Editorial

Avoiding the Old Pitfalls: Opportunities in a New Discipline

Restoration ecology, although a practice with a long history, just now is emerging as a recognized discipline. Making choices will be a critical part of ensuring the best possible future for the discipline. Restoration ecologists can choose the best from established science and practice, and they can reject what is faulty. This means that restoration ecologists have a great opportunity to build the most effective framework for the new discipline. We can point out two pitfalls that ecology continues to fall into from time to time—pitfalls that restoration ecology can avoid from its beginning.

The first pitfall is the assumption that there is one reference state or system that can inform restoration. The untouched biosphere, with its collection of different and diverse ecosystems and communities, unarguably provided the stage and materials for continual evolution, and for flexible and persistent ecological function. But even without the massive intervention of humans, the natural world exhibited a variety of pathways of change and myriad compositions of natural ecosystems. Which of these states should be the reference system for restoration? Assuming that there is only one ecologically legitimate or ideal system for a site is a trap.

The second pitfall is to think of restoration as a discrete event. Because the natural world is an evolving and dynamic collection of systems, restoration should be seen as intervention into an ongoing process rather than as a lasting patch or repair.

An analysis of the most general lessons from modern ecology explains why the two points above are in fact pitfalls and suggests how to avoid them.

Keeping the Ecological in Ecological Restoration

The simplest way to summarize the general lessons of ecology is to refer to the modern paradigm of the science. A paradigm comprises the fundamental assumptions and modes of problem solving that a discipline employs. Ecology now assumes that the systems it studies can (1) be open, (2) be regulated by processes arising outside their boundaries, (3) exhibit multiple equilibria or end points, (4) have multiple and probabilistic successions, (5) be subject to natural disturbances, and (6) incorporate humans and their effects (Pickett et al. 1992). Taken together, these assumptions suggest that the natural world will always be in flux from some perspective. Acceptance of these assumptions, rather than their opposites that governed ecology for decades, was driven by both empirical comparisons with the ecological world and by the conspicuous failure of the old assumptions in management (Botkin 1990).

The new paradigm in ecology can be represented by an informal metaphor of the "flux of nature." Such an admittedly nonscientific phrase has connotations of change, variety, and dynamism, rather than stasis and fixed equilibrium points, which are the unfortunate baggage of the hoary "balance of nature" metaphor. That metaphor, like all metaphors, has no exact scientific content, but it seems more appropriate under the old paradigm of equilibrium as the dominant state in ecology. Since that paradigm no longer holds sway in ecology, its metaphor can be abandoned. Restoration ecologists may find much richness in the new metaphor of the flux of nature.

This new paradigm suggests the kind of information that is necessary to understand or to manage a population, community, or ecosystem. Two general kinds of phenomena capture all the necessary information. First is *process,* which incorporates movement and interaction among organisms, the transformation of energy and material, and the successional trajectories, changes in patchiness, or responses to environmental change that a system exhibits. As a result of such processes, dynamics and flux will characterize natural systems.

The second phenomenon the new paradigm highlights is the *context* of ecological systems. If systems can be open and regulated by processes arising outside of them, then the spatial connections and situation of a system can be critical determinants of its dynamics. Context reminds ecologists that systems are embedded in heterogeneous, changing, and influential landscapes (Forman 1987). Just how those landscapes are put together and where in them exists a system of interest can be key pieces of information for understanding a system.

The process and context focus of modern ecology can be summarized in the concept of *contingency.* Although sound ecological generalizations and predictions arise from regularities in species characteristics, environmental properties, and the interaction of species with one another and with physical environments, the specific dynamics of any one system will be contingent on its history, the accidents of arrival of species at the site, and the nature of the system's connections to the surrounding landscape. In other words, the behavior of an ecological system depends to some degree on its unique past, specific spatial setting, and current influences.

Contingency means that restoration ecologists will have a variety of reference states to choose from. Contingency establishes a whole range of systems, not just one "climax" or predisturbance state. Of course there are many ecological and societal reasons to choose certain reference states, including aesthetics, commodity production, ecosystem services, and species protection, among others. But the point is that restoration ecologists must choose, and nature provides a range of ecologically valid system states. Choices must be made in full awareness of the contingency of ecological systems. If a restorationist chooses a reference state, erroneously assuming that it is unchanging or that if disturbed it will return necessarily and readily to a certain equilibrium, then the dynamics of the system will thwart success. All restoration choices therefore must be made with knowledge of the processes affecting the system. Similarly, if a restorationist chooses a strategy that erroneously assumes that the system is substantially

closed to external influences, then that strategy will likely lead to the failure of the restoration effort when unexpected external forces intrude on the system.

A few examples will illustrate the range of choices available. The contrasting species composition and productivity of prairies, shrublands, and forests can be established by contrasting temporal patterns and intensities of fire. The different impacts of wild and husbanded herbivores can influence system structure and function. Historical or adjacent human land uses can affect ecological systems. Each state of the systems suggested by the gradients above will have different ecological status and characteristics, and different values to society.

The changing impact of humans is an important part of the ongoing contingency of ecological systems. Humans' effects, both direct and indirect, may have suppressed processes needed to sustain a system. Natural disturbances, such as fire and migration of organisms, are often suppressed by humans. On the other hand, humans introduce new processes into systems. Interaction with invasive exotic species and catastrophic disturbance beyond the tolerance of the native species are two clear cases. In many situations, human alteration of processes is ongoing, as where urbanization (including its exurban and indirect effects) is spreading, or where patterns of resource extraction or management are changing (McDonnell & Pickett 1993; Parker 1993). Such changes suggest ongoing involvement in a restoration effort. It may be unwise to effect restoration of a changing landscape and expect the effort to succeed when left to its own devices. All of these insights represent a shopping list of process and context that ecological restoration can exploit to ensure success.

Restoration as a Science

In addition to alerting restorationists to the processes and context that must be accounted for in understanding and managing ecological systems, ecology can make a more general contribution to the nascent discipline. As a science, ecology can offer a methodological template for restoration. Any modern science is essentially an ongoing dialogue between a model of the world and the way the world actually works. Such a dialogue attempts to generate understanding and relies on a complex picture or conceptual model of the world, which is called a theory. Scientists test their model or theory by comparing it to the world through observation, experiment, or mathematical analysis. When the available model of the world is complete and internally consistent, and when it matches the world, then scientists can be said to understand the aspect of the world they are studying. But scientific understanding can change as new information, better tests, or more complete models are generated. So scientists constantly monitor the state of their models and data and are ready to adjust their theories.

Restoration can be considered to be a dialogue as well. But in restoration the goal is to provide a working ecological system. In essence, the system that a restorationist installs is a model or theory of how such a system works, contingent on the locale and relevant ecological

history. Unfortunately, restoration often stops with the installation, before the question posed by the model can be answered by the actual workings of the world. Restoration needs to carry through with the rest of the scientific method and to complete the dialogue by including testing, monitoring, and adjustment of the model. In a sense, restorations are experiments (National Research Council 1986) that test models of how restorationists think the world works. For the full benefit to be derived from restoration, the experimental results need to be analyzed over the long term and the models adjusted.

One remaining aspect of the scientific dialogue is worth incorporating in restoration. Scientific understanding, the match between theory and reality, is of no value if the larger scientific community—and, through it, society as a whole—has no access to it. For this reason, a key requirement in science is that the dialogue be carried on in public. This most often means that scientific work is published. In addition to making the dialogue available for evaluation and use by other scientists, the very act of writing causes scientists to be explicit about saying what their models are, why they consider the tests they perform to be appropriate, and exactly how their tests worked out. As restorationists have increasingly adopted this strategy, progress in ecological restoration has also increased. And so we celebrate this society and this journal, organized for just this purpose of dialogue.

Caveats

As restoration develops as a discipline and applies modern ecological insights, several caveats must be kept in mind. Most disciplines tend to fragment and narrow as they develop. This is dangerous in ecological restoration because systems are so complex, and the variety of processes and diversity of connections to spatial context are so great. Keeping a large vision and interacting with people who are focused on other aspects of ecological systems is a healthy strategy. Constantly referencing restoration projects to the broad networks of processes and their contexts is a way to avoid the pitfall of overspecialization.

The temptation and pressure to re-enter the pit of the old ecological paradigm is great. The old paradigm is closely allied with the nonscientific idea of "the balance of nature." Although the idea has no rigorous scientific content, it can lull people into thinking that old assumptions abandoned by ecology are still universally applicable. Because restoration ecologists must interact with the public and clients who may not know about the deep changes the science of ecology has undergone, they may find themselves subtly or overtly pressured to improperly consider all ecological systems as closed, in equilibrium, self-regulated, deterministic, free of disturbance, and devoid of human effects. Although some systems at some temporal and spatial scales may meet certain of the old assumptions, it is unwise to accept those assumptions without empirical evidence that they hold. The best antidote will be to keep the new ecological paradigm in mind, and to consider using an informal metaphor that invites the broader new assumptions to be taken seriously. The "flux of nature" is such a

metaphor, which can replace the inappropriate connotations of balance.

Putting all this into practice requires looking after the results of restoration projects to assess their relationship to the flux of nature, evaluating their success as models of the way the world works, and catching any changes in context before the project is compromised by untoward outside influences. Altogether, these steps can be the foundation of restoration as a new and healthy discipline.

S. T. A. Pickett
Institute of Ecosystem Studies
Millbrook, New York

V. Thomas Parker
Department of Biology
San Francisco State University
San Francisco, California

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