Restoration ecology is the study of renewing a degraded, damaged, or destroyed ecosystem through active human intervention. Restoration ecology specifically refers to the scientific study that has evolved as recently as the 1980s. Land managers, laypeople, and stewards have been practicing restoration for many hundreds, if not thousands of years (Anderson 2005), yet the scientific field of " **restoration ecology**" was first identified and coined in the late 1980s by John Aber and William Jordan. The study of restoration ecology has only become a robust and independent scientific discipline over the last two decades (Young et al. 2005).

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” (SER 2004). The practice of ecological restoration includes wide scope of projects including: erosion control, reforestation, removal of non-native species and weeds, revegetation of disturbed areas, daylighting streams, reintroduction of native species, as well as habitat and range improvement for targeted species. The term "ecological restoration" refers to the practice of the discipline of "restoration ecology".

In the view of biologist E. O. Wilson, "**Here is the means to end the great extinction spasm. The next century will, I believe, be the era of restoration in ecology.**
".

Contents

Rationale for restoration

There is consensus in the scientific community that the current environmental degradation and destruction of many of the Earth's biota is considerable, and is taking place on a “catastrophically short timescale” (Novacek & Cleland 2001). In fact, estimates of the current extinction rate are 1000 to 10,000 times the normal rate (Wilson 1988). For many people biological diversity (biodiversity) has an intrinsic value; humans have a responsibility toward other living things, and obligations to future generations.

On a more anthropocentric level, natural ecosystems provide human society with food, fuel and timber. More fundamentally, ecosystem services involve the purification of air and water, detoxification and decomposition of wastes, regulation of climate, regeneration of soil fertility, and pollination of crops. Such processes have been estimated to be worth trillions of dollars annually (Daily et al. 1997).

Habitat loss is the leading cause of both species extinctions (Wilson 1988) and ecosystem service decline (Daily et al. 1997). There are two ways to reverse this trend of habitat loss: conservation of currently viable habitat and restoration of degraded habitats.

Conservation biology and restoration ecology

With regard to biodiversity preservation, it should be noted that restoration activities are complementary to, not a substitute for, conservation efforts. Many conservation programmes, however, are predicated on historical bio-physical conditions - i.e. they are incapable of responding to global climate change, and the assemblages "locked in" that become increasingly fragile and liable to catastrophic collapse. In this sense, restoration is essential to provide new spaces for migration of habitats and their associated flora and fauna (Harris et al., 2006). Also, conservation biology has organisms, and not entire ecosystems and their functions, as its focus, and therefore has limited goals and aims.

Restoration ecology, as a scientific discipline, is theoretically rooted in conservation biology. While restoration ecology may be viewed as a sub-discipline of conservation biology, foundational differences exist between the disciplines' approaches, focuses and modes of inquiry.

Approaches

The fundamental difference between conservation biology and restoration ecology lies in their philosophical approaches to the same problem. Conservation biology attempts to preserve and maintain existing habitat and biodiversity. In contrast, restoration ecology assumes that environmental degradation and population declines are somewhat reversible processes. Therefore, targeted human intervention can lead to habitat and biodiversity recovery and eventual gains.

Focuses

First, both conservation biology and restoration ecology have an unfortunate temperate terrestrial bioregion bias. This issue is probably the result of these fields developing in the geopolitical north, and both fields should attempt to reconcile this bias.

Second, perhaps because plants tend to dominate most (terrestrial) ecosystems, restoration ecology has developed a strong botanical bias, while conservation biology is more strongly zoological (Young 2000).

Similarly, the principal systemic levels of interest differ between the disciplines. Conservation biology has historically focused on target individuals (i.e. endangered species), and has thus concentrated on genetic and population level dynamics. Since restoration ecology is aimed at rebuilding a functioning ecosystem, a broader (i.e. community or ecosystem) perspective is necessary.

Finally, since soils define the foundation of any functional terrestrial system, restoration ecology's ecosystem-level bias has placed more emphasis on the role of soil physical and microbial processes (Allen et al. 2002; Harris, 2003).

Modes of inquiry

Conservation biology's focus on rare or endangered species limits the number of manipulative studies that can be performed. As a consequence, conservation studies tend to be descriptive, comparative and unreplicated (Young 2000). However, the highly manipulative nature of restoration ecology allows the researcher to more rigorously test hypotheses. In fact, every restorative activity is, in essence, an experimental test of what limits populations (Young et al. 2005).

Theoretical foundations

Restoration ecology draws on a wide range of ecological concepts. The following are brief descriptions of some of the more influential concepts. (Note the community and ecosystem level bias.)

Disturbance

Disturbance is a change of environmental conditions, which interferes with the functioning of a biological system. Disturbance at a variety of spatial and temporal scales is a natural, and even essential, component of many communities (White & Jentsch 2004).

Humans have had limited “natural” impacts on ecosystems for as long as humans have existed, however the severity and scope of our modern influences has accelerated in the last few centuries. Understanding and minimizing the differences between modern anthropogenic and “natural” disturbances is crucial to restoration ecology. For example, new forestry techniques that better imitate historical disturbances are now being implemented.

In addition, restoring a fully sustainable ecosystem often involves studying and attempting to restore a natural disturbance regime (e.g., fire ecology).

Succession

Ecological succession is the process by which the component species of a community changes over time. Following a disturbance, an ecosystem generally progresses from a simple level of organization (i.e. few dominant species) to a more complex community (i.e. many interdependent species) over a few generations. Depending on the severity of the disturbance, restoration often consists of initiating, assisting or accelerating ecological successional processes (Luken 1990).

In many ecosystems, communities tend to recover following mild to moderate natural and anthropogenic disturbances. Restoration in these systems involves hastening natural successional trajectories. However, a system that has experienced a more severe disturbance (i.e. physical or chemical alteration of the environment) may require intensive restorative efforts to recreate environmental conditions that favor natural successional processes.

Fragmentation

Habitat fragmentation is the emergence of spatial discontinuities in a biological system. Through land use changes (e.g. agriculture) and "natural" disturbance, ecosystems are broken up into smaller parts. Small fragments of habitat can support only small populations and small populations are more vulnerable to extinction. Further, fragmenting ecosystems decreases interior habitat. Habitat along the edge of a fragment has a different range of environmental conditions and therefore supports different species than the interior. Fragmentation effectively reduces interior habitat and may lead to the extinction of those species which require interior habitat. Restorative projects can increase the effective size of a habitat by simply adding area or by planting habitat corridors that link and fill in the gap between two isolated fragments. Reversing the effects of fragmentation and increasing habitat connectivity are central goals of restoration ecology.

Ecosystem function

Ecosystem function describes the foundational processes of natural systems, including nutrient cycles and energy fluxes. These processes are the most basic and essential components of ecosystems. An understanding of the full complexity and intricacies of these cycles is necessary to address any ecological processes that may be degraded. A functional ecosystem, that is completely self-perpetuating (i.e. no management required), is the ultimate goal of restorative efforts. Because these ecosystem functions are emergent properties of the system as a whole, monitoring and management are crucial for the long-term stability of an ecosystem.

Emerging concepts

Restoration ecology, because of its highly manipulative nature, is an ideal testing ground for emerging community ecological principles (Bradshaw 1987). There are also the emerging concepts of inventing new and successful restoration technologies, performance standards, time frames, local genetics, and society's relationship to restoration ecology, and new ethical and religious possibilities, as future topics of discussion and debate.

Local Genetics

When conducting a restoration project, and you are replanting a local native ecosystem, how local should the gentic material be, that you use for the project? Should it come from a few hundred meters of the site, from the next watershed, from the next State, from a few states away, or a commercial selection of that species?

Time frame, Performance standards

Time frames for successful restoration projects plus performance standards, are the keys to take restoration ecology from the academic experiment to the professional level. If restoration ecology is merely a long term experiment, then you do not need hard time frames or performance standards. Performance standards, could be defined as: Your restoration technologies are able to produce a certain amount of locally genetic native plant cover with a minimum number of species to produce a functioning ecosystem, within a certain amount of time, with a lack or very low level of weed cover, and be able to be self-sustaining at a certain time, into the future; for a societal reasonable amount of money.

Societal reasonable amounts of money for projects

What this means, is it better to invest in a single restoration project, with the hope of inventing a new successful restoration technology, or should society invest that money directly into inventing the technologies, and keep funding until the successful technologies are invented for a particular ecosystem? Society funds hundreds of restoration projects each year, both experimental and professional, but at what cost? For example, is it reasonable to have a mine owner have to pay a certain amount per acre as mitigation to restore her mine, when the successful restoration technologies to restore that mine has not even been invented yet? These are the questions that government officials are faced with, when requiring mitigation on commercial project, when it is well known that neither the government officials, the commercial interest, nor the restoration professionals, have not yet invented the technologies necessary for the restoration job. What is a reasonable amount of money, when the technologies have not been invented yet, and instead of a mitigation project, should it be a technology inventing project instead?

Inventing successful restoration technologies, especially for non-riparian projects

Non-riparian and non-coastal projects are especially difficult, especially in areas of dense weeds, or lack of rainfall, like the arid Western US. However, these are the areas where the professionals need to be able to perform for their clients, usually to mitigate for a commercial project like mine restoration, or developments, and sometimes to restore Endangered Species habitats. Professionals and clients should know that successful non-riparian restoration technology is a separate valuable item, that has a great value and should be licensed from the professional to the client. The very low numbers of annual patent filing for the whole restoration ecology profession, may indicate that there is a lack of commercially successful restoration technologies today for non-riparian area, or are being invented or improved every year.

Assembly

Community assembly “is a framework that can unify virtually all of (community) ecology under a single conceptual umbrella” (Young et al. 2005). 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 (Young et al. 2001). Essentially, if all species are fairly ecologically equivalent then random variation in colonization, migration and extinction rates, between species, drive differences in species composition between sites with comparable environmental conditions.

Stable states

Alternative stable states are discrete species compositional possibilities that may exist within a community. According to assembly theory, differences in species colonization, interspecific interactions and community establishment may result in distinct community species equilibria. A community has numerous possible compositional equilibria that are dependent on the initial assembly. That is, random fluctuations lead to a particular initial community assembly, which affects successional trajectories and the eventual species composition equilibrium.

Multiple stable states is a specific theoretical concept, where all species have equal access to a community (i.e., equal dispersal potential) and differences between communities arise simply because of the timing of each species' colonization (Young et al. 2001).

These concepts are central to restoration ecology; restoring a community involves not only manipulating the timing and structure of the initial species composition, but also working toward a single desired stable state. In fact, a degraded ecosystem may be viewed as an alternative stable state under the altered environmental conditions (van Andel & Grootjans 2006).

Ontogeny

The ecology of ontogeny is the study of how ecological relationships change over the lifetime of an individual. Organisms require different environmental conditions during different stages of their life-cycle. For immobile organisms (e.g. plants) the conditions necessary for germination and establishment may be different from those of the adult stage (Young et al. 2005). As an ecosystem is altered by anthropogenic processes the range of environmental variables may also be altered. A degraded ecosystem may not include the environmental conditions necessary for a particular stage of an organism's development. If a self-sustaining, functional ecosystem must contain environmental conditions for the perpetual reproduction of its species, restorative efforts must address the needs of organisms throughout their development.

Restoration Ecology as a basis for a new world religion

The possibility has been suggested, that restoration ecology may form a new ethical and/or religious relationship between humans and the planet's natural ecosystems.

Application of theory

Restoration is defined as the application of ecological theory to ecological restoration. However, for many reasons, this can be a challenging prospect. Here are a few examples of theory informing practice.

Soil heterogeneity effects on community heterogeneity

Spatial heterogeneity of resources can influence plant community composition, diversity and assembly trajectory. Baer et al. (2005) manipulated soil resource heterogeneity in a tallgrass prairie restoration project. They found increasing resource heterogeneity alone was insufficient to insure species diversity in situations where one species may dominate across the range of resource levels. Their findings were consistent with theory regarding the role of ecological filters on community assembly. The establishment of a single species best adapted to the physical and biological conditions can play an inordinately important role in determining community structure.

Invasion, competitive dominance and resource use

“The dynamics of invasive species may depend on their abilities to compete for resources and exploit disturbances relative to the abilities of native species.” Seabloom et al. (2003) tested this concept and its implications in a California grassland restoration context. They found native grass species were able to successfully compete with invasive exotics for a range of resources. This suggests native California grasses are dispersal limited and exotics may currently dominate because of historical land use patterns.

Successional trajectories

Progress along a desired successional pathway may be difficult if multiple stable states exist. Looking at over 40 years of wetland restoration data Klotzi and Gootjans (2001) argue that unexpected and undesired vegetation assemblies “may indicate environmental conditions are not suitable for target communities.” 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 a desired outcome.

Ethical considerations

Purposefully altering ecosystems is a controversial issue; Restoration poses several ethical quandaries. Below are a summary of the more cogent objections as well as brief rebuttals. All of these questions are important considerations when designing a restorative project.

Restoration is "faking it"

Argument: Humans cannot create real natural systems, they can only create simplified replicas.

Rebuttal: While this argument is superficially correct, it misses restoration ecology’s deeper ecological principles. The goal of restoration is not to immediately recreate replacement ecosystems, rather to “jump-start” natural recuperative processes.

Mitigation’s black eye

Argument: The concept of restoration implies that any habitat destruction can be remediated. This permits habitat destruction in some areas since mitigation in other areas will "balance" overall loss.

Rebuttal: Mitigation is often used in a way that is a perversion of the overall goals of restorative efforts (i.e. to increase viable habitat and biodiversity). This is not necessarily a problem with restoration, rather a problem with statutes that allow for poor mitigation as a way around species and habitat protections.

Ultimate complexity versus limited knowledge

Argument: Because of the complexity of natural systems, restoration efforts are likely to result in unforeseen and negative outcomes.

Rebuttal: This argument is undoubtedly true. However, some restorative efforts are successful. By further developing restoration ecology as a science, we can increase our knowledge and tip the balance toward positive outcomes.

Where's the target?

Argument: If restoration is repairing an ecosystem toward some reference state, what state do we strive toward? The choice of a reference state is necessarily arbitrary and can simply be a reflection of human bias.

Rebuttal: This problem is serious and can only be addressed on a site specific basis.

- If we wish to restore an ecosystem to its state “prior to degradation”, when do we choose?

- If we use modern reference equivalents, how do we know these are not also degraded?
- If we wish to restore some level of function, how do we choose the desired process?

See also

- Applied ecology
- Bioremediation
- Conservation Effects Assessment Project
- Ecological design
- Land restoration of depleted mines
- Land rehabilitation
- *Litmus Gardens* in Vintondale, Pennsylvania
- Prairie restoration

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External links

- A Guide to Prairie and Wetland Restoration In Eastern Nebraska
- A Guide to Restoration Ecology
- Conservation Effects Assessment Project bibliographies
- UF Water Institute
- Earth Repair & Restoration - Ecological Restoration Specialists
- Information regarding seagrass restoration can be found at: SeagrassLI
- Back to Natives Restoration a 501(c)3 (Irvine, CA)

Societies and journals

- Society for Ecological Restoration International - official website.
- *Ecological Restoration* - Journal published by the University of Wisconsin Press for people interested in all aspects of the practice of ecological restoration.

- *Restoration Ecology* - Journal published on behalf of the Society for Ecological Restoration International.

- Indigenous Flora and Fauna Association (Australia)

Educational opportunities

- MSc Land Reclamation and Restoration Cranfield University
- Graduate Study at the University of California, Davis
- Graduate Study at the University of Mississippi
- Center for Urban Restoration Ecology
- North Carolina State Restoration Ecology Program
- University of Victoria Restoration of Natural Systems Program
- Golden Hour Restoration Institute - A Field Based Restoration Ecology school
- University of Liverpool, UK, MSc Restoration Ecology of Terrestrial and Aquatic Environments
- IFAS Water Institute
- University of Waikato, Hamilton, Aotearoa/New Zealand: Restoration Ecology
- University of Washington, Seattle, WA: Restoration Ecology Network
- Brandenburg University of Technology (BTU) Cottbus, Germany: International Masters Program "Restoration Ecology" (E-Learning / Blended Learning)
- University of Florida online programs in Ecological Restoration
- Msc in Eco Restoration course is running smoothly for last Five years at Dimoria College,Khetri,Kamrup Assam.India All are requested to help this course to success and visit our web.www.dimoriacollege.nic.in This course is the first of its kind in south-east India

Ecological restoration internships and non-profit organizations

- Back to Natives Restoration a 501(c)3 A non profit organization dedicated to restoring Orange County and California Wildlands through education and restoration programs featuring native plants and biodiversity as a centralizing them.(Irvine, California)