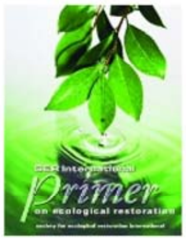
SER International Primer on Ecological Restoration



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Section 1. Overview

Ecological restoration is an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability. Frequently, the ecosystem that requires restoration has been degraded, damaged, transformed or entirely destroyed as the direct or indirect result of human activities. In some cases, these impacts to ecosystems have been caused or aggravated by natural agencies such as wildfire, floods, storms, or volcanic eruption, to the point at which the ecosystem cannot recover its predisturbance state or its historic developmental trajectory.

Restoration attempts to return an ecosystem to its historic trajectory. Historic conditions are therefore the ideal starting point for restoration design. The restored ecosystem will not necessarily recover its former state, since contemporary constraints and conditions may cause it to develop along an altered trajectory. The historic trajectory of a severely impacted ecosystem may be difficult or impossible to determine with accuracy. Nevertheless, the general direction and boundaries of that trajectory can be established through a combination of knowledge of the damaged ecosystem’s pre-existing structure, composition and functioning, studies on comparable intact ecosystems, information about regional environmental conditions, and analysis of other ecological, cultural and historical reference information. These combined sources allow the historic trajectory or reference conditions to be charted from baseline ecological data and predictive models, and its emulation in the restoration process should aid in piloting the ecosystem towards improved health and integrity.

Restoration represents an indefinitely long-term commitment of land and resources, and a proposal to restore an ecosystem requires thoughtful deliberation. Collective decisions are more likely to be honored and implemented than are those that are made unilaterally. For that reason, it behooves all stakeholders to arrive at the decision to initiate a restoration project by consensus. Once the decision to restore is made, the project requires careful and systematic planning and a monitored approach towards ecosystem recovery. The need for planning intensifies when the unit of restoration is a complex landscape of contiguous ecosystems.

Interventions employed in restoration vary widely among projects, depending on the extent and duration of past disturbances, cultural conditions that have shaped the landscape, and contemporary constraints and opportunities. In the simplest circumstances, restoration consists of removing or modifying a specific disturbance, thereby allowing ecological processes to bring about an independent recovery. For example, removing a dam allows the return of an historical flooding regime. In more complex circumstances, restoration may also require the deliberate reintroduction of native species that have been lost, and the elimination or control of harmful, invasive exotic species to the greatest practicable extent. Often, ecosystem degradation or transformation has multiple, protracted sources, and the historical constituents of an ecosystem are substantially lost. Sometimes the developmental trajectory of a degraded ecosystem is blocked altogether, and its recovery through natural processes appears to be delayed indefinitely. In all of these cases, however, ecological restoration aims to initiate or facilitate the resumption of those processes which will return the ecosystem to its intended trajectory.

When the desired trajectory is realized, the ecosystem under manipulation may no longer require external assistance to ensure its future health and integrity, in which case restoration can be considered complete. Nevertheless, the restored ecosystem often requires continuing management to counteract the invasion of opportunist species, the impacts of various human activities, climate change, and other unforeseeable events. In this respect, a restored ecosystem is no different from an undamaged ecosystem of the same kind, and both are likely to require some level of ecosystem management. Although ecosystem restoration and ecosystem management form a continuum and often employ similar sorts of intervention, ecological restoration aims at assisting or initiating recovery, whereas ecosystem management is intended to guarantee the continued well-being of the restored ecosystem thereafter.

Some ecosystems, particularly in developing countries, are still managed by traditional, sustainable cultural practices. Reciprocity exists in these cultural ecosystems between cultural activities and ecological processes, such that human actions reinforce ecosystem health and sustainability. Many cultural ecosystems have suffered from demographic growth and external pressures of various kinds, and are in need of restoration. The restoration of such ecosystems normally includes the concomitant recovery of indigenous ecological management practices, including support for the cultural survival of indigenous peoples and their languages as living libraries of traditional ecological knowledge. Ecological restoration encourages and may indeed be dependent upon long-term participation of local people. Cultural conditions in traditional cultures are currently undergoing unprecedented global change. To accommodate this change, ecological restoration may accept and even encourage new culturally appropriate and sustainable practices that take into account contemporary conditions and constraints. In this regard, the North American focus on restoring pristine landscapes makes little or no sense in places like Europe where cultural landscapes are the norm, or in large parts of Africa, and Latin America, where ecological restoration is untenable unless it manifestly bolsters the ecological base for human survival.

What makes ecological restoration especially inspiring is that cultural practices and ecological processes can be mutually reinforcing. Accordingly, it is not surprising that interest in ecological restoration is growing rapidly worldwide and that, in most cases, cultural beliefs and practices are drawn upon to help determine and shape of what is to be performed under the rubric of restoration.

The definition presented below, the one officially endorsed by the Society for Ecological Restoration, is sufficiently general to allow a wide variety of approaches to restoration, while giving prominence to the historically-rich idea of "recovery."

Section 2. Definition of Ecological Restoration

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

Section 3. Attributes of Restored Ecosystems

This section addresses the question of what is meant by "recovery" in ecological restoration. An ecosystem has recovered - and is restored - when it contains sufficient biotic and abiotic resources to continue its development without further assistance or subsidy. It will sustain itself structurally and functionally. It will demonstrate resilience to normal ranges of environmental stress and disturbance. It will interact with contiguous ecosystems in terms of biotic and abiotic flows and cultural interactions.

The nine attributes listed below provide a basis for determining when restoration has been accomplished. The full expression of all of these attributes is not essential to demonstrate restoration. Instead, it is only necessary for these attributes to demonstrate an appropriate trajectory of ecosystem development towards the intended goals or reference. Some attributes are readily measured. Others must be assessed indirectly, including most ecosystem functions, which cannot be ascertained without research efforts that exceed the capabilities and budgets of most restoration projects.

1. The restored ecosystem contains a characteristic assemblage of the species that occur in the reference ecosystem and that provide appropriate community structure.
2. The restored ecosystem consists of indigenous species to the greatest practicable extent. In restored cultural ecosystems, allowances can be made for exotic domesticated species and for non-invasive ruderal and segetal species that presumably co-evolved with them. Ruderals are plants that colonize disturbed sites, whereas segetals typically grow intermixed with crop species.
3. All functional groups necessary for the continued development and/or stability of the restored ecosystem are represented or, if they are not, the missing groups have the potential to colonize by natural means.
4. The physical environment of the restored ecosystem is capable of sustaining reproducing populations of the species necessary for its continued stability or development along the desired trajectory.
5. The restored ecosystem apparently functions normally for its ecological stage of development, and signs of dysfunction are absent.
6. The restored ecosystem is suitably integrated into a larger ecological matrix or landscape, with which it interacts through abiotic and biotic flows and exchanges.
7. Potential threats to the health and integrity of the restored ecosystem from the surrounding landscape have been eliminated or reduced as much as possible.
8. The restored ecosystem is sufficiently resilient to endure the normal periodic stress events in the local environment that serve to maintain the integrity of the ecosystem.
9. The restored ecosystem is self-sustaining to the same degree as its reference ecosystem, and has the potential to persist indefinitely under existing environmental conditions. Nevertheless, aspects of its biodiversity, structure and functioning may change as part of normal ecosystem development, and may fluctuate in response to normal periodic stress and occasional disturbance

events of greater consequence. As in any intact ecosystem, the species composition and other attributes of a restored ecosystem may evolve as environmental conditions change.

Other attributes gain relevance and should be added to this list if they are identified as goals of the restoration project. For example, one of the goals of restoration might be to provide specified natural goods and services for social benefit in a sustainable manner. In this respect, the restored ecosystem serves as natural capital for the accrual of these goods and services. Another goal might be for the restored ecosystem to provide habitat for rare species or to harbor a diverse genepool for selected species. Other possible goals of restoration might include the provision of aesthetic amenities or the accommodation of activities of social consequence, such as the strengthening of a community through the participation of individuals in a restoration project.

Section 4. Explanations of Terms

Various technical terms are introduced throughout this document. Some of these terms may be unfamiliar to readers who are not ecologists, while others have multiple connotations from differential usage. To reduce the potential for misunderstandings, key terms are explained in the manner in which they are used in this document.

An **ecosystem** consists of the **biota** (plants, animals, microorganisms) within a given area, the **environment** that sustains it, and their **interactions**. Populations of species that comprise the biota are collectively identified as the**biotic communit**. This community is frequently segregated on the basis of**taxonomic** status (e.g., the insect community) or **life form** (e.g., the tree community). Assemblages of organisms can also be recognized by their functional roles in the ecosystem (e.g. primary producers, herbivores, carnivores, decomposers, nitrogen fixers, pollinators), in which case they are known as **functional groups**. The **physical** or **abiotic environment** that sustains the biota of an ecosystem includes the soil or substrate, the atmospheric or aqueous medium, hydrology, weather and climate, topographic relief and aspect, the nutrient regime, and the salinity regime. **Habitat** refers to the dwelling place of an organism or community that provides the requisite conditions for its life processes.

An ecosystem can be recognized in a spatial unit of any size, from a microsite containing only a few individuals to an area showing some degree of structural and taxonomic homogeneity such as a small-scale and community-based "wetland ecosystem," or a large-scale and biome-based "tropical rainforest ecosystem." Ecological restoration can be conducted at a wide variety of scales, but in practice all ecosystem restoration should be approached with a spatially explicit landscape perspective, in order to ensure the suitability of flows, interactions and exchanges with contiguous ecosystems. A **landscape**consists of a mosaic of two or more ecosystems that exchange organisms, energy, water and nutrients. A legitimate and indeed important object of much ecological restoration is the reintegration of fragmented ecosystems and landscapes, rather than focusing on just a single ecosystem.

A **natural landscape** or **ecosystem** is one that developed by natural processes and that is self-organizing and self-maintaining. A **cultural landscape** or **ecosystem** is one that has developed under the joint influence of natural processes and human-imposed organization. Many grasslands and savannas are maintained in large part by the human activities such as the regular ignition of surface fires for hunting, gathering or animal husbandry. In Europe, many of the species-rich meadows are cultural ecosystems that arose following forest removal in the Bronze Age, and have been maintained through mowing and seasonal grazing by livestock. The repair of a damaged meadow qualifies as ecological restoration, even though the meadow ecosystem that is selected as the landscape of reference derives from human activities. In another example, a dense coniferous forest currently occupies large parts of western North America. In the 19th century, much of this forest was open and park-like with copious herbaceous cover, owing to the frequent use of fire and plant species utilization by indigenous tribal people. This woodland seemed natural and its condition was sustainable under the regime of tribal land usage. The return of this ecosystem to an open, park-like woodland, occupied and utilized in the traditional tribal manner, qualifies as ecological restoration.**Sustainable cultural practices** are traditional human land uses that maintain biodiversity and productivity. In this context, the biota is valued as much for its importance to ecosystem stability as it is for its short-term worth as commodities. Perhaps all natural ecosystems are culturally influenced in at least some small manner, and this reality merits acknowledgement in the conduct of restoration.

The terms degradation, damage, destruction and transformation all represent deviations from the normal or desired state of an intact ecosystem. The meanings of these terms overlap, and their application is not always clear.**Degradation** pertains to subtle or gradual changes that reduce ecological integrity and health. **Damage** refers to acute and obvious changes in an ecosystem. An ecosystem is **destroyed** when degradation or damage removes all macroscopic life, and commonly ruins the physical environment as well.**Transformation** is the conversion of an ecosystem to a different kind of ecosystem or land use type.

A **reference ecosystem** can serve as the model for planning an ecological restoration project, and later serve in the evaluation of that project. In instances where the object of restoration consists of two or more kinds of ecosystems, the reference can be called the **reference landscape** or, if only a portion of a local landscape is to be restored, the **reference landscape unit**. The designated ecosystem, landscape or unit can simply be called the**reference**. Typically, the reference represents a point of advanced development that lies somewhere along the intended trajectory of the restoration. In other words, the restored ecosystem is eventually expected to emulate the attributes of the reference, and project goals and strategies are developed in light of that expectation. The reference can consist of one or several specified locations that contain model ecosystems, a written description, or a combination of both. Information collected on the reference includes both biotic and abiotic components. A more comprehensive discussion of the reference ecosystem appears in Section 5.

An **ecological trajector** is one that describes the developmental pathway of an ecosystem through time. In restoration, the trajectory begins with the unrestored ecosystem and progresses towards the desired state of recovery that is expressed in the goals of a restoration project and embodied in the reference ecosystem. The trajectory embraces all ecological attributes - biotic and abiotic - of an ecosystem, and in theory can be monitored by the sequential measurement of coherent suites of ecological parameters. Any given trajectory is not narrow and specific. Instead, a trajectory embraces a broad yet confined range of potential ecological expressions through time, as might be described mathematically by chaos theory, or predicted by various ecological models. A fully empirical description of a trajectory is impeded in two ways. First, the number of ecosystem traits that can be measured far exceeds those that can be reasonably monitored, and the description of the trajectory over time is necessarily incomplete. Second, the monitoring data lend themselves to the plotting of trajectories for individual parameters, but their combination into a single trajectory representing the entire ecosystem requires highly complex multivariate analysis of a kind that has yet to be developed. This represents a critical research challenge for the future.

Biodiversity refers to biota in terms of taxonomic and genetic diversity, the variety of life forms present and the community structure thereby created, and the ecological roles performed. The **biota** is organized hierarchically from the level of the genome up to individual organisms, species, populations, and communities. Two related aspects of biodiversity are **species composition**, i.e. the taxonomic array of species present, and species richness, i.e. the number of different species present. The importance of an ample recovery in species composition cannot be overstated in restoration. All functional species-groups must be represented if a restored ecosystem is to maintain itself. **Species redundancy**, i.e. the presence of multiple species that play similar roles in ecosystem dynamics, provides assurance that ecosystem health is maintained in response to stress, disturbance or other environmental changes.

In order for an ecosystem to be well adapted to local site conditions and to display resilience in response to a stressful or changing environment, the species-populations that comprise it must possess **genetic fitness**. An ecosystem containing genetically fit populations is one that is not only adapted to the current environmental regime, but possesses some "genetic redundancy", whereby the gene pool contains a diversity of alleles that may be selected in response to environmental change. Under normal circumstances, the reintroduction of **local ecotypes** is sufficient to maintain genetic fitness. Nevertheless, in sites that have suffered substantial damage and consequent alteration to their physical environment, the introduction of**diverse genetic stock** may be the preferred strategy, thereby allowing recombination and the eventual development of novel, more adaptive ecotypes.

By **community structure** is meant the physiognomy or architecture of the community with respect to the density, horizontal stratification, and frequency distribution of species-populations, and the sizes and life forms of the organisms that comprise those communities.

Ecological processes or **ecosystem functions** are the dynamic attributes of ecosystems, including interactions among organisms and interactions between organisms and their environment. Ecological processes are the basis for self-maintenance in an ecosystem. Some restoration ecologists limit the use of the term "ecosystem functions" to those dynamic attributes which most directly affect metabolism, principally the sequestering and transformation of energy, nutrients, and moisture. Examples are carbon fixation by photosynthesis, trophic interactions, decomposition, and mineral nutrient cycling. When ecosystem functions are strictly defined in this manner, other dynamic attributes are distinguished as "ecosystem processes" such as substrate stabilization, microclimatic control, differentiation of habitat for specialized species, pollination and seed dispersal. Functioning at larger spatial scales is generally conceived in more general terms, such as the long-term retention of nutrients and moisture and overall ecosystem sustainability.

Ecosystem functions and processes, along with the reproduction and growth of organisms, are what cause an ecosystem to be self-renewing or**autogenic**. A common goal for the restoration of any natural ecosystem is to recover autogenic processes to the point where assistance from restorationists is no longer needed. In this regard, the central role of a restoration practitioner is to initiate autogenic processes. Restoration practitioners commonly assume that autogenic processes will commence once the appropriate species composition and structure have been re-established. This is not always a valid assumption, but it is a reasonable starting point for ecosystem restoration.

Some dynamic processes are external in origin, such as fires, floods, damaging wind, salinity shock from incoming tides and storms, freezes, and droughts. These external processes stress the biota and are sometimes designated as**stressors**. The biota of any given ecosystem must be resistant or resilient to the normal stress events that periodically occur in the local environment. These events serve to maintain ecosystem integrity, by preventing the establishment of other species that are not adapted to those stress conditions. For example, the tidal influx of saline water is essential to maintain a salt marsh ecosystem and prevent its conversion to a freshwater ecosystem. In cultural ecosystems, human-mediated activities such as burning or grazing qualify as stressors. The terms **disturbance** or **perturbation** are sometimes used interchangeably for "stressor" or "stress event". However, the term "disturbance" is restricted herein to impacts on ecosystems that are more severe or acute than normal stress events.

Resistance is the term describing an ecosystem's ability to maintain its structural and functional attributes in the face of stress and disturbances.**Resilience** is the ability of an ecosystem to regain structural and functional attributes that have suffered harm from stress or disturbance. **Ecosystem stability** is the ability of an ecosystem to maintain its given trajectory in spite of stress; it denotes dynamic equilibrium rather than stasis. Stability is achieved in part on the basis of an ecosystem's capacity for resistance and resilience.

The terms ecosystem integrity and ecosystem health are commonly used to describe the desired state of a restored ecosystem. Although some authors use the terms interchangeably, they are distinct in meaning. **Ecosystem integrity** is the state or condition of an ecosystem that displays the biodiversity characteristic of the reference, such as species composition and community structure, and is fully capable of sustaining normal ecosystem functioning.

Ecosystem health is the state or condition of an ecosystem in which its dynamic attributes are expressed within 'normal' ranges of activity relative to its ecological stage of development. A restored ecosystem expresses health if it functions normally relative to its reference ecosystem, or to an appropriate set of restored ecosystem attributes such as those that are listed above in Section 3. A state of ecosystem integrity suggests, but does not necessarily confirm, a concurrent state of ecosystem health and a suitable abiotic environment.

Section 5. Reference Ecosystems

A reference ecosystem or reference serves as a model for planning a restoration project, and later for its evaluation. In its simplest form, the reference is an actual site, its written description, or both. The problem with a simple reference is that it represents a single state or expression of ecosystem attributes. The reference that is selected could have been manifested as any one of many potential states that fall within the historic range of variation of that ecosystem. The reference reflects a particular combination of stochastic events that occurred during ecosystem development.

In the same manner, an ecosystem that undergoes restoration can develop into any of a potentially large array of states. Any state that is expressed is acceptable as restoration, as long as it is comparable to any of the potential states into which its reference could have developed. Thus, a simple reference inadequately expresses the constellation of potential states and the historic range of variation expressed by the restored ecosystem. Therefore, a reference is best assembled from multiple reference sites and, if necessary, other sources. This composite description gives a more realistic basis for restoration planning.

Sources of information that can be used in describing the reference include:
ecological descriptions, species lists and maps of the project site prior to damage;

historical and recent aerial and ground-level photographs;

remnants of the site to be restored, indicating previous physical conditions and biota;

ecological descriptions and species lists of similar intact ecosystems;

herbarium and museum specimens;

historical accounts and oral histories by persons familiar with the project site prior to damage;

paleoecological evidence, e.g. fossil pollen, charcoal, tree ring history, rodent middens.

The value of the reference increases with the amount of information it contains, but every inventory is compromised by limitations of time and funding. Minimally, a baseline ecological inventory describes the salient attributes of the abiotic environment and important aspects of biodiversity such as species composition and community structure. In addition, it identifies the normal periodic stress events that maintain ecosystem integrity. Descriptions of the reference for cultural ecosystems should identify the cultural practices that are critical in restoring and later in managing that ecosystem.

The description of a reference is complicated by two factors that should be reconciled to assure its quality and usefulness. First, a reference site is normally selected for its well-developed expression of biodiversity, whereas a site in the process of restoration typically exhibits an earlier ecological stage. In such a case, the reference requires interpolation back to a prior developmental phase for purposes of both project planning and evaluation. The need for interpretation diminishes where the developmental stage at the restoration project site is sufficiently advanced for direct comparison with the reference. Second, where the goal of restoration is a natural ecosystem, nearly all available references will have suffered some adverse human-mediated impacts that should not be emulated. Therefore, the reference may require interpretation to remove these sources of artifice. For these reasons, the preparation of the description of the reference requires experience and sophisticated ecological judgement.

Written restoration project goals are critical for determining the detail that is needed in the description of the reference. For large, landscape-scale restoration for which only general goals are prescribed, the description of the reference can be equally general. In such instances, aerial photographs may represent the most important source of information for the preparation of the reference. Restoration at a finer scale may require much more detailed reference information, such as data that are collected on-site in small plots.

Section 6. Exotic Species

An exotic species of plant or animal is one that was introduced into an area where it did not previously occur through relatively recent human activities. Since ecological restoration of natural ecosystems attempts to recover as much historical authenticity as can be reasonably accommodated, the reduction or elimination of exotic species at restoration project sites is highly desirable. Nonetheless, financial and logistical constraints often exist, and it is important to be realistic and pragmatic in approaching exotic species control. In cultural landscapes, exotic species are frequently an integral part of the ecosystem, particularly as crops and livestock, and even as ruderals or segetals that have presumably co-evolved with these domesticated species. Such exotic species are acceptable for cultural restoration.

In natural ecosystems, invasive exotic species commonly compete with and replace native species. However, not all exotic species are harmful. Indeed, some even fulfill ecological roles formerly played by the native species that have become rare or extirpated. In such instances, the rationale for their removal may be tenuous. Some exotic species were introduced centuries ago by human or non-human agents and have become naturalized, so that their status as an exotic is debatable. Other species have migrated in and out of the region in response to climatic fluctuations during the Holocene, and can scarcely be regarded as exotics. Even if all exotic species are removed from a restoration site, the opportunity for re-invasion may remain high. Therefore it becomes essential for a policy to be developed for each exotic species present, based upon biological, economic and logistical realities. Highest priority is best reserved for the control or extirpation of those species which pose the greatest threats. These include invasive plant species that are particularly mobile and pose an ecological threat at landscape and regional levels, and animals that consume or displace native species. Care should be taken to cause the least possible disturbance to indigenous species and soils as exotics are removed.

In some instances, non-indigenous plants are used for a specific purpose in the restoration project, for example as cover crops, nurse crops or nitrogen fixers. Unless these are relatively short-lived, non-persistent species that will be replaced in the course of succession, their eventual removal should be included in restoration plans.

Section 7. Monitoring and Evaluation

A properly planned restoration project attempts to fulfill clearly stated goals that reflect important attributes of the reference ecosystem. Goals are attained by pursuing specific objectives. The goals are ideals, and the objectives are concrete measures taken to attain these goals. Two fundamental questions should be asked with respect to the evaluation of a restored ecosystem. Were the objectives accomplished? Were the goals fulfilled? Answers to both questions gain validity only if the goals and objectives were stated prior to implementation of restoration project work.

Ecosystems are complex, and no two intact ecosystems are ever identical, at least not when examined in fine resolution. For that reason, no restored ecosystem at a project site can ever be identical to any single reference. The number of ecosystem variables that can be used in an evaluation is too great for all to be measured within a reasonable period of time. The selection of which variables to assess and which to ignore requires pragmatism and value judgment by the evaluator.

Objectives are evaluated on the basis of **performance standards**, also known as design criteria or success criteria. These standards or criteria are conceived in large part from an understanding of the reference ecosystem. Performance standards provide an empirical basis for determining whether or not project objectives have been attained. Objectives, performance standards, and protocols for monitoring and for data assessment should be incorporated into restoration plans prior to the start of a project. If interpretation of the data collected during monitoring shows that performance standards have been met, there can be no doubt that project objectives were achieved, and the restored ecosystem is likely to be sufficiently resilient to require little or no further assistance from the restoration practitioner.

It is assumed that project goals are, or soon will be, fulfilled once the objectives are attained. The validity of this assumption is not guaranteed, since the objectives and performance standards that were designated may prove to be inadequate, and unanticipated environmental vicissitudes can deflect the restoration trajectory. For that reason, and since goals are ideals that resist strict empirical measurement, an element of professional judgment and subjectivity is inevitable in the evaluation of goals.

Three strategies exist for conducting an evaluation: *direct comparison, attribute analysis* and *trajectory analysis.* In **direct comparison**, selected parameters are determined or measured in the reference and restoration sites. If the reference description is thorough, as many as 20 or 30 parameters can be compared that include aspects of both the biota and the abiotic environment. This can lead to ambiguity of interpretation when the results of some comparisons are close and others are not. The question arises - how many parameters must have similar values and how close must the values be before restoration goals are satisfied? The most satisfactory approach may be to carefully select a coherent suite of traits that collectively describe an ecosystem fully yet succinctly.

In **attribute analysis**, attributes are assessed in relation to the list provided in Section 3. In this strategy, quantitative and semi-quantitative data from scheduled monitoring and other inventories are useful in judging the degree to which each goal has been achieved.

Trajectory analysis is a promising strategy, still under development, for interpreting large sets of comparative data. In this strategy, data collected periodically at the restoration site are plotted to establish trends. Trends that lead towards the reference condition confirm that the restoration is following its intended trajectory.

Evaluations include the assessment of any stated goals and objectives that pertain to cultural, economic and other societal concerns. For these, the techniques of evaluation may include those of the social sciences. The evaluation of socio-economic goals is important to stakeholders and ultimately to policy-makers who decide whether or not to authorize and finance restoration projects.

Section 8. Restoration Planning

Plans for restoration projects include, at a minimum, the following:

a clear rationale as to why restoration is needed;

an ecological description of the site designated for restoration;

a statement of the goals and objectives of the restoration project;

a designation and description of the reference;

an explanation of how the proposed restoration will integrate with the landscape and its flows of organisms and materials;

explicit plans, schedules and budgets for site preparation, installation and post-installation activities, including a strategy for making prompt mid-course corrections;

well-developed and explicitly stated performance standards, with monitoring protocols by which the project can be evaluated;

strategies for long-term protection and maintenance of the restored ecosystem.

Where feasible, at least one untreated control plot should be included at the project site, for purposes of comparison with the restored ecosystem.

Section 9. Relationship between Restoration Practice and Restoration Ecology

Ecological restoration is the practice of restoring ecosystems as performed by practitioners at specific project sites, whereas **restoration ecology** is the science upon which the practice is based. Restoration ecology ideally provides clear concepts, models, methodologies and tools for practitioners in support of their practice. Sometimes the practitioner and the restoration ecologist are the same person—the nexus of practice and theory. The field of restoration ecology is not limited to the direct service of restoration practice. Restoration ecologists can advance ecological theory by using restoration project sites as experimental areas. For example, information derived from project sites could be useful in resolving questions pertaining to assembly rules of biotic communities. Further, restored ecosystems can serve as references for set-aside areas designated for nature conservation.

Section 10. Relationship of Restoration to Other Activities

Ecological restoration is one of several activities that strive to alter the biota and physical conditions at a site, and are frequently confused with restoration. These activities include reclamation, rehabilitation, mitigation, ecological engineering and various kinds of resource management, including wildlife, fisheries and range management, agroforestry, and forestry. All of these activities can overlap with and may even qualify as ecological restoration if they satisfy all criteria expressed in Section 3 of this document. Relative to other kinds of activities, restoration generally requires more post-installation aftercare to satisfy all these criteria.

Rehabilitation shares with restoration a fundamental focus on historical or pre-existing ecosystems as models or references, but the two activities differ in their goals and strategies. Rehabilitation emphasizes the reparation of ecosystem processes, productivity and services, whereas the goals of restoration also include the re-establishment of the pre-existing biotic integrity in terms of species composition and community structure. Nonetheless, restoration, as broadly conceived herein, probably encompasses a large majority of project work that has previously been identified as rehabilitation.

The term **reclamation**, as commonly used in the context of mined lands in North America and the UK, has an even broader application than rehabilitation. The main objectives of reclamation include the stabilization of the terrain, assurance of public safety, aesthetic improvement, and usually a return of the land to what, within the regional context, is considered to be a useful purpose. Revegetation, which is normally a component of land reclamation, may entail the establishment of only one or few species. Reclamation projects that are more ecologically based can qualify as rehabilitation or even restoration.

Mitigation is an action that is intended to compensate environmental damage. Mitigation is commonly required in the USA as a condition for the issuance of permits for private development and public works projects that cause damage to wetlands. Some, but perhaps relatively few, mitigation projects satisfy the attributes of restored ecosystems listed in Section 3, and thus qualify as restoration.

The term **creation** has enjoyed recent usage, particularly with respect to projects that are conducted as mitigation on terrain that is entirely devoid of vegetation. The alternate term **fabrication** is sometimes employed. Frequently, the process of voiding a site causes sufficient change in the environment to require the installation of a different kind of ecosystem from that which occurred historically. Creation that is conducted as supervised engineering or landscape architecture cannot qualify as restoration because restoration initiates ecosystem development along a preferred trajectory, and thereafter allows autogenic processes to guide subsequent development with little or no human interference.

Ecological engineering involves manipulation of natural materials, living organisms and the physical-chemical environment to achieve specific human goals and solve technical problems. It thus differs from civil engineering, which relies on human-made materials such as steel and concrete. Predictability is a primary consideration in all engineering design, whereas restoration recognizes and accepts unpredictable development and addresses goals that reach beyond strict pragmatism and encompass biodiversity and ecosystem integrity and health. When predictability is not at issue, the scope of many ecological engineering projects could be expanded until they qualify as restoration.

Section 11. Integration of Ecological Restoration into Larger Programs

Ecological restoration is sometimes only one of many elements within a larger public or private sector enterprise, such as development projects and programs for watershed management, ecosystem management and nature conservation. Project managers of these larger undertakings should be aware of the complexities and costs involved in planning and implementing ecological restoration. Cost savings can be realized by careful coordination of restoration activities with other aspects of a large program. For this reason, project managers will benefit by recognizing ecological restoration as an integral component of a program. If this is done, the restorationist can contribute substantively to all aspects of the program that impinge on restoration. Moreover, the restorationist will be in a position to ensure that all ecological restoration is well conceived and fully realized. In this manner, the public good is served.

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name, photos have been added, and the graphics redesigned. Version 2 was published simultaneously in print and on the internet at www.ser.org

The principal authors of this Primer were André Clewell (Holmes Beach, FL USA), James Aronson (Montpellier, France), and Keith Winterhalder (Sudbury, ON Canada). Clewell initially proposed the Primer and wrote its first draft. Aronson and Winterhalder, in collaboration with Clewell, revised the Primer into its present form. Winterhalder, in his capacity as Chairperson of SER's Science & Policy Working Group, coordinated this effort and invited other Working Group members to participate. Eric Higgs (Victoria, BC Canada) crafted the Overview section. Dennis Martinez (Douglas City, CA USA) contributed a position paper that became the basis for text pertaining to cultural ecosystems. Other Working Group members provided critiques and suggestions as the work progressed, including Richard Hobbs (Murdoch, WA Australia), James Harris (London, UK), Carolina Murcia (Cali, Colombia), and John Rieger (San Diego, CA USA). The SPWG acknowledges Eric Higgs, former Chairperson of SER's Board of Directors, for his encouragement and for bringing the Primer before SER's Directors for its official adoption as a SER document on 6 April 2002, by unanimous vote.

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This document supercedes SER's Project Policies that were initially published in Restoration Ecology 2(2):132-133, 1994, and that were later posted on SER's website. This document also supercedes the policy on Project Evaluation that was posted on the SER website. SER environmental policies, initially published in Restoration Ecology 1(3):206-207, 1993, remain in effect.

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