Courtesy of Michael R. Wagner

Restoration Ecology

A New Forest Management Paradigm, or Another Merit Badge for Foresters?

That ecological restoration is a growing field is illustrated by the startup of a professional association (the Society for Ecological Restoration, created in 1987), the development of two new journals *(Restoration Ecology* and *Ecological Restoration,* the latter having been *Restoration and Management Notes),* and the publication of 50 or more papers each year. In the

Focusing on the Southwest but raising questions that are more broadly applicable, we compare ecological restoration with conventional management regimes—multiple-use management, ecosystem management, and managing for specific resource objectives. That restoration assumes a holistic perspective and active intervention does not distinguish it from other approaches to achieving ecosystem health. We find that foresters and restorationists both use ecology, but restorationists use a reference condition as a substitute for specific objectives. We believe that restorationists who advocate substituting a reference condition for meeting a priori objectives must demonstrate the advantage of this approach. We identify the conceptual limitations to ecological restoration and question the uses of restoration.

By Michael R. Wagner, William M. Block, Brian W. Geils, and Karl F. Wenger

Southwest alone, several large forest restoration projects are under way.

The notion of "restoring" ecosystems seems laudable enough. For some, however, ecological restoration assumes a moral imperative for a "bold new orientation toward nature" (Higgs 1991). We evaluate ecological restoration in the larger context of other land management philosophies like multiple-use management, ecosystem management, and managing for specific resource objectives (e.g., wildlife, commodity production). We ask, is ecological restoration sufficiently conceptually developed, experimentally tested, and necessary to warrant its adoption as a new forest management paradigm?

Ecological Restoration, Defined

The techniques, objectives, and definitions of ecological restoration have evolved over the past decade as practitioners and scientists sought to define a new, applied discipline. Between 1991 and 1997 the Society of Ecological Restoration modified its definition of ecological restoration five times (Palmer et al. 1997). Restoration was first used to describe landscaping and replanting to reclaim stripmines and toxic dumps. Later, restoration described agricultural lands that were revegetated to resemble native prairies, and new wetlands that were created to replace those lost to other uses. More recently, and especially in southwestern forests, the term *forest restoration* has been used to describe activities intended to recreate the forest structure and fire regime that prevailed just prior to Euro-American settlement (Covington and Moore 1994; Covington et al. 1997; Stone et al. 1999).

The purpose of restoration has been variously described as repairing damage, renewing ecosystem health, recovering ecological integrity, and regenerating harmony between humans and nature (SER 1994; Higgs 1997; Palmer et al. 1997). Health and integrity refer to desired biological diversity and sustained ecosystem functioning. In terms familiar to foresters, a recent Society of Ecological Restoration workshop definition read, "ecological restoration entails negotiating the best possible outcome for a specific site based on ecological knowledge and the diverse perspectives of interested stakeholders."

Certainly, restoration generally assumes a holistic perspective and a need for active intervention, but that hardly distinguishes it from ecosystem management or other approaches for achieving ecosystem health (sustainability, integrity, etc.). Is ecological restoration the only way to achieve ecosystem health? If a management activity improves forest health, is it then ecological restoration?

What distinguishes restoration from other land management activities is that recovering the ecological integrity of a site requires using the techniques of reestablishing the composition, structure, and disturbance regime of a historical or indigenous reference ecosystem (Cairns 1993; Meffe and Carroll 1994; Bradshaw 1996).

Choice of Reference

A reference or standard is essential for planning and monitoring any project that promises to produce certain results within given specifications. Desired conditions and performance standards may be determined by a collaborative decision process that assesses the likely outcome of alternative management policies. A restorationist's approach is to define desired conditions and standards as those exemplified by a specific historical or indigenous ecosystem. For the Southwest, a preferred reference is the ponderosa pine forest that existed just prior to European settlement, produced under a disturbance regime of frequent ground fires resulting in open stands with groups of large ponderosa pine trees and a sparse woody understory but dense grassy cover (Covington et al. 1997).

Although some dendrochronology data support the contention that fire occurred at a regular but variable frequency prior to Euro-American settlement, there is also some relatively new information based on extensive research in other ponderosa pine stands suggesting that the severity, frequency, and spatial occurrence of fire was even

***Opposite:* A stand of ponderosa pine as captured in this historical photograph (circa 1890s) from the Coconino National Forest, Arizona. Clumps of large-diameter ponderosa pine and open savannah between clumps are the common reference condition used in the Southwest. Note in the background somewhat more dense pockets of young trees.**

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An abundance of the exotic mullein *(Verbascum thapsus),* which was largely absent in the untreated control, is apparent in the understory vegetation five years after a full restoration treatment in ponderosa pine at Fort Valley Experimental Forest, Arizona. Details of the treatments are in Stone et al. (1999).

more variable than previously thought (Shinneman and Baker 1997; Brown et al. 1999). Brown et al. also clearly demonstrate the existence of stand-replacing fires, which had rarely been considered a component of the southwestern reference condition.

The Presettlement Condition

Human influence on forest conditions prior to European settlement is underappreciated. The latest estimate of the native population of North America at the time of discovery is 50 million. According to DeVivo (1991), the precontact New World population peaked between 90.04 million and 112.55 million indigenous people, equally split between North and South America. But Europeans introduced diseases for which the natives had no resistance. As the inhabitants tried to flee the diseases, they apparently spread them throughout eastern North America. DeVivo concludes, "No doubt, the aboriginal inhabitants of mainland North America suffered dramatic population decline before face-to-face contact with Europeans" from the diseases introduced by the Europeans. The population decline apparently had not yet run its course during the 1539–42 DeSoto expedition through what is now the eastern United States. In the Blue Ridge Mountains they marched for "one day through cultivated fields." Towns in eastern Tennessee had "vast quantities of maize." In the Coosa Valley of present-day Alabama they found "large and numerous settlements and the fields were continuous" (DeVivo 1992).

The European immigrants of the early 17th century found perhaps only small, scattered villages, still rather extensive open fields, but also "dense second-growth forests characterized by fifty to 100 year old trees, unhindered by human impact." This offered the illusion of "virgin forest" (DeVivo 1991). Similarly, in the Southwest there were periods of occupation and abandonment by native peoples. Thus, the activities of native peoples were the major agents determining the vegetative conditions over much of the United States until the time of the Revolutionary War. Should the reference condition include or exclude the human impact of indigenous people?

Transient Climate

Dendrochronology studies in the Southwest suggest that from roughly 1800 to the present, the climate was substantially wetter than from 1400 to 1800 (Grissino-Mayer et al. 1997) *(fig. 1).* The common reference period in the Southwest is the pre–European settlement period of roughly 1860 to the 1880s, or 60 to 80 years after a 400-year dry period. The climate that created this popular reference condition may never be repeated, so why should we assume that a past forest structure is better suited to the much different climate that exists today? Add uncertain global climate change and Pacific decadal oscillations, and recreating forest structure to reflect a unique historical climate seems of dubious value.

From a forest management perspective, a climatic pattern that has persisted for 200 years is more than ample time to produce one or two rotations of multiple products. It seems most sensible to manage existing forests in the existing climate to meet current objectives rather than managing to recreate the past. Aronson et al. (1995) insist that a reference ecosystem, even if arbitrary and imperfect, is necessary for the design and evaluation of restoration projects. The question, however, is whether any single ecosystem condition is a sufficient reference if it was the product of a unique combination of climate and human interaction that may never be repeated.

Obstacles to Restoration

The evolving science and theory of ecosystems. Ecosystems are always responding to previous disturbances: tree fall, firestorm, volcanic eruption, ice ages, and meteor strikes. Ecosystem development after disturbance is greatly influenced by chance; what remains and what is nearby influence ecosystem trajectory. Ecosystems endure with change. Species evolve and are replaced, structures are built and decay, process rates vary but life goes on. The significance of these characteristics is that every ecosystem is unique to the place and time in which it exists.

Ecological restoration relies on many ecological concepts, some of which are not clearly understood; others are still being defined and tested. One of the basic concepts of succession was once viewed as a single, deterministic pathway to a climatic climax type. This basic concept has been replaced by a nonlinear model of exploitation-conservation-release-reorganization (Holling 1995). For example, restorationists often cite a need for diversity to ensure ecosystem stability. The ecological debate on that issue has progressed from discussions on stability to resilience, to a recent suggestion that overconnectedness leads to brittleness (Holling 1995). Likewise, it is equivocal whether diversity creates stability or structure ensures function in ecosystems.

New ecosystem components. Another major obstacle in restoration is dealing with the components of the ecosystem that are present now that didn't exist previously or organisms that exist in greater numbers than before. Specifically, we are referring to exotic organisms. The open vegetation structure and reintroduction of fire as a disturbance agent that characterize forest restoration in the Southwest are also conditions that are highly suitable for invasive species. With the exception of Allen (1995) and Montalvo et al. (1997), few authors have discussed the relationship between ecological restoration and increased invasion by exotic species. Some authors have suggested that exotic invasions can be beneficial (Hobbs and Mooney 1993). Recent data on understory vegetation response (Griffis et al., in press) suggest that exotic species respond dramatically to the reintroduction of fire as part of surrogate restoration treatments *(fig. 2, p. 26).* This response is also visually dramatic in full restoration treatments. Consequently, in forests where exotic species become established, ecological restoration treatments may create a forest health problem that is as undesirable as the pretreatment condition.

Societal needs. What often distinguishes foresters from ecologists is that foresters are asked to manage forests to achieve specific societal objectives within ecological constraints. Forestry as an applied science has developed alongside ecology. These sciences matured together and benefited from interaction. A science can be defined by the questions it asks. Forestry asks how trees grow, respond to competition and release, and reproduce. Foresters are also interested in maintaining soil, water, and species other than trees. Tending a stand of trees is seen as a long-term commitment, but economics dictates a minimum of intervention. A forester could be satisfied with an age-diverse landscape (regulated forest) of stocked stands of well-growing

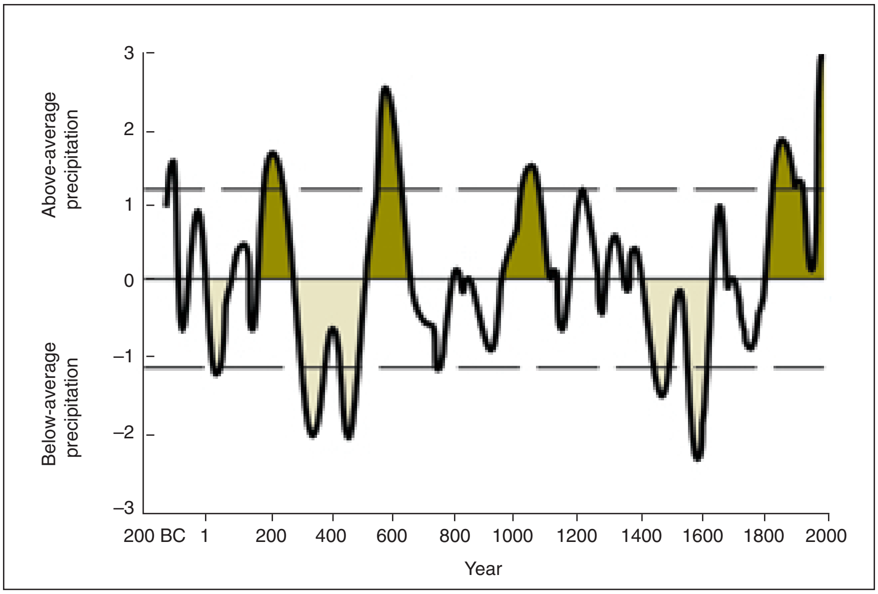

Figure 1. **A 2,129-year reconstruction of precipitation based on 10-year averages for northwestern New Mexico. Unprecedented above-average precipitation characterizes the most recent 200-year period, which was preceded by significant droughts. Which climatic period should be used as the reference condition?**
Source: **Grissno-Mayer et al. 1997**

trees that provide a diversity of habitats (multiple use); harvest and regeneration activities that protect soil and water (sustained yield); and fire, insect, and disease within acceptable limits from a long-term perspective (forest health). Silvics, silviculture, mensuration, and forest protection indicate that these are realistic objectives, achievable using tools like timber harvest.

Foresters and restorationists use the same ecology, but restoration ecologists use a reference condition as a substitute for specific objectives. Creating a reference ecosystem condition has its greatest utility as a research tool to better understand how ecosystems function (Ehrenfeld and Toth 1997; Michener 1997). We certainly recognize understanding ecosystems as a laudable goal of ecological restoration. Fixing badly degraded ecosystems—landscapes that have been deforested or contaminated with environmental toxins—also is an important ecological restoration objective (Dobson et al. 1997). Again we concur this is a laudable use of restoration.

Compatibility with achieving other values. To answer the question we pose in our title—whether restoration should be viewed as an alternative land management paradigm for the bulk of forest lands in the United States currently under forest management—we want to use the example of ecological restoration and wildlife.

Numerous goals underlie traditional management of wildlife, including maintaining viable populations of all native and desired nonnative vertebrates (prescribed by the National Forest Management Act of 1976), recovering threatened and endangered species (mandated by the Endangered Species Act of 1973), and providing consumptive (hunting, fishing, trapping) and nonconsumptive (birdwatching, photography) recreational opportunities. To achieve these goals, management is often directed at maintaining or enhancing conditions for focal species. In contrast, ecological restoration is guided by broader goals that emphasize ecosystem composition, structure, and function rather than specific ecosystem elements. Implicit in restoration is the assumption that successful restoration will provide favorable conditions for native species of wildlife. Thus, effects of restoration on wildlife are more appropriately considered an outcome rather than a specific goal of management.

Given that traditional approaches to wildlife management are mandated by law or deeply imbedded in many societies (Leopold 1933, 1949), it is un-

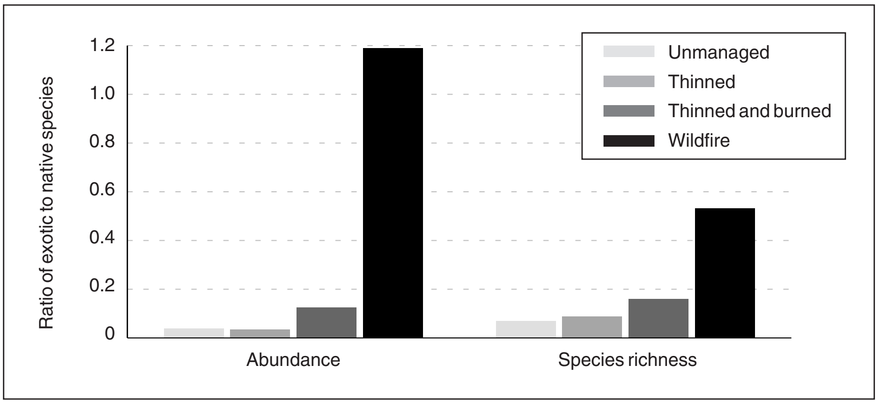

Figure 2. **Ratio of exotic to native understory species in ponderosa pine forests following four experimental stand treatments (Griffis et al., in press). Surrogate restoration treatments of thinning and burning significantly increased the proportion of exotic species, as did stand-replacing wildfire.**

likely that ecological restoration will supplant those approaches. The question then arises, Is ecological restoration compatible with established approaches to wildlife management, or even desirable? Our conclusion is that there is no assurance that ecological restoration can sustain populations of all target species, nor is there assurance that managing for target species can result in a restored ecosystem.

Management of some target species, particularly threatened or endangered species, may entail a laissez-faire approach. This is often the case with species that rely on dense, mature forests, such as the threatened Mexican spotted owl *(Strix occidentalis lucida),* or species that use exotic plants like salt cedar *(Tamarix chinensis)* as an important habitat element, such as the endangered southwestern willow flycatcher *(Empidonax traillii extimus)*. A restoration prescription calling for an open forest structure would probably not be permitted in areas occupied by spotted owls, nor would salt cedar removal be possible in flycatcher nesting areas. Such constraints would essentially preclude restoration as a viable management option. Management practices for many game species—wild turkey *(Meleagris gallopavo),* elk *(Cervus elaphus)*, and deer *(Odocoileus)*—often require maintaining dense vegetation structure to provide nesting, bedding, hiding, and escape cover. Providing dense cover may be counter to restoration prescriptions that strive for an open park-like forest. Here, goals of game management may be incompatible with those of ecological restoration.

The assumption that restoring vegetation structure and composition will lead to a "restored" wildlife community is a field of dreams. To our knowledge, there is certainly no conclusive evidence to validate this assertion. Wildlife communities are dynamic and change as the result of natural phenomena and human influences. When the system is perturbed, biotic and abiotic relationships of the system's components change. Changes to the wildlife community may take the form of population changes, extirpation or extinction of species, invasion by exotic species, and changing relationships (such as food webs) among the remaining species. When a system is "restored," extinct species will not return, exotic species often remain, population levels may not return to "reference" levels, and community structure and organization will likely be unique to that place and time. Thus, will ecological restoration result in a restored wildlife community? Undoubtedly, it will not in most situations.

Summary

Our article summarizes three broad issues that should be considered before foresters adopt an ecological restoration management paradigm:

1. Changing climate and land uses by humans make the selection of an appropriate reference condition problematic.

2. Even if as a society we could agree that some previous condition was more desirable, there is considerable doubt that we have sufficient knowledge of how ecosystems function to get there.

3. Previous forest conditions, at least when applied across a landscape scale, probably do not better meet social needs and desires than other alternatives currently available.

There are in addition several other issues that relate to the feasibility of ecological restoration—economics, institutional constraints, sustainability, and difficulty in achieving societal consensus—that we do not have space to discuss. Restoration prescriptions in the Southwest that lead to lower stand densities and the use of prescribed fire are generally desirable. Conventional silvicultural prescriptions can, however, provide similar benefits while also achieving other societal values like improved game habitat, protection of specific endangered wildlife, and the production of marketable wood products.

One's orientation to the human role in ecosystem management has much to do with how one answers the question, Should ecosystems be restored to a previous condition? A forester views a recently cut, regenerating stand under even-age management as a renewable resource to meet human needs. The previous condition of the stand was part of a sustainable forest (the ecosystem) producing ecological services and extractable products. If regeneration is only a phase of a continuous process, is "restoration" even applicable? That past can never be reconstituted, but perhaps an acceptable facsimile can and should be made. Other people want an area where natural processes of growth, reproduction, and evolution occur without human presence. The fundamental difference in these perspectives is the relative degree of human involvement in ecosystems.

In recent years, three concepts have emerged on the forest management scene: forest health, ecosystem management, and now ecological restoration. All of these concepts have initially generated considerable debate, but we believe all are basically fully consistent with modern forest management activities. Some authors define ecological restoration in terms nearly synonymous with what many in the Society of American Foresters call "good forest stewardship." We welcome these new ideas and techniques, but restorationists who advocate substituting a reference condition for meeting societal objectives must demonstrate the advantage of this approach over conventional silvicultural prescription. The question is not whether ecological restoration is good for ecosystems; but rather, is it marginally better than the other options available to improve ecosystem health? Professional foresters should carefully consider how they can use ecological restoration on badly degraded lands or as part of long-term research where it is most appropriate, and sew on another merit badge for a 100-year history of service as "ecological restorationists."

Literature Cited

ALLEN, E.B. 1995. Restoration ecology: Limits and possibilities in arid and semiarid lands. In *Proceedings: Wildland Shrub and Arid Land Restoration Symposium,* October 19–21, 1993, Las Vegas, comps. B.A. Roundy, E.D. McArthur, J.S. Haley, and D.K. Mann. INT-GTR-315. Ogden, UT: USDA Forest Service, Intermountain Research Station.

ARONSON, J., S. DHILLION, and E.L. FLO'H. 1995. On the need to select an ecosystem reference, however imperfect: A reply to Pickett and Parker. *Restoration Ecology* 3:1–3

BRADSHAW, A.D. 1996. Underlying principles of restoration. *Canadian Journal of Fisheries and Aquatic Science* 53(suppl.1):3–9.

BROWN, P.M., M.R. KAUFMANN, and W.D. SHEPPERD. 1999. Long-term, landscape patterns of past fire events in a montane ponderosa pine forest of central Colorado. *Landscape Ecology* 14:513–32.

CAIRNS, J. 1993. Ecological restoration: Replenishing our national and global ecological capital. In *Nature conservation 3: Reconstruction of fragmented ecosystems, global and regional perspectives,* eds. D.A. Saunders, R.J. Hobbs, and P.R. Ehrlich, 193–208.Chipping Norton, New South Wales, Australia: Surrey Beatty & Sons.

COVINGTON, W.W., and M.M. MOORE. 1994. Postsettlement changes in natural fire regimes and forest structure: Ecological restoration of old-growth ponderosa pine forests. In *Assessing forest ecosystem health in the inland West,* eds. R.N. Sampson and D.L. Adams, 153–81. New York: Haworth Press.

COVINGTON, W.W., P.Z. FULÉ, M.M. MOORE, S.C. HART, T.E. KOLB, J.N. MAST, S.S. SACKETT, and M.R. WAGNER. 1997. Restoring ecosystem health in ponderosa pine forests of the Southwest. *Journal of Forestry* 95:23–29.

DEVIVO, M.S. 1991. Indian use of fire and land clearance in the southern Appalachians. In *Fire and the environment: Ecological and cultural perspectives,* eds. S.C. Nordview and T.A. Waldrop, 306–10. Asheville, NC: USDA Forest Service.

———. 1992. A landscape interpretation: Eastern North America in 1492. *Carver Interdisciplinary Journal* 10(1).

DOBSON, A.P., A.D. BRADSHAW, and A.J.M. BAKER. 1997. Hopes for the future: Restoration ecology and conservation biology. *Science* 277:515–22.

EHRENFELD, J.G., and L.A. TOTH. 1997. Restoration ecology and the ecosystem perspective. *Restoration Ecology* 5:307–17.

GRIFFIS, K.L., J.A. CRAWFORD, M.R. WAGNER, and W.H. MOIR. In press. Understory response to management treatments in northern Arizona pondersoa pine forests. *Forest Ecology and Management.*

GRISSINO-MAYER, H.D. 1997. The rare, old-aged conifers of El Malpais—their role in understanding climatic change in the American Southwest. *New Mexico Bureau of Mines and Mineral Resources Bulletin* 156:155–61.

HIGGS, E.S. 1991. A quantity of engaging work to be done. *Restoration and Management Notes* 9:97–104.

———. 1997. What is good ecological restoration? *Conservation Biology* 11:338–48.

HOBBS, R.J., and H.A. MOONEY. 1993. Restoration ecology and invasions. In *Nature conservation 3: Reconstruction of fragmented ecosystems, global and regional perspectives,* eds. D.A. Saunders, R.J. Hobbs, and P.R. Ehrlich, 127–33. Chipping Norton, New South Wales, Australia: Surrey Beatty & Sons.

HOLLING, C.S. 1995. What barriers? What bridges? In *Barriers and bridges to renewal of ecosystems and institutions,* eds. L.H. Gunderson, C.S. Holling, and S.S. Light, 3–34. New York: Columbia University Press.

LEOPOLD, A. 1933. *Game management.* New York: Charles Scribner's Sons.

———. 1949. *A Sand County almanac and sketches here and there.* New York: Oxford University Press.

MEFFE, G.K., and C.R. CARROLL. 1994. Ecological restoration. In *Principles of conservation biology,* eds. G.K. Meffe and C.R. Carroll, 409–38. Sunderland, MA: Sinauer Associates.

MICHENER, W.K. 1997. Quantitatively evaluating restoration experiments: Research design, statistical analysis, and data management considerations. *Restoration Ecology* 5:324–37.

MONTALVO, A.M., S.L. WILLIAMS, K.J. RICE, S.L. BUCHMANN, C. CORY, S.N. HANDEL, G.P. NABHAN, R. PRIMACK, and R.H. ROBICHAUX. 1997. Restoration biology: A population perspective. *Restoration Ecology* 5:277–90.

PALMER, M.A., R.F. AMBROSE, and N.L. POFF. 1997. Ecological theory and community restoration ecology. *Restoration Ecology* 5:291–300.

SHINNEMAN, D.J., and W.L. BAKER. 1997. Nonequilibrium dynamics between catastrophic disturbances and old-growth forests in ponderosa pine landscapes of the Black Hills. *Conservation Biology* 11:1276–88.

SOCIETY FOR ECOLOGICAL RESTORATION (SER). 1994. Definitions, definitions, definitions. *SER News* 7:5.

STONE, J.E., T.E. KOLB, and W.W. COVINGTON. 1999. Effects of restoration thinning on presettlement *Pinus ponderosa* in northern Arizona. *Restoration Ecology* 7:172–82.

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