

Ecological restoration

Ecological restoration, the process of repairing sites in nature whose biological communities (that is, interacting groups of various species in a common location) and ecosystems have been degraded or destroyed. In many ecosystems, humans have altered local native populations of plants and animals, introduced invasive species, converted natural communities to extractive use (such as agriculture or mining), fouled waters, and degraded soil resources. Ecological restoration focuses on repairing the damage human activities have caused to natural ecosystems and seeks to return them to an earlier state or to another state that is closely related to one unaltered by human activities. Ecological restoration is distinguished from the practice of conservation, which is primarily concerned with preventing further losses to ecosystems.

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wetland restoration

Wetland restoration along the Târnava Mică (Tîrnava Mică) River in Romania. A former gravel mine (left) was transformed into a functional wetland (right).

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Concepts

To repair and restore ecosystems, restoration specialists apply concepts from the field of ecology. For example, in temperate coniferous forests, plant species provide food and shelter for various animals. The forest ecosystem provides important services, such as nutrient cycling, both for the animals that live there and for humans who use the forest for timber and recreation. To remain healthy, many forest

species rely on periodic disturbances such as wildfires. However, some disturbances, such as deforestation, are so damaging that they may instead impair the normal functioning of the forest by increasing soil erosion or by eliminating wildlife habitat. Thus, restorationists must understand the ecosystem's pattern of ecological disturbances. (Disturbance ecology is the subdiscipline of ecology that explores the

causes and consequences of both natural and anthropogenic [human-caused] disturbances.) In order to restore a deforested site, restoration ecologists often attempt to reverse the ecological changes caused by the removal of trees and other plants, the displacement of animals, and changes to the now-exposed soil (which may be more prone to drying and erosion after deforestation). Ecological succession, the long-term evolution of the structure of an ecosystem's biological community that follows a disturbance event, is also an important part of the restoration process.

Planning

The restoration process begins with an assessment of the degraded site. The current site conditions should be thoroughly examined to identify the need for restoration and any potential actions required to restore the site. Restorationists should consider the causes of degradation, the likelihood that the degradation can be reversed or lessened, and the ways in which restoration can be accomplished. Early in the planning process, restorationists should identify the necessary resources (such as funding, labour, equipment, plant materials, and technical knowledge) that directly affect the project's feasibility. Support and participation from local communities and government institutions early in the planning process and throughout implementation can be invaluable.

A critical step in restoration planning is to establish realistic goals. Pre-disturbance conditions, often represented by nearby "reference sites," are common restoration targets, although actual targets are tailored to local ecological, social, legal, and economic conditions. In addition, preventing further loss of protected populations or habitat is a common motivator of restoration. Other goals may include erosion control, rangeland forage production, protection of wildlife habitat, and preservation of cultural landscapes. Planning for climate change has become increasingly important. Once the goals of the restoration project have been established, the next step is to outline objectives and identify measures of success. Clearly articulated objectives and regular assessment of measurable progress toward those objectives provide information on the trajectory and success of the project, including how and when restoration activities should be modified.

Implementation

In some cases, restoration specialists simply need to remove the source of the

disturbance and allow sites to recover naturally through ecological succession. This process is called passive restoration because restoration specialists do not need to take much action. For example, halting agricultural tillage or stemming the overuse of riverbanks by livestock may be enough to bring a site back to a pre-disturbed state.

In other cases, the ecosystem has passed a threshold of degradation, and disturbed sites within it are not able to recover on their own or can only recover very slowly. This is particularly common when soil and water resources have been compromised through erosion, earth-moving activities, or some other major disturbance. To restore such highly disturbed sites, the removal or cessation of the disturbance is only the first step. Restorationists must then engage in active restoration, which starts or accelerates the recovery process or attempts to change the site's ecological succession.

One component of active restoration is soil rehabilitation and land stabilization. This component includes the restoration of the soil's or water's original chemical, biological, and physical characteristics. Examples include applying amendments (such as lime) to improve soil pH, stemming the flow of fertilizers to artificially enriched soil or water, inoculating soils with beneficial microorganisms, and tilling to improve aeration and root penetration. Erosion control and land stabilization tools include physical structures along stream banks, blankets of mulch placed on hillsides, and plantings to stabilize slopes.

Another component of active restoration is restoring the plant community. After the site is prepared, restorationists generally select seeds, seedlings, or cuttings for revegetation. Ecological principles related to the assembly of the biological community help explain the long-term consequences of how and when different species are added to a site.

When selecting seeds and propagules, restorationists generally try to find the species and cultivars that will be most suitable for local conditions as well as for the site's intended uses (such as habitat for native wildlife, land stabilization, or livestock forage). Local plants and animals are likely to be well adapted to the target ecosystem. Alternatively, restorationists may use plant materials from seed companies or nurseries that are typically tailored for certain environmental conditions. At the same time, many restoration projects attempt to maximize the

genetic diversity of the site by collecting seeds or propagules from a large number of source individuals (see biodiversity). Increased genetic diversity gives restored plant populations a greater ability to survive disturbance events and other ecosystem changes. Such genetic concerns can also be important for animals, which are sometimes transported or reintroduced to an area.

To create a sustainable restored ecosystem, restoration specialists often need to couple the restoration of plants and animals with that of landscape processes and natural disturbances. Some restored sites are relatively small and isolated, which can lead to problems associated with fragmented habitats. Populations in smaller and more-isolated habitat patches experience a greater risk of inbreeding, local extinction of species, and negative edge effects (that is, the effects of one habitat on an adjacent habitat). For example, small, narrow, sinuous patches of forest have greater amounts of edge than larger square or circular patches. As a result, more of their interiors border other ecosystems, which may increase the forest's exposure to different pests, predators, and weather and climatic conditions than would normally occur in forests with shorter borders and thus more-insulated interiors (see ecotone).

Many restoration projects try to mitigate fragmentation-related problems by increasing the size of the habitat patch, bolstering genetic diversity, and fostering ecological linkages between patches. Restoration may also reestablish historical disturbance patterns, such as those involving flooding or fire.

Monitoring and documentation are essential in the restoration process. Regular monitoring guides adaptive management and also determines when and if restoration goals are being met. In some cases only limited human intervention (followed by appropriate management) may be necessary, while in other cases human intervention may be necessary for decades.

Examples of ecological restoration projects

Walker Basin

Since 2005, legislators, private stakeholders, researchers, and restoration specialists have been working together to restore and maintain a desert lake in western

Nevada. Walker Lake is unusual because it is a terminal lake; it has many inlets but no outlet. The long-term survival of Walker Lake's ecosystem, fishery, and associated economy are threatened by water diversions that lowered the water level by approximately 46 metres (about 150 feet) and raised salinity levels substantially. Like many other ecological restoration efforts, the Walker Basin project exists within a complex political, economic, social, and ecological context. To return water to Walker Lake, restorationists obtain water rights from farmers upstream and then convert existing agricultural land to drought-resistant crops or native desert vegetation. Ecologists continue to monitor whether changes in upstream water use are improving the health of Walker Lake. Since 2009 the project has continued to acquire water rights and instituted a voluntary program in which landowners upstream reduce their water use, allowing more water to flow into the basin.

North American eastern deciduous forest

One of the most dramatic examples of passive restoration is the resurgence of North America's eastern deciduous forests. Largely cleared for agriculture between the 17th and 19th centuries, this land was abandoned as agriculture moved west and the eastern United States industrialized. After tilling ceased, forests began to recover with no active restoration efforts, and today they cover millions of acres. These forests are still relatively young and are missing a few key elements (such as chestnut trees [*Castanea dentata*] and passenger pigeons [*Ectopistes migratorius*]) but appear to be remarkably similar to pre-1650 forests.



deciduous forest

Oaks, beeches, birches, chestnuts, aspens, elms, maples, and basswoods (or lindens) are the dominant trees in mid-latitude deciduous forests.

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Calcareous grasslands

In parts of northern Europe, calcareous grasslands (grasslands growing on thin alkaline soils) are being restored on land previously managed for agriculture. These sites were historically characterized by nutrient-poor, often acidic soils supporting a unique flora.

Restoration practices after years of fertilization for crops often involve some form of soil impoverishment (topsoil removal and repeated biomass removal) and acidification followed by oversowing with native plant species. Many of

these sites are now mature and retain their restored plant associations.

Ongoing issues and debates

Ecological restoration is not without issues. There is often debate about the appropriate goals of restoration. For example, while many applaud the return of wolves (*Canis lupus*) to areas from which they were extirpated, some livestock managers strongly disapprove. Sometimes restoring a landscape to a more natural but less aesthetically desirable state conflicts with long-established elements of cultural landscapes, such as mountain grasslands in the Alps, Scottish heaths, or pigs (family Suidae) in Hawaii. Controlled burning in the western U.S. is viewed as an essential restoration practice by the U.S. Forest Service but has been met with apprehension by local property owners. Involving such stakeholders early and often in restoration planning can help reduce such conflicts.

In a world of limited resources, there will also be conflicts with those who fund a restoration project. Although restoration holds the promise of repairing damage caused by human activities, the legal process of mitigation has been criticized as providing a justification of ongoing destructive actions. Additional philosophical debates involve discussion about the hubris of thinking that human beings can recreate “authentic” nature and whether “nativeness” is an appropriate (or feasible) criterion of species selection. All of these issues and debates are indicative of a young and vital field still defining itself, but restoration likely will be central to the future of human-environment interactions.

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