Role of succession in restoration and recovery of ecosystem

Succession

Ecological succession is the process by which a community changes over time, especially following a disturbance. In many instances, an ecosystem will change from a simple level of organization with a few dominant pioneer species to an increasingly complex community with many interdependent species. Restoration often consists of initiating, assisting, or accelerating ecological successional processes, depending on the severity of the disturbance. Following mild to moderate natural and anthropogenic disturbances, restoration in these systems involves hastening natural successional trajectories through careful management. However, in a system that has experienced a more severe disturbance (such as in urban ecosystems), restoration may require intensive efforts to recreate environmental conditions that favour natural successional processes.

Fragmentation

Habitat fragmentation describes spatial discontinuities in a biological system, where ecosystems are broken up into smaller parts through land-use changes (e.g., agriculture) and natural disturbance. This both reduces the size of the population and increases the degree of isolation. These smaller and isolated populations are more vulnerable to extinction. Fragmenting ecosystems decreases the quality of the habitat. The edge of a fragment has a different range of environmental conditions and therefore supports different species than the interior. Restorative projects can increase the effective size of a population by adding suitable habitat and decrease isolation by creating habitat corridors that link isolated fragments. Reversing the effects of fragmentation is an important component of restoration ecology.

Ecosystem function

Ecosystem function describes the most basic and essential foundational processes of any natural systems, including nutrient cycles and energy fluxes. An understanding of the complexity of these ecosystem functions is necessary to address any ecological processes that may be degraded. Ecosystem functions are emergent properties of the system as a whole, thus monitoring and management are crucial for the long-term stability of ecosystems. A completely self-perpetuating and fully functional ecosystem is the ultimate goal of restorative efforts. We must understand what ecosystem properties influence others to restore desired functions and reach this goal.

Community assembly

Community assembly "is a framework that can unify virtually all of (community) ecology under a single conceptual umbrella". Community assembly theory attempts to explain the existence of environmentally similar sites with differing assemblages of species. It assumes that species have similar niche requirements, so that community formation is a product of random fluctuations from a common species pool. Essentially, if all species are fairly ecologically equivalent, then random variation in colonization, and migration and extinction rates between species, drive differences in species composition between sites with comparable environmental conditions.

Population genetics

Genetic diversity has shown to be as important as species diversity for restoring ecosystem processes. Hence ecological restorations are increasingly factoring genetic processes into management practices. Population genetic processes that are important to consider in restored populations include founder effects, inbreeding depression, outbreeding depression, genetic drift, and gene flow. Such processes can predict whether or not a species successfully establishes at a restoration site.

Restoration ecology

Restoration ecology is the scientific study supporting the practice of ecological restoration, which is the practice of renewing and restoring degraded, damaged, or destroyed ecosystems and habitats in the environment by active human intervention and action. Effective restoration requires an explicit goal or policy, preferably an unambiguous one that is articulated, accepted, and codified. Restoration goals reflect societal choices from among competing policy priorities, but extracting such goals is typically contentious and politically challenging. Natural ecosystems provide ecosystem services in the form of resources such as food, fuel, and timber; the purification of air and water; the detoxification and decomposition of wastes; the regulation of climate; the regeneration of soil fertility; and the pollination of crops. These ecosystem processes have been estimated to be worth a lot of money annually. There is consensus in the scientific community that the current environmental degradation and destruction of many of the Earth's biota are taking place on a "catastrophically short timescale". Habitat loss is the leading cause of both species' extinctions and ecosystem service decline. Two methods have been identified to slow the rate of species extinction and ecosystem service decline, they are the conservation of currently viable habitat and the restoration of degraded habitat. The commercial applications of ecological restoration have increased exponentially in recent years. The United Nations General Assembly (01.03.2019) declared 2021– 2030 the UN Decade on Ecosystem Restoration.

Definition

Restoration ecology is the academic study of the process, whereas ecological restoration is the actual project or process by restoration practitioners. The Society for Ecological Restoration defines "ecological restoration" as an "intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability". Ecological restoration includes a wide scope of projects including erosion control, reforestation, removal of non-native species and weeds, revegetation of disturbed areas, daylighting streams, the reintroduction of native species (preferably native species that have local adaptation), and habitat and range improvement for targeted species. For many researchers, the ecological restoration must include the local communities: they call this process the "social-ecological restoration".

Australia has been one of the big sites for the historically significant ecological restoration projects. In 1935 Ambrose Crawford commenced restoring a degraded four acres (1.7 hectares) patch of the Big Scrub (Lowland Tropical Rainforest) at Lumley Park reserve, Alstonville, in northern New South Wales. Clearing of weeds and planting of suitable indigenous flora species were his main restoration techniques. The restored rainforest reserve still exists today and is home to threatened plant and animal species. In 1936 Albert Morris and his restoration colleagues initiated the Broken Hill regeneration area project, which involved the natural regeneration of indigenous flora on a severely degraded site of hundreds of hectares in arid western New South Wales. Completed in 1958, the successful project still maintains ecological function today as the Broken Hill Regeneration Area.

Traditional Ecological Knowledge and Restoration Ecology

Traditional Ecological Knowledge from Indigenous Peoples demonstrates how restoration ecology is a historical field, lived out by humans for thousands of years. This means there are many things that could be learned from people locally indigenous to the ecosystem being restored because of the deep connection and biocultural and linguistic diversity of place. However, restoration ecologists must consider that Traditional Ecological Knowledge is place dependent due to intimate connection and thus when engaging Indigenous Peoples to include knowledge for restoration purposes, respect and care must be taken to avoid appropriation of the Traditional Ecological Knowledge. Successful ecological restoration which includes Indigenous Peoples must be led by Indigenous Peoples to ensure non-indigenous people acknowledge the unequal relationship of power

Theoretical foundations

Restoration ecology draws on a wide range of ecological concepts. Disturbance is one of them. Disturbance is a change in environmental conditions that disrupt the functioning of an ecosystem. Disturbance can occur at a variety of spatial and temporal scales, and is a natural component of many communities. For example, many forest and grassland restorations implement fire as a natural disturbance regime. However, the severity and scope of anthropogenic impact has grown in the last few centuries. Differentiating between human-caused and naturally occurring disturbances is important if we are to understand how to restore natural processes and minimize anthropogenic impacts on the ecosystems.

Applications

Leaf litter accumulation

Leaf litter accumulation plays an important role in the restoration process. Higher quantities of leaf litter hold higher humidity levels, a key factor for the establishment of plants. The process of accumulation depends on factors like wind and species composition of the forest. The leaf litter found in primary forests is more abundant, deeper, and holds more humidity than in secondary forests. These technical considerations are important to take into account when planning a restoration project.

Soil heterogeneity effects on community heterogeneity

Spatial heterogeneity of resources can influence plant community composition, diversity, and assembly trajectory. The establishment of a single species, best adapted to the physical and biological conditions can play an inordinately important role in determining the community structure.

Invasion and restoration

Restoration is used as a tool for reducing the spread of invasive plant species many ways. The first method views restoration primarily as a means to reduce the presence of invasive species and limit their spread. As this approach emphasizes the control of invaders, the restoration techniques can differ from typical restoration projects. The goal of such projects is not necessarily to restore an entire ecosystem or habitat. These projects frequently use lower diversity mixes of aggressive native species seeded at high density. They are not always actively managed following seeding. The target areas for this type of restoration are those which are heavily dominated by invasive species. The goals are to first remove the species and then in so doing, reduce the number of invasive seeds being spread to surrounding areas. An example of this is through the use of biological control agents (such as herbivorous insects) which suppress invasive weed species while restoration practitioners concurrently seed in native plant species that take advantage of the freed resources. These approaches have been shown to be effective in reducing weeds, although it is not always a sustainable solution long term without additional weed control, such as mowing, or re-seeding. Restoration projects are also used as a way to better understand what makes an ecological community resistant to invasion. As restoration projects have a broad range of implementation strategies and methods used to control invasive species, they can be used by ecologists to test theories about invasion. Restoration projects have been used to understand how the diversity of the species introduced in the restoration affects invasion. We know that generally higher diversity prairies have lower levels of invasion. The incorporation of functional ecology has shown that more functionally diverse restorations have lower levels of invasion. Furthermore, studies have shown that using native species functionally similar to invasive species are better able to compete with invasive species. Restoration ecologists have also used a variety of strategies employed at different restoration sites to better understand the most successful management techniques to control invasion.

Successional trajectories

Progress along a desired successional pathway may be difficult if multiple stable states exist. Succession may move in unpredicted directions, but constricting environmental conditions within a narrow range may rein in the possible successional trajectories and increase the likelihood of the desired outcome.

Sourcing material for restoration

For most restoration projects it is generally recommended to source material from local populations, to increase the chance of restoration success and minimize the effects of maladaptation. However, the definition of local can vary based on species, habitat and region.

Principles

Rationale

There are many reasons to restore ecosystems. Some include:

- Restoring natural capital such as drinkable water or wildlife populations
- Helping human communities and the ecosystems upon which they depend adapt to the impacts of climate change (through ecosystem-based adaptation)
- Mitigating climate change (e.g., through carbon sequestration)
- Helping threatened or endangered species
- Aesthetic reasons
- Moral reasons: human intervention has unnaturally destroyed many habitats, and there exists an innate obligation to restore these destroyed habitats
- Regulated use/harvest, particularly for subsistence
- Cultural relevance of native ecosystems to Native people
- The environmental health of nearby populations
- There exist considerable differences of opinion on how to set restoration goals and how to define their success. Ultimately specifying the restoration target or desired state of an ecosystem is a societal choice, informed by scientists and technocrats, but ultimately it is a policy choice. Selecting the desired goal can be politically contentious. Some urge active restoration (e.g., eradicating invasive animals to allow the native ones to survive) and others who believe that protected areas should have the bare minimum of human interference, such as rewilding.

Ecosystem restoration has generated controversy. Sceptics doubt that the benefits justify the economic investment or who point to failed restoration projects and question the feasibility of restoration altogether. One reason to consider ecosystem restoration is to mitigate climate change through activities such as afforestation. Afforestation involves replanting forests, which remove carbon dioxide from the air. Carbon dioxide is a leading cause of global warming and capturing it would help alleviate climate change.

Challenges

Some view ecosystem restoration as impractical, partially because restorations often fall short of their goals. In other instances, an ecosystem may be so degraded that abandonment (allowing a severely degraded ecosystem to recover on its own) may be the wisest option. Local communities sometimes object to restorations that include the introduction of large predators or plants that require disturbance regimes such as regular fires, citing threat to human habitation in the area. High economic costs can also be perceived as a negative impact of the restoration process. Public opinion is very important in the feasibility of a restoration; if the public believes that the costs of restoration outweigh the benefits, they will not support it. Many failures have occurred in past restoration projects, many times because clear goals were not set out as the aim of the restoration, or an incomplete understanding of the underlying ecological framework lead to insufficient measures.

Science-practice gap

One of the struggles for both fields is a divide between restoration ecology and ecological restoration in practice. Many restoration practitioners as well as scientists feel that science is not being adequately incorporated into ecological restoration projects. In a 2009 survey of practitioners and scientists, the "science-practice gap" was listed as the second most commonly cited reason limiting the growth of both science and practice of restoration. There are a variety of theories about the cause of this gap. One approach to addressing this gap has been the development of International Principles & Standards for the Practice of Ecological Restoration by the Society for Ecological restoration - however this approach is contended, with scientists active in the field suggesting that this is restrictive, and instead principles and guidelines offer flexibility. There is further complication in that restoration ecologists who want to collect large-scale data on restoration projects can face enormous hurdles in obtaining the data. This limits the ability of scientists to analyze restoration projects and give recommendations based on empirical data.

Contrasting restoration ecology and conservation biology

Restoration ecology may be viewed as a sub-discipline of conservation biology, the scientific study of how to protect and restore biodiversity. Ecological restoration is then a part of the resulting conservation movement. Conservation biology often concentrates on vertebrate animals because of their salience and popularity, whereas restoration ecology concentrates on plants. Restoration ecology focuses on plants because restoration projects typically begin by establishing plant communities. Ecological restoration, despite being focused on plants, may also have "poster species" for individual ecosystems and restoration projects. Restoration ecology has a stronger focus on soils, soil structure, fungi, and microorganisms because soils provide the foundation of functional terrestrial ecosystems.

Reference

Ecology And Environment By P. D. Sharma, Sharma P.D.

Ecology, sustainability, and environment as capital by M.J.Harte

Dickens, Sara Jo M.; Suding, Katharine N. (2013-06-01). "Spanning the Science-Practice Divide: Why Restoration Scientists Need to be More Involved with Practice". Ecological Restoration.

Principles of Environmental Management: The Greening of Business - Aug 1992 by Rogene A. Buchholz

Sustaining Earth: Response. To the Environmental Threat, Macmillan, Basingstoke. - Angell, D. J.R., Comer, J.D. and Wilkinson, ML.N. 1990.

Berry, R. L. 1992; Environmental Dilemmas, Ethics and Decisions, Chapman and Hall; London.