Science Driven Restoration: A Candle in a Demon Haunted World—Response to Cabin (2007)

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Abstract

Cabin (2007) asks whether formal science is an effective framework and methodology for designing and implementing ecological restoration programs. He argues that beyond certain ancillary benefits, restoration science has little of practical value to offer the practice of restoration. He goes on to suggest that restoration science most often represents an impediment to restoration practice because an "ivory tower" mentality limits the utility of experiments and diverts research dollars away from answering practical questions. His conclusion is that a nonscientific gardening approach may be more effective at restoring degraded ecosystems. We disagree with this perspective because: (1) restoration science has moved beyond exclusively using "square grids" placed on small patches of land to examine treatment effects on species representation; (2) Cabin's critique greatly undervalues the contribution of science to restoration practice even where the input of restoration scientists is not directly evident; and (3) the practice of restoration is unlikely to advance beyond small-scale and truly haphazard successes without well-designed studies that can provide peer-reviewed and widely accessible published information on the mechanisms underlying both successes and failures. We conclude that through integration with other disciplines, restoration science increasingly will provide novel approaches and tools needed to restore ecosystem composition, structure, and function at stand to landscape scales. As with the broader role of science in the human enterprise (Sagan 1996), the contribution of restoration science to restoration practice can only grow as the discipline matures.

Key words: ecological restoration, ecosystem function, forest restoration, Hawaii, landscape restoration, restoration practice, restoration science, tropical dry forest.

The Conflict and the Critique

Restoration science is a young but rapidly evolving discipline that seeks to address some of the world's most pressing and complex ecological problems. Expanding human populations, growing numbers of problematic invasive species, and climate change conspire to make the challenge of restoring species assemblages and ecosystem processes in highly degraded landscapes all the more daunting. Recognizing these facts, the restoration scientist is tasked with asking meaningful questions that in the answering will yield site or condition specific information that is also broadly relevant to restoration practitioners, defined here as those implementing restoration prescriptions.

Based on a narrow working definition of science, Cabin (2007) argues in a recent Restoration Ecology editorial opinion piece (vol. 15, no. 1, pp. 1–7) that beyond ancillary benefits of heightened prestige, increased visibility and some extra funding for ecological restoration, restoration science has little practical to offer restoration practice. He suggests that disciplinary pressures to publish in prestigious journals and funding agency preferences for experiments that are scientifically rigorous and elegant combine to reinforce a disconnection between restoration science and restoration practice. We support Cabin's effort to stimulate debate on whether the discipline is achieving self-stated goals. However, we believe that his critique is flawed because: (1) his view of restoration science is too narrowly defined; (2) he projects unfounded personal doubts about his own restoration science experiences; and (3) he has unrealistically high expectations for how quickly and completely restoration science should be able to inform restoration practice.

A Broader Definition of Restoration Science

Restoration science may be defined as the process through which scientists provide practitioners with the "clear concepts, models, methodologies, and tools" needed to support ecological restoration (SER 2004). Cabin defines this science as consisting of "square grids" placed on small patches of land with the goal of understanding treatment effects on species representation. However, restoration science now

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includes a much wider diversity of tools to meet the growing needs of restoration practitioners who increasingly are concerned with not just species representation but also the end goals of restoring ecosystem structure and function in a landscape context (Hobbs & Norton 1996). This landscape perspective is critical to the real work of restoration (Lamb et al. 2005; Mansourian et al. 2005), yet is conspicuously absent from Cabin's critique of restoration science.

To solidify the scientific underpinnings of this emerging discipline (Hobbs & Norton 1996; Dudley et al. 2005; Morrison et al. 2005) and embrace the complex social and political forces that can shape the restoration process (Davis & Slobodkin 2004; Higgs 2005), the multiscale and multistep process that is ecological restoration has been conceptualized as a process that starts with the identification and stabilization of relatively pristine ecosystems supporting an intact and functioning native assemblage of plant and animal species (Fig. 1). These ecological benchmarks serve to guide scientific understanding of which restoration treatments are needed and at what scale, as well as to provide seed sources and when appropriate to help evaluate restoration success. Following, though not necessarily in sequence, restoration goals and resulting treatments must be explicitly defined and prioritized to meet the constraints of limited funds, time and/or community support, as well as the scale at which restoration can proceed. Scale-appropriate monitoring indices need to be delineated to assess restoration efficacy. When restoration treatments are applied, these indices will be utilized to document success–perhaps best defined as attainment of the nine attributes of restored ecosystems (SER 2004).

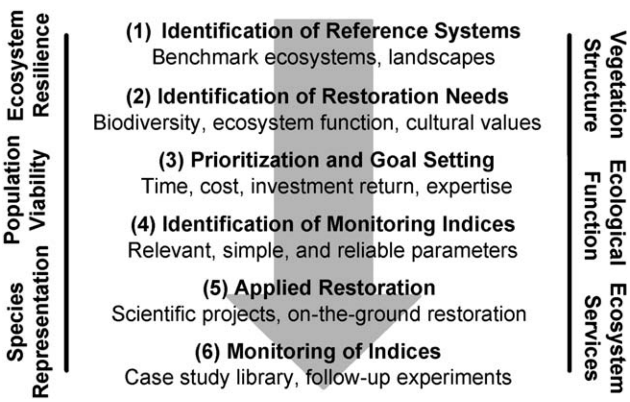

Figure 1. Ecological restoration ideally encompasses a series of steps, though not necessarily followed sequentially, to maximize the likelihood of achieving diverse restoration goals. Developing an ecological basis for achieving these restoration goals requires science-based information. Restoration that focuses on one step or one attribute will be of reduced impact relative to restoration conducted within a broader framework. Restoration practice should address species targets (species and, increasingly, genetic representation, population viability, and resilience of restored populations) and ecosystem targets (vegetation structure, ecological function, and ecosystem services). Structure can include habitat morphology or for forests, tree age classes and canopy layers. Function can include attributes relating to biogeochemistry (nutrient cycling, organic matter processing), physiology (canopy photosynthesis, light interception), or recruitment (avenues of native species regeneration). Finally services most often relate to products of human value: timber and nontimber products, clean water, carbon sequestration, biodiversity and aesthetic or recreational services. The figure is synthesized from information in Hobbs and Norton (1996), Dudley et al. (2005), and Morrison et al. (2005).

From these diverse and foundational efforts, it is clear that the process of ecological restoration will be most effective when it actively engages not only practitioners and stakeholders, but also scientists (along with their credentials) who are needed to help assess, describe, and select: (1) the integrity of ecological benchmarks (step 1); (2) the most pressing ecological problems in need of restoration, whether species or ecosystem-based, after careful assessment of risk from taking no or alternative actions (step 2); (3) the likelihood of success for a prioritized list of restoration goals, often based on preliminary scientific studies on treatment feasibility and efficacy (step 3); (4) identification of indices following careful study that will quickly allow practitioners to accurately assess whether restoration treatments have accomplished stated restoration goals (step 4); (5) the timing and location of treatment implementation (step 5); and (6) quantification of indices in response to treatments to understand if restoration goals have been achieved (step 6). If restoration goals were not met or if new goals emerge, a new process is initiated.

Although restoration science can increase the efficiency with which a prescription is developed, implemented, and results assessed, we do not claim that restoration practice requires the active involvement of scientists. The ultimate goal of any restoration scientist is to develop a rigorous set of prescriptions that the practitioner can use independently to restore degraded systems. To this end, previous restoration, forestry and ecology research has yielded a wide diversity of readily available and adaptable tools for restoration practice, along with important baseline information on native ecosystem composition, structure, and function. However, the practice of restoration often runs into dead ends. An herbicide may permit a new suite of weeds to invade; seed sources or nursery propagation techniques may not be available for certain desired species; new threats may prevent the recruitment of natives; and as a result restored systems may not be sustainable and require continuous interventions. In addition, restoration science is increasingly being challenged to address emerging questions including restoration of genetic diversity (Falk et al. 2006), population viability and the resilience of restored systems (Maschinski 2006), ecophysiological constraints on restoration success (Ehleringer & Sandquist 2006), and restoration at landscape scales (Lamb et al. 2005; Mansourian et al. 2005) to name but a few (Palmer et al. 2006). It is in new problem areas such as these that restoration science will continue making the greatest contributions to restoration practice.

Restoration Science Informs the Practice of Restoration

The lament of Ehrenfeld (2000) regarding the drifting of conservation biology away from real species conservation is informative and important, but Cabin's attempt to link these trends to restoration science is tenuous and selective. First, a simple review of the 15 research articles published in the same Restoration Ecology issue as Cabin (2007) reveals a strong focus on highly applied research by teams of scientists committed to finding cost-effective means of restoring native species and ecosystem function to degraded sites. These are not "ivory tower" studies, but science-based efforts that address locally relevant needs and provide useful information to restoration practitioners. Second, although Ehrenfeld does make a strong argument that the research of conservation biologists often does not directly result in the conservation of plant or animal species, he does not recommend that conservation be practiced without the input of scientists. In fact, his main point is that the science of conservation biology needs to improve at "regularly monitoring the effectiveness of its research and recommendations" by "understanding the place of its work in the life of the community." He makes the compelling case that science is not the problem, but rather science in a vacuum cannot overcome barriers to conservation due to overriding social and political forces. This message is clearly important to restoration science—without collective input from practitioners, stakeholders, and scientists, our restoration efforts risk failing to achieve the discipline's underlying mission.

Restoration science, as with any young applied discipline that borrows expertise from more established academic disciplines, will struggle with maintaining a balance between academic rigor and applied practicality. A fundamental feature of this dynamic is balancing academic and funding agency pressures to conduct and publish high quality science while providing meaningful restoration prescriptions. However, applied scientists are not and should not be forced to choose between that which is rigorous and compelling and that which leads to a practical outcome. In this spirit, restoration scientists must and often do conduct research that provides locally meaningful yet scientifically rigorous prescriptions. Yes, funding agencies need to be educated, old disciplines need to be informed, and professional societies need to be encouraged, but great progress is being made and not at the glacial pace suggested by Cabin. The Ecological Society of America now regularly cohosts an annual meeting with the Society for Ecological Restoration. In addition, academic departments are hiring restoration ecologists and charging them with developing research programs and curricula dedicated to ecological restoration. Finally, funding agencies increasingly recognize the need for practical restoration research.

At the other extreme, restoration scientists are often confronted with questions of such complexity and scope that the required experiments are not easily designed, let alone funded. When funding is secured, answers for practitioners are slow to appear. Frustration is inevitable when loss of native species results from a lack of information or worse, the uncertainty of limited information. It is this facet of restoration science that appears to be most problematic for Cabin—it should not take a decade let alone a career of experiments to develop a comprehensive understanding of a complex problem when the solution is needed immediately. Would dollars perhaps be better spent on gardening approaches managed through stewardship programs? On the surface, this question is compelling, but only when restoration science is demonized for being conducted on small scales and over short periods. The limitations identified by Cabin are not the inevitable outcome of the science, but rather relate to the scale and complexity of the problem.

In attacking the problem, practitioners and researchers play distinct roles in the restoration process, but Cabin's critique reveals a fundamental misunderstanding of these roles. For the researcher, achievement is often equated with publications, but in applied fields, achievement also includes the impact of a scientist's work on practitioners. Within the USDA Forest Service, where Cabin worked when conducting much of his restoration research in Hawaii, the latter carries significantly more weight than the former, though the two are inextricably linked because the medium of expression is the publication. Also, treatments that fail to achieve a desired outcome can be a component of effective restoration research by documenting the viability of options available to a practitioner. For practitioners, the currency is different, usually land area effectively treated, and failure is not an acceptable outcome.

Given the differences between science and practice, there inevitably will be conflicts, especially for researchers who yearn to be practitioners. However, the real contributions of a research program to the practice of restoration may take decades or more to fully assess. Therefore, although funding agencies charged with deciphering relevant from otherwise sound but less relevant research will offer insights, the decision to conduct research or to practice (or both) is fundamentally a personal one. If more mature applied disciplines can provide any useful clues it is that the science and practice of restoration requires passionate and talented individuals across this spectrum—ideally working together to inform and guide rigorous research that addresses pressing questions of both local and global importance. So our greatest task is to direct limited resources (but growing interest) toward compelling science that meets the greatest practical good. It is within this matrix of often-committed stakeholders and demanding practitioners that public debate can help restoration science to focus on the most relevant questions.

Not Seeing the Forest for the Trees

Restoration of high elevation moist forests in Hawaii has been the focus of decades of diverse and successful research (Scowcroft 1981, 1983; Scowcroft & Sakai 1983, 1984; Scowcroft & Hobdy 1987; Scowcroft & Conrad 1988; Scowcroft & Jeffrey 1999; Scowcroft et al. 2000, 2007), but Cabin's work at Kaupulehu in Hawaii's understudied dry forest broke new ground. His first "square grid" efforts were applied to a complex problem plaguing an extremely complex system, and some disillusionment was to be expected. That several years of work did not answer the overarching question of how to restore this ecologically and culturally important component of the Hawaiian landscape, also was to be expected. However, in this regard, Cabin sells his work short. Much of Cabin's Kaupulehu research has since provided critical baseline information widely adopted by land managers and restoration practitioners on the impacts of exotic ungulates (Cabin et al. 2000), the control of invasive plant species (Cordell et al. 2002), and the propagation of native species in highly degraded habitats (Cabin et al. 2002*a*, 2002*b*). Notably, one reason why this information is so widely adopted is because it is scientifically rigorous and available in peer-reviewed outlets.

Viewed in a landscape context, Cabin's research in Hawaii primarily addresses steps 1–3 of the restoration process (Fig. 1), and occupies the smallest scale in a spatial hierarchy of restoration science (Fig. 2). Stand-level research spanning passive to active treatments (fencing to herbicide control of invading plants to enrichment planting) is the logical starting point for understanding how an ecosystem type can be restored. Cabin should be surprised not by how little was derived from the studies he led at a single site during a pair of funding cycles, but rather how

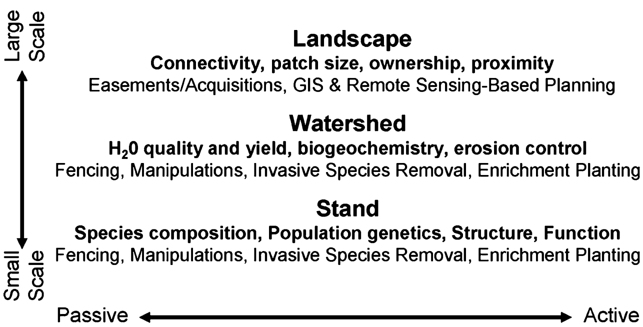

Figure 2. Ecological restoration can be implemented at scales from stands to watersheds and landscapes, and from passive approaches such as fencing to active approaches such as enrichment planting. Most restoration activities start at small scales with, for example, a focus on species representation through passive approaches like fencing to exclude ungulates. When not efficient to achieve restoration goals by themselves, passive approaches can be supplemented by active approaches including control of invasive plants, species enrichment through planting, and even stand establishment. As with the passive to active gradient, restoration efforts can also address multiple spatial scales, from stands to watersheds to entire landscapes. These efforts will necessarily rely on available techniques appropriate for that scale and that span passive to active management. The figure is synthesized from information in Vallauri et al. (2005).

quickly restoration science in Hawaii is evolving the capacity to develop science-based prescriptions to address landscape-scale problems. His original research should not be dismissed as being of minor significance, but rather viewed as an integral piece of a more complex approach that in Hawaii now extends beyond species-level considerations at the stand scale to include tools from ecophysiology, ecosystem ecology, landscape ecology, and remote sensing (Elmore et al. 2005; Elmore & Asner 2006; Litton et al. 2006). These studies, as well as soon to be published findings, are showing that many of the tools developed at Kaupulehu can be broadly applied not only in dry systems but in more mesic systems as well.

Intelligent Tinkering on the Shoulders of Giants

Although appealing in its simplicity, the garden metaphor is far more complicated than presented by Cabin. In cultivating his garden, Cabin can leave his research credentials at the gate, right next to the agroecologists, exactly because countless millions of research hours have been dedicated to maximizing productivity and yield through improved plant genetics, matching cultivars to temperature and water regimes, pest control, and nutrition management, to name just a few. When new problems appear, science-based solutions can be found in garden shops, with local extension agents and increasingly on the web. To casually dismiss the tremendous contributions of science to agriculture is dangerous. The societal costs of a few less tomatoes in a hobby garden are minimal, but in subsistence economies or on the large scales of corn yields in the United States, the costs of making small errors are enormous. For this reason, science is absolutely the foundation on which day-to-day agricultural decisions are made. Similarly, where restoration leads to the conservation of endangered species or is conducted across ownerships governed through agency mandates or diverse stakeholders, science-based information is often the one resource that can be used to effectively direct restoration activities. In the case of controversial restoration actions (excluding ungulates, reintroducing wildlife species, prescribed burning), stakeholders demand that management decisions are based on rigorous science.

As with Cabin's garden metaphor, the proposed "adopt-an-acre" program is far more complicated than presented. Without scientific information on why one "adoption" fails and another succeeds, an "adopt-an-acre" approach would be unproductive in Hawaiian dry forest systems. This is not speculation. Hawaii landowners often begin federal and state stewardship projects with clearly defined goals for creating mini wilderness areas through planting of diverse native species. Very quickly, these stewardship ecologists realize that very little is known about appropriate seed sources, growth rates, disease and pest issues, nutrition management, and weed control, among many problem areas. What little information that can be applied in these situations is often borrowed from research conducted on exotic commercial species and, ironically, the few dry forest prescriptions derived from Cabin's original research at Kaupulehu. As a result, the success of private stewardship-based restoration projects focused on native dry forest species has been limited. Even for wetter sites that are more amenable to forest growth, landowners are left to plant exotic species because their management has a predictable outcome.

A Commitment to Scientific Knowledge

A mix of superstition and trial-and-error tinkering guided our first 10,000 years of medical practice, whereas a largely science research approach has been guiding our last 100 years. The medical breakthroughs of the past 100 years, especially when linked to science-based traditional knowledge, have been tremendous compared to the previous 10,000 years. If medical research had not been pursued and published in peer-reviewed journals and books, we still would be treating illnesses with well-intentioned, but often erroneous and sometimes superstitious practices. Yes, the application of medical science to medical practice has its shortcomings; preventative approaches often are underutilized and antibiotics overprescribed. However, vilifying medical science and preaching a return to leeches and talismans would be viewed at best as foolish.

Restoration science also will be challenged to stay relevant and on occasion will stumble. As with medical research, the outcome of the scientific process in ecological restoration is uncertain, necessarily so, as we can only guess what the outcome of an experiment will be without actually performing the study. These experiments will take time. Restoration scientists also need to obtain highly competitive funding to act on good sometimes even great ideas, and sometimes may stray to ask questions that are more compelling than practical. Although some luck is involved in conducting research once funded, its small role is rarely blind. Taken together, these imperfections do not justify abandoning the pursuit of scientific knowledge. Rather, they should motivate us to better apply that science-based recipe that has been at the base of human progress (Sagan 1996).

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