation, conservation of a threatened species, or other management purpose (MacMahon and Holl 2001) rather than achieve the re-establishment of a reference ecosystem.

Desirable species – species from the reference ecosystem (or sometimes non-native nurse plants), that will enable the local native ecosystem to recover. The corollary of desirable species is undesirable species, which are usually but not exclusively non-native invasive species (McDonald et al. 2016).

Destruction (of an ecosystem) – when degradation or damage removes all macroscopic life, and commonly ruins the physical environment of an ecosystem (SER 2004).

Ecological reference – see *Reference ecosystem*.

Ecological restoration (syn. ecosystem restoration) – the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed (SER 2004).

Ecosystem – small or large scale assemblage of biotic and abiotic components in water bodies 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 assemblage of any size or scale.

Ecosystem attributes – see *Key ecosystem attribute categories.*

Ecosystem maintenance – ongoing activities – applied after full recovery - intended to counteract processes of ecological degradation to sustain the attributes of an ecosystem. 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 (McDonald et al. 2016).

Ecosystem resilience – the capacity of a system to absorb disturbance and reorganize while still retaining similar function, structure, and feedbacks (Suding

2011). In plant and animal communities this property is highly dependent on adaptations by individual species to disturbances or stresses experienced during the species' evolution (Westman 1978).

Ecosystem services – the direct and indirect contributions of ecosystems to human well-being. They include the production of clean soil, water and air, the moderation of climate and disease, nutrient cycling and pollination, the provisioning of a range of goods useful to humans and potential for the satisfaction of aesthetic, recreation and other human values. Restoration targets may specifically refer to the reinstatement of particular ecosystem services or amelioration of the quality and flow of one or more services (de Groot et al. 2010).

Environmental repair – any intentional restorative activity that improves ecosystem functionality, ecosystem services, or biodiversity (McDonald et al. 2016).

External exchanges – the 2-way flows that occur between ecological units within the landscape or aquatic environment including flows of energy, water, fire, genetic material, animals and seeds. Exchanges are facilitated by habitat linkages (SER 2004).

Five-star (5-star) recovery – a semi-quantitative rating system based on biotic and abiotic factors that provides comparative assessment of how well the attributes of an ecosystem are recovering after treatment. (McDonald et al. 2016) (Note, it is not a rating of the restoration activities but of the recovery outcomes.)

Full recovery – the state whereby all ecosystem attributes closely resemble those of the reference ecosystem (model). It is preceded by the ecosystem exhibiting self-organization that leads to the full resolution and maturity of ecosystem attributes. At the point of self-organization, the restoration phase could be considered complete and the site shifts to a maintenance phase (McDonald et al. 2016).

Functions, of an ecosystem – the workings of an ecosystem arising from interactions and relationships between biota and abiotic elements. This includes ecosystem processes such as primary production, decomposition, nutrient cycling and transpiration and emergent properties such as competition and resilience. Functions represent the potential that ecosystems will be able to deliver ecosystem goods and services to humans (van Andel and Aronson 2012).

Gene flow – exchange of genetic material between individual organisms that maintains the genetic diversity of a species' population. In nature, gene flow can be limited by dispersal 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., embryos, seeds, vegetative materials) that provide a source of genetic material for future populations.

Indicators of recovery – characteristics of an ecosystem that can be used for measuring the progress towards restoration goals or objectives at a particular site (e.g. measures of presence/absence and quality of biotic or abiotic components of the ecosystem) (Conservation Measures Partnership 2013).

Intervention (restoration) – action undertaken to achieve restoration, such as substrate amendment, exotics control, habitat conditioning, reintroductions.

Inventory – see *Baseline inventory*.

Key ecosystem attribute categories – broad categories developed for restoration standards to assist practitioners with evaluating the degree to which biotic and abiotic properties and functions of an ecosystem are recovering. In this document six categories are identified: absence of threats, physical conditions, species composition, community structure, ecosystem functionality, and external exchanges (McDonald et al 2016). From the attainment of these attributes emerge complexity, self-organization, resilience, and sustainability.

Landscape flows – exchanges that occur at a level larger than the site (including aquatic environments) and including flows of energy, water, fire and genetic material. Exchanges are facilitated by habitat linkages (Wiens 1992).

Local native ecosystem – an ecosystem comprising species or subspecies (excluding invasive non-native 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 and historical information can help inform the most probable local native ecosystems. These are distinguished from 'cultural ecosystems' (e.g., agroecosystems) if the ecosystems have been substantially modified in extent and configuration beyond natural analogues or fall outside the range of natural variation for that 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. (Sometimes referred to as 'mitigation', Galatowitsch 2012.)

Natural (spontaneous) **regeneration** – Germination, birth or other recruitment of biota including plants, animals and microbiota, whether arising from colonization or in situ processes. A 'natural regeneration' approach to restoration relies on increases in individuals, without direct planting or seeding, after the removal of causal factors alone, as distinct from an 'assisted natural regeneration' approach that depends upon active intervention (Prach & Hobbs 2008, Clewell & McDonald 2009).

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

Over-utilization – 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.).

Partial recovery – the state whereby ecosystem attributes—or not all ecosystem attributes—have improved but do not yet closely resemble those of the reference ecosystem.

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

Reallocation – is the conversion of an ecosystem to a different kind of ecosystem or land use primarily for purposes other than the conservation management of local native ecosystems (Aronson et al. 1993).

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 by which an ecosystem regains its composition, structure and functionality relative to the levels identified for the reference ecosystem. In restoration, recovery is assisted by restoration activity – and recovery can be described as partial or full.

Recruitment – production of a subsequent generation of organisms. This is measured not by numbers of new organisms alone (e.g., not every hatchling or seedling) but by the number that develop as independent individuals in the population.

Reference ecosystem – a community of organisms and abiotic components able to act as a model or benchmark for restoration. A reference ecosystem usually represents a non-degraded version of the ecosystem complete with its flora, fauna, abiotic elements, functions, processes and successional states that would have existed on the restoration site had degradation, damage or destruction not occurred – but should be adjusted to accommodate changed or predicted environmental conditions. An alternative term for reference ecosystem is 'ecological reference'.

Reference model – see *Reference ecosystem*

Regeneration – see *Natural regeneration* and *Assisted regeneration*.

Rehabilitation – direct or indirect actions with the aim of reinstating a level of ecosystem functionality where ecological restoration is not sought, but rather renewed and ongoing provision of ecosystem goods and services.

Restoration – see *Ecological restoration.*

Restoration ecology – the branch of ecological science that provides concepts, models, methodologies and tools for the practice of ecological restoration.

Restoration program – a larger composite of many small restoration projects, whether at a single site or many.

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 used in this document as a generic term for any restoration project or program unless 'program' is specified. It is not used in this document to refer to a specific limited set of works confined to a contract or funding round.

Restorative – describing activities and outcomes that may not necessarily be ecological restoration but which are based on the principles underpinning ecological restoration.

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

Self-organizing – a state whereby all the necessary elements are present and the ecosystem's attributes can continue to develop towards the appropriate reference state without outside assistance (Clewell & Aronson 2013). 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 or location. Can occur at different scales but is generally at the patch or property scale (i.e., smaller than a landscape).

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

Spatial patterning – see *Spatial mosaic.*

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

Stressors (ecological) – naturally occurring drivers of ecological dynamics (e.g. fire, flooding, drought, freezing and herbivory to which species have become adapted) (Clewell & Aronson 2013). (See also *Triggers*)

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

Structural diversity – key ecosystem attribute category used in this document to convey both 'ecosystem structure' and 'community structure'. Ecosystem structure refers to the physical organization of an ecological system including density, stratification, and distribution of species (their populations, habitat size and complexity), canopy structure and pattern of habitat patches, as well as abiotic elements. 'Community structure' refers to hierarchies of the biota of an ecosystem including trophic pyramids, food webs and food chains.

Structure, of an ecosystem – see definition contained under Structural diversity.

Succession (ecological) – patterns of change and replacement occurring within ecosystems over time in response to disturbance. Disturbance-adapted ecosystems require disturbance to maintain a diversity of successional states or a specific successional state.

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

Threshold (ecological) – a point at which a small change in environmental or biophysical conditions causes a shift in an ecosystem to a different ecological state (Holling 1973, May 1977). Once one or more ecological thresholds have been crossed, an ecosystem may not easily return to its previous state or trajectory without major human interventions.

Trajectory (ecological) – a course or pathway of an ecosystem over time. It may entail degradation, stasis, or adaptation to changing environmental conditions, or response to ecological restoration – ideally recovery of lost integrity and resilience (Holling 1973).

Translocation – the intentional transporting (by humans) of organisms to a different part of a given landscape or aquatic environment or to more distant areas. The purpose is generally to conserve an endangered species, subspecies or population.

Triggers (recovery) – natural or applied disturbances or resource fluxes that initiate recovery of plants (e.g. soil disturbance, herbivory, fire, flooding etc.) or placement of key resources to attract and support animals (e.g. perch trees, coarse woody debris). (See also *Stressors*)

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

Wellbeing – a context-and situation-dependent state of humans, comprising basic material for a good life, freedom and choice, health, good social relations and security (IFAD Entry number 2261).

LITERATURE CITED

Alexander S, Nelson CR, Aronson J, Lamb D, Cliquet A, Erwin KL, Finlayson CM, de Groot RS, Harris JA, Higgs ES, Hobbs RJ, Robin Lewis RR, Martinez D, and Murcia C (2011) Opportunities and challenges for ecological restoration within REDD+. Restoration Ecology 19:683-689

Aronson J, and Alexander S (2013) Ecosystem restoration is now a global priority: time to roll up our sleeves. Restoration Ecology 21:293-296

Aronson J, Floret C, Le Floc'h E, Ovalle C, and Pontanier R (1993) Restoration and rehabilitation of degraded ecosystems in arid and semi-arid lands. I. A view from the south. Restoration Ecology 1:8-17

Clewell A, and McDonald T (2009) Relevance of natural recovery to ecological restoration. Ecological Restoration 27:122-124

Clewell AF, and Aronson J (2013) Ecological restoration: principles, values, and structure of an emerging profession. 2nd edition. Island Press, Washington, D.C.

Clewell AF, Rieger J, and Munroe J (2005) Guidelines for developing and managing ecological restoration projects. Society for Ecological Restoration International, Tuscon, Arizona www.ser.org

Conservation Measures Partnership (2013) Open standards for the practice of conservation. Version 3. http://cmp-openstandards.org/ (accessed March 15 2016)

de Groot R, Fisher B, Christie M, Aronson J, Braat L, and Haines-Young R (2010) Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation. Pages 9-40 In: Kumar P (ed) The economics of ecosystems and biodiversity: the ecological and economic foundations. Earthscan, London

Galatowitsch SM (2012) Ecological restoration. Sinauer, Sunderland, Massachusetts

Gann GD, and Lamb D (2006) Ecological restoration: a means of conserving biodiversity and sustaining livelihoods. Society for Ecological Restoration International, Tucson, Arizona

Groom MA, Meffe GK, and Carroll CR (2006) Principles of conservation biology. Sinauer, Sunderland, Massachusetts

Hobbs RJ, and Harris JA (2001) Restoration ecology: repairing the earth's ecosystems in the new millennium. Restoration Ecology 9:239-246

Holling CS (1973) Resilience and stability of ecological systems. Annual Review of Ecology and Systematics 4:1-23

IFAD (undated) Indigenous peoples glossary. https://www.ifad.org/documents/10180/4cd018b6-c7eb-40c4-9190-2066e5b9dc91 Entry 2261

IUCN/SSC (2013) Guidelines for reintroductions and other conservation translocations. Version 1. IUCN Species Survival Commission, Gland, Switzerland

Keenleyside KA, Dudley N, Cairns S, Hall CM, and Stolton S (2012) Ecological restoration for protected areas: principles, guidelines and best practices. IUCN, Gland, Switzerland

MacMahon JA, and Holl KD (2001) Ecological restoration: a key to conservation biology's future. Pages 245-269 In: Soulé ME and Orians GH (eds) Conservation biology: research priorities for the next decade. Island Press, Washington, D.C.

May RM (1977) Thresholds and breakpoints in ecosystems with a multiplicity of stable states. Nature 269:471-477

McDonald T, Jonson J, and Dixon KW (2016) National standards for the practice of ecological restoration in Australia. Restoration Ecology 24:S6-S32

Millenium Ecosystem Assessment (2005) Ecosystems and human well-being: synthesis. Island Press, Washington, D.C.

Offard CA, and Meagher PF (2009) Plant germplasm conservation in Australia. Australian Network for Plant Conservation, Canberra, Australia

Pearson RG, and Dawson TP (2003) Predicting the impacts of climate change on the distribution of species: are bioclimate envelope models useful? Global Ecology and Biogeography 12:361-371

Prach K, and Hobbs RJ (2008) Spontaneous succession versus technical reclamation in the restoration of disturbed sites. Restoration Ecology 16:363-366

Society for Ecological Restoration International Science and Policy Working Group (2004) The SER International primer on ecological restoration. Society for Ecological Restoration International, Tuscon, Arizona www.ser.org

Suding KN (2011) Toward an era of restoration in ecology: successes, failures, and opportunities ahead. Annual Review of Ecology, Evolution, and Systematics 42:465-487

van Andel J, and Aronson J (2012) Restoration ecology: the new frontier. 2nd edition. Wiley-Blackwell, Oxford

Walker BH, and Salt DA (2006) Resilience thinking: sustaining ecosystems and people in a changing world. Island Press, Washington, D.C.

Westman WE (1978) Measuring the inertia and resilience of ecosystems. Bioscience 28:705-740

Whisenant SG (1999) Repairing damaged wildlands: a process-oriented landscape-scale approach. Cambridge University Press, New York

Wiens JA (1992) Ecological flows across landscape boundaries: a conceptual overview. Pages 217-235 In: Hansen AJ and DiCastri F (eds) Landscape boundaries. Springer-Verlag, New York

APPENDIX 1: VALUES AND PRINCIPLES THAT UNDERPIN ECOLOGICAL RESTORATION[2]

Restoration should be Effective, Efficient, and Engaging (modified from Keenleyside et al. 2012)

- **Effective** ecological restoration re-establishes and maintains values.
- **Efficient** ecological restoration maximizes beneficial outcomes while minimizing costs in time, resources and effort.
- **Engaging** ecological restoration collaborates with partners and stakeholders, promotes participation and enhances experience.

EFFECTIVE ECOLOGICAL RESTORATION:

- **Supports and is modeled on existing native ecosystems and does not cause further harm.** Examples of relatively intact land and water ecosystems remain across the globe, 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.
- **Is aspirational.** The ethic of ecological restoration is to seek the highest and best conservation outcomes. Even if it takes long time frames, full recovery should be the goal wherever it may be ultimately attainable and desirable. Where full recovery is clearly not attainable or desirable, at least partial recovery and continuous improvement in the condition of ecosystems to provide 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 practicing ecological restoration, we seek a more ethical and satisfying relationship between humans and the rest of nature.
- **Is not a substitute for sustainably managing and protecting ecosystems.** The promise of restoration cannot be invoked as

[2] The underlying principles and their definitions are modified from SER 2004, the SER website, Keenleyside 2012 and McDonald et al 2016

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. Therefore, great caution and prudence are required when undertaking transformation, exploitation or fragmentation, or when negotiating offsets.

EFFICIENT ECOLOGICAL RESTORATION DEPENDS UPON:

ECOLOGICAL

- **Addressing causes at multiple scales to the extent possible.** Degradation will continue to undermine restoration inputs unless the causes of degradation are addressed or mitigated. The range of anthropogenic threats include over-utilization, clearing, erosion and sedimentation, contamination, 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 facilitates a process of recovery carried out by the organisms themselves.** Re-assembling species and habitat features on a site invariably provides just the starting point for ecological recovery; the longer-term process is performed by the organisms themselves. The speed of this process can sometimes be increased with greater levels of financial resourcing.
- **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 sequence and 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).
- **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 until goals have been reached.
- **Addressing all biotic components.** Terrestrial restoration commonly starts with re-establishing plant communities but must integrate all important groups of biota including plants and animals (particularly those that are habitat-forming) and other biota at all levels from micro- to macro-organisms. This is particularly important considering the role of plant-animal interactions and trophic complexity required to achieve the reinstatement of functions such as nutrient cycling, soil disturbance, pollination and dispersal. Collaboration between fauna and flora specialists is required to identify appropriate scales of interventions 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. Conversely, the genetic isolation of

narrow endemics can be compromised by the introduction of closely-related taxa, leading to extinction through hybridization.

LOGISTICAL

- **Drawing rigorous, relevant, and applicable knowledge 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.
- **Knowing your ecosystems and being aware of past mistakes.** Success can increase with increased working knowledge of (i) the target ecosystem's biota and abiotic conditions and how they establish, function, interact and reproduce under various conditions including anticipated climate change; and (ii) responses of these species to specific restoration interventions tried elsewhere.
- **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 can be modified 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 restoration outcomes will be assessed. This will not only ensure that a project collects the right information but that it can also better attune the planning process to devise strategies and actions more likely to end in success (Box 3).
- **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 may be able to 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 functionality over the short, medium and longer term duration of the recovery process.

ENGAGING ECOLOGICAL RESTORATION DEPENDS UPON:

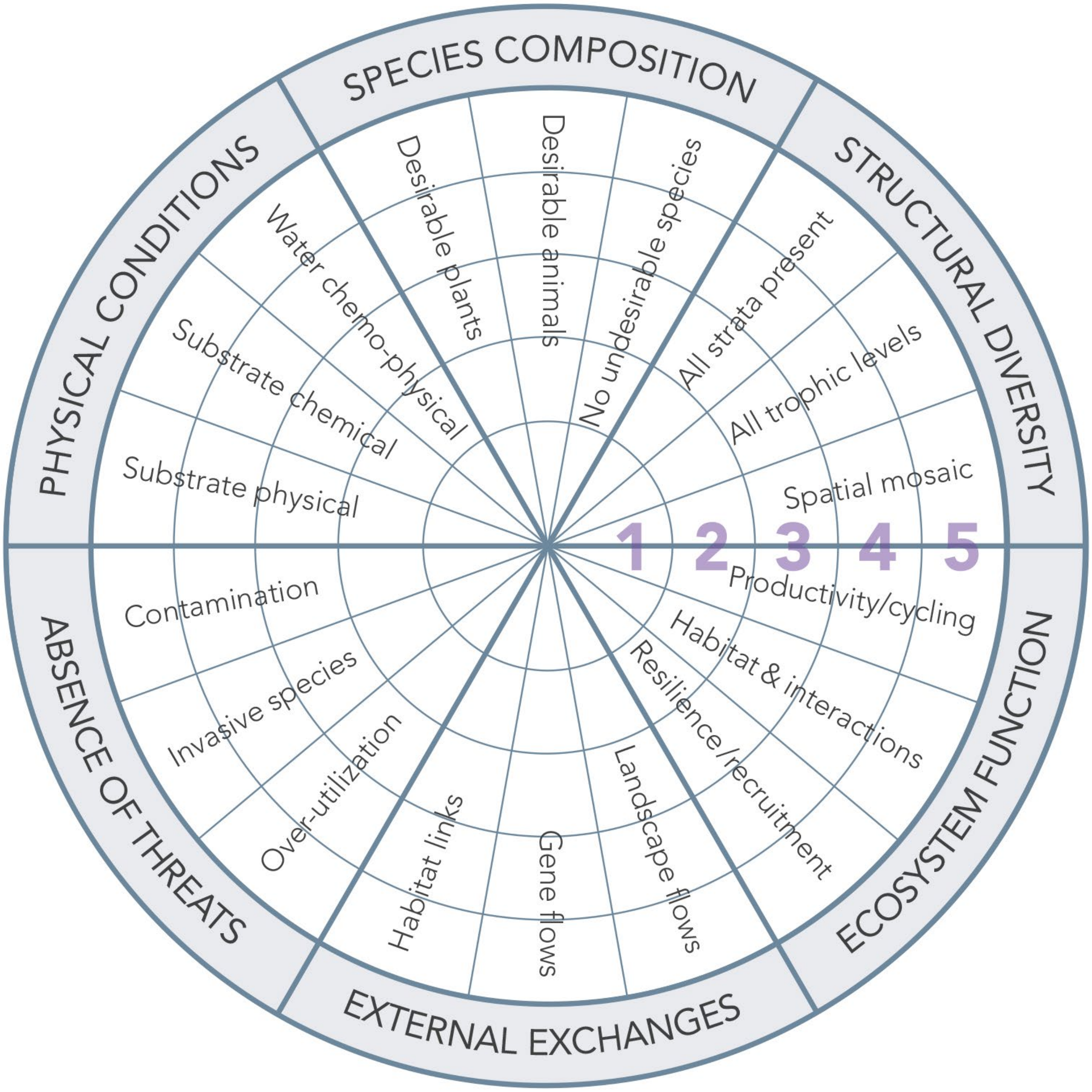
- **Establishing effective communication and outreach to and with stakeholders.** Successful restoration projects have strong engagement with stakeholders including local communities, particularly traditional communities and Indigenous peoples who retain traditional ecological knowledge. This communication and outreach is best achieved if the involvement commences at the planning stage and continues throughout the project and after restoration works are completed. Prior to expending limited restoration resources, potential benefits of the restored ecosystem to the whole of society must be explicitly examined and recognized. For restoration to be carried out in a secure social context, stakeholder agreement is needed to confirm that a restored ecosystem is the preferred long-term goal.

Involving stakeholders in the development of solutions for improved management and restoration of sites. Ecological restoration outcomes are often more effective and efficient if stakeholders are engaged in assessing problems and devising solutions. The outcome of restoration is also more secure when there are appreciable benefits or incentives available to the stakeholders; and where stakeholders are themselves engaged in the restoration effort, building 'ownership' into local cultures.

Students from Ranui Primary School Maori immersion class release whitehead/pōpokotea *(Mohoua albicilla)* as part of the Ark in the Park project in the Waitakere Range in New Zealand. Ark in the Park provides sanctuary from rats, stoats and other invasive species that predate on endemic species. Culturally important to the Maori, whiteheads were considered to be fortune tellers and were used in traditional ceremonies.

Photo credit: Jacqui Geux

APPENDIX 2. BLANK PROJECT EVALUATION TEMPLATES



Recovery wheel

EVALUATION OF ECOSYSTEM RECOVERY

Site ____

Assessor ____________________________________

Date____

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




SER SOCIETY FOR ECOLOGICAL RESTORATION

SER is a non-profit organization supported by member dues, foundation and corporate grants, and private donations. To become a member, start a regional chapter, donate to SER, or sponsor a conference, please contact us.

www.ser.org

1133 15th St. NW Suite 300
Washington, DC 20005 USA
202.299.9518
info@ser.org

SER AUSTRALASIA SOCIETY FOR ECOLOGICAL RESTORATION

Institute for Regional Conservation