PERSPECTIVE

Spanning the Science-Practice Divide: Why Restoration Scientists Need to be More Involved with Practice

Sara Jo M. Dickens and Katharine N. Suding

Restoration ecology is at a critical juncture. As environmental management policy increasingly embraces restoration, the field of restoration ecology must span the science-practice divide, or risk becoming obsolete. Parties on both sides of the divide agree that science needs to be incorporated into restoration practice and that current approaches are "simply not sufficient" (Hobbs 2007, Weiher 2007, Palmer 2009). There is a resounding call for reforms that better address current limitations facing ecological restoration and a higher priority placed on the scientific understanding of ecosystem restoration. The "science-practice gap" is frequently cited as a major factor limiting both the science and practice of restoration, and there are few individuals or institutions working directly to change this dynamic (Giardina et al. 2007, Weiher 2007, Palmer 2009, Cabin et al. 2010). This gap persists despite agreement about the need for rigorous, publication-quality studies to identify relevant restoration methods (Giardina 2007).

Restoration ecology has faced critiques from both sides of the science-practice divide. Science argues that restoration ecology is largely ad-hoc, site specific, and lacking a conceptual framework (Hobbs and Norton 1996, Allen et al. 1997). Practitioners question how much science is necessary for the successful practice of restoration and are frequently frustrated that research is not applied at appropriate scales for practitioner application (Cabin 2007, Halle 2007). These critiques present very different perspectives of how restoration ecology should proceed: the former calling for broader across-site theory and research and the latter emphasizing site-specific practicality over scientific goals. Together, these perspectives have slowed the development of a third perspective: application of restoration ecology research to inform practice and the utility of practice to inform the science.

It is at this science-practice boundary that research can best evaluate whether the science of restoration ecology effectively informs successful management efforts and determine how to increase the efficiency of information transfer. We begin with a broad overview of critiques from both sides of the science-practice debate. We then detail lessons we have learned from a project where we (as restoration scientists) worked alongside practitioners in an attempt to better inform restoration practice. We conclude with ways that a boundary-spanning approach might be most effective in addressing this divide.

From the Science Side

Basic ecological research that includes speculations on implications for restoration is largely responsible for the increase in restoration-related research in the last decade. For instance, 64 review papers focused on restoration in 2009 and 2010 (ISI Web of Science, keyword "restoration," subject area "ecology" and document type "review"). Many focused on extending basic conceptual frameworks to restoration or elaborating on conceptual advances, but rely on future research to translate these ideas into practice (e.g., Suding and Hobbs 2009, Hoeksema et al. 2010, Kardol and Wardle 2010). Works such as these are largely responsible for the growing link between ecology theory and restoration ecology, but are several steps removed from directly informing ecosystem restoration. Others advocated particular approaches and guiding principles related to restoration (Hobbs et al. 2009, Chazdon et al. 2011), less than a quarter directly reviewed restoration techniques and outcomes to provide recommendations for successful restoration practice (Rodrigues et al. 2009, Matthews et al. 2009). Very few in this last group were quantitative and even fewer took a multi-site or multi-system approach.

There are also many logistical issues associated with research in restored systems: the large scale at which restoration occurs, replication of treatments is limited, reference sites and controls to compare treatments against are often lacking, and funding for projects is hard to come by (Allen et al. 1997). Trends in funding and publication of applied science suggest an opinion that such applied work is of lower value, which can discourage driven researchers (Gibbons et al. 2008, Arlettaz et al. 2010). A fundamental

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change in how this type of research is valued by publishing and funding communities is necessary to make collaborations between science and practitioners more accessible.

There will always be a need for basic research stimulated by the fundamental desire to understand the details of ecosystem recovery that is not immediately relevant to practitioners. However, if the bulk of restoration ecology research remains primarily theoretical and fundamental, then the field will have little impact on restoration policies or management practices. Researchers often complain that policy-makers and practitioners make poorly-informed decisions because they ignore, under-utilize, or misrepresent research findings (Gibbons et al. 2008). This is an indication that research findings are hard to apply to management practices. The collaborative scientist-practitioner model would discourage practices that have no scientific basis and research that has no clear implications for practice.

Past efforts to compile monitoring data have often resulted in frustration over the lack of data collected by practitioners (Palmer et al. 2007). Researchers often have more success collecting standardized response data themselves or in partnership with the practitioners (Matthews et al. 2009), although this approach necessarily limits the scope of the evaluation and often requires a funding source beyond that for the restoration project itself. Researchers have been able to utilize compliance-related monitoring data, collected to document legal compliance to regulatory policy or as a stipulation of funding; however, regulatory criteria used to assess project success is often not based on ecological criteria (Matthews and Endress 2008, O'Donnell and Galat 2008). Expert knowledge is a valuable resource which can be better capitalized on by the scientific community to augment systematic assessments (Rowe 2010, Orsi et al. 2011). Additional requirements of public reporting with the necessary confidential safeguards, rather than paper reports relegated to "gray literature", would increase access to researchers as well as other practitioners (Kentula 2000, Reiss et al. 2009). Use of such data could aid in developing the theoretical constructs necessary to predict likelihood of success (Allen et al. 1997).

From the Practice Side

Policy-makers and practitioners often complain that researchers do not understand their needs or fully grasp how economic limitations and stakeholder opinion impact restoration (Halle 2007). For many practitioners, research is thought to focus on issues not applicable to them or having limited consideration of social, political, and logistic constraints (Arlettaz et al. 2010). For instance, respondents in the Cabin et al. (2010) survey viewed the gap as largely a problem of inadequate science or scientific communication rather than practice or policy limitations.

Some critics of the utility of restoration science describe the practice of restoration as more art than science (Cabin 2007, Halle 2007). The essence of this critique is a need for the recognition of practical knowledge formed on the site and with its stakeholders. It is also reflected in practitioners' desire to prioritize one-on-one interactions between scientists and practitioners to effectively share local knowledge. Partnerships with practitioners and scientists are critical (Gonzalo-Turpin et al. 2008), and require that scientists participate in on-the-ground restoration projects and decision-making (Arlettaz et al. 2010). Successful ecological restoration projects are characterized by community involvement, transfer of knowledge among scientists, practitioners, community members, and administrative organizations in the decision-making process (Tischew and Kirmer 2007, Bernhardt et al. 2007).

A general lack of assessment and knowledge transfer concerning completed projects hinders restoration science (Allen et al. 1997, Hassett et al. 2007, Katz et al. 2007, Kondolf et al. 2007, Palmer et al. 2007, Tischew et al. 2010, but see Neumann 2007 as an exception). Projects will move forward without the advantage of past knowledge of what has previously worked, what has not, and how these outcomes have varied across projects. A small investment in documenting the factors contributing to restoration outcomes will lead to large returns in planning for future projects and enhance the ability to compete for funding.

Lessons Learned from the NROC Project

We have been involved with a collaborative project to determine restoration outcomes across the 14,974 ha (37,000 acre) Nature Reserve of Orange County (NROC), in Irvine, CA USA. NROC is managed by eight land owners and agencies consisting of both public (California State Parks, City of Irvine, City of Newport Beach, Orange County Parks and Transportation Corridor Association) and private (The Irvine Company). Their effort to preserve the lands of NROC is mandated by the Natural Community Conservation and Habitat Conservation Plans (NCCP-HCP) (Meade R.J. Consulting, Inc. 1996). While the land practitioners of NROC have conducted numerous restorations and long-term weed control programs, data tracking the progress of these efforts were difficult to obtain. Files recording previous restorations were either absent, stored as a hard copy in a filing cabinet, or not recorded at all (Figure 1). A larger proportion of management methodology was obtained from conversation with senior practitioners and agency representatives: valuable data that will be lost once they move on. Similar to the experience of Hassett and others (2007), limited recorded data meant interviews were crucial to establishing a database that could be used to assess success.

The practitioners and agency representatives stakeholders associated with NROC voiced a strong desire to increase

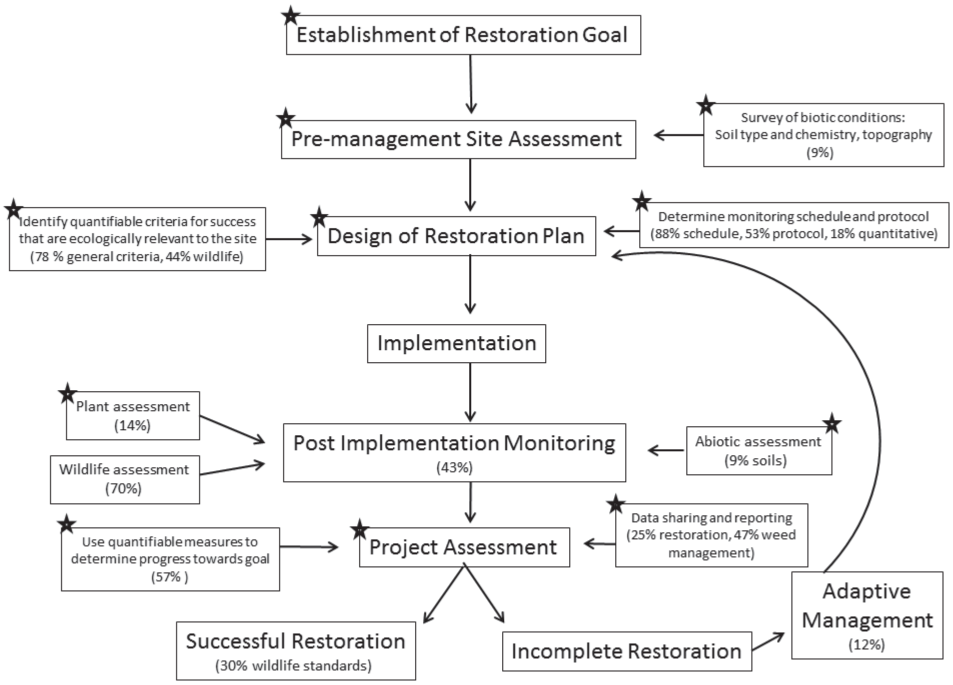

Figure 1. The process of restoration implementation is limited at many critical steps by information needs, time, and resources. For restoration steps that data was available from NROC participants, the percentage of sites that carried out individual steps within the pathway or included quantitative planning and analysis is located within the associated box. Stars indicate steps specifically identified by NROC practitioners as areas where there is a need for better information and tools and where scientific research could assist.

information collection and data sharing. In conversations with practitioners, it became clear that they lack tools and resources necessary to assess progress of restorations. An early attempt to communicate with practitioners included an online survey developed through discussion with local agency representatives and experienced practitioners. We received almost no participation in filling out the survey which likely indicated a lack of incentive for land practitioners already under an overburdened work load. It may also reflect a common concern that time invested in research surveys will result in studies that do not address their needs. We subsequently conducted our own field surveys and interviewed practitioners to obtain management history data.

Personal relationships between researchers and practitioners were key to successfully identifying research needs. Publication of research findings alone does not suffice to transfer important findings to practitioners (Gibbons et al. 2008). In working one-on-one with practitioners, we were able to establish trust and gain participation and recognition of needs. The interviews also gave us a more realistic understanding of current restoration limitations.

Group learning and sharing opportunities such as workshops and field days can facilitate relationships that drive cooperative decision making and effective management planning (Gibbons et al. 2008). NROC utilizes meetings, workshops and site visits to maintain collaboration among practitioners and their agencies. The existing NROC management coalition made orchestrating these meetings easier as we would not need to identify stakeholders for an initial meeting. This was a unique and extremely fortuitous situation for us, as researchers, into which to enter. Our stakeholders came from management, policy, regulation, and science, providing a variety of viewpoints, backgrounds, and skills creating what Gonzola-Turpin et al. (2008) called "hybrid knowledge." Every stakeholder had the opportunity to contribute their experience and expertise to create hybrid knowledge more suitable to address the complexity of restoration ecology.

Given a recognized strong need for assessment, data sharing and informative reporting, why do assessments and data sharing not occur more often? In our experience, we can identify five key factors: 1) unclear or unshared goals; 2) uncertainty over what and how to monitor; 3) a lack of time and resources; 4) lack of incentive for data sharing and fear of failure; and 5) little to no room for adaptive or experimental management within the current funding system.

Unclear or Unshared Goals

Restoration goals provide the expectations and roadmap for detailed management plans along with quantifiable criteria for success (Ehrenfeld 2000). Restoration can be assessed using multiple methods and perspectives: society/public approval, ecological, functional/ecosystem services (Arletazz et al. 2010). Many goals and criteria for success are possible and valid (Palmer et al. 2005), but project assessment is often hindered by a lack of criteria for successful goal achievement (Hobbs and Norton 1996). The practitioners of NROC share a common goal under the NCCP-HCP which provides very general management guidance. Restoration goals tended to be qualitative in that they aim for enhancement of either a vegetation type or the specific habitat of a key wildlife species. Quantifiable success criteria were mainly limited to mitigations, which represent less than 20% of restoration projects occurring in NROC. For projects without measurable criteria, it will be difficult to direct restoration actions with no clear goal trajectory or means of assessing progress along the trajectory we defined (Palmer 2005).

Monitoring Uncertainty and Limited Information

What to measure using which assessment methods are valid questions that have been asked by both practitioners and researchers for decades (Hobbs et al. 2009). Within NROC, practitioners and agency representatives have differing opinions on what is important to measure based on manager knowledge of the discrepancy between the resources needed to conduct assessments and the resources available to them. Further, only some practitioners have strong opinions of which methods are best. Others do not have a background in restoration but possess training and experience in other aspects of land management. They may lack the skills necessary to conduct assessments. This knowledge gap contributes to the issues that have resulted in low monitoring rates across the reserve (Figure 1, Table 1). Identifying a standard in NROC would be difficult because each managing group has their own methods and apply them for differing reasons. However, there is support throughout the group to establish three to five standard measurements, such as target exotic species cover, percent bare ground, exotic versus native plant richness/percent cover, and sensitive wildlife species use/presence, to be conducted over time at all sites in order to enhance reserve-wide analysis. This new approach for data tracking in NROC is supported by the findings of Baasch and others (2010) suggesting that less intensive studies can be very effective if done over a long time period.

Lack of Time and Resources

Of all the factors limiting restoration, a lack of time and resources ultimately rises to the top of the list and NROC is no exception. Monitoring and assessments are chronically under budgeted items in restoration planning and therefore go unimplemented (DellaSala et al. 2003, Baasch et al. 2010). Budgets are already too thin to hire the personnel necessary to conduct management, monitoring, and produce assessment reports. For some agencies, restoration is only possible because they are fortunate enough to have committed volunteers. It is not uncommon for NROC practitioners to have annual reports required by some agencies and quarterly reports to another. With the great number of reports, time spent in the office can begin to inhibit field efforts. Tools that could reduce reporting time to enable more regular reporting of restoration data are critical. To address this issue, we worked with practitioners to develop a web-tool that will allow for a direct link between data entry and report generation. The format of the tool and the report it will generate are a product of many workshops and input of practitioners, agency representatives and local restoration specialists. Practitioner participation increased the likelihood that the end product of the study will be used as a regular management tool because practitioner and agency representative input ensured the product would provide a solution to the urgent and shared need for access to information, reserve wide data collection/storage, and easy report generation.

Table 1. The number of sites in which each level of assessment quality occurred in the 116 sites surveyed across NROC. Assessment numbers includes both pre- and post-management monitoring. Post-management monitoring was 43% overall.

Assessment quality	# of sites	% of sites
None	25	22
Qualitative data	64	55
Quantitative data	21	18
Unspecified	6	5

Current reporting requirements focus on descriptions of the work conducted and resources used to conduct management. Items such as the area treated for weeds or experiencing restoration and the name and rates of herbicide use dominate reports. While this information is useful and necessary in assessing the effectiveness of weed control and efficient use of funding, it has limited contribution to assessment of progress towards ecosystem restoration goals. Progress would be better represented through reporting of the percent attainment of measureable success criteria or even better, the submission of summary data from quantitative monitoring efforts.

An additional concern of practitioners was the expectation that they are skilled in all fields associated with the restoration process. Practitioners may not be skilled in data management and analysis but in land management from public affairs, to legal requirements, and general ecological field maintenance. To assume that they also are statisticians is unrealistic and unfair. NROC is fortunate in that it does have members of the reserve who are skilled in data analysis; however these individuals are not distributed throughout all managing agencies and juggle a great number of duties beyond data analysis. The intuitive management planning of more experienced NROC practitioners shows a clear sense of the function and processes within their systems and lands. Their recommendations frequently correlate with scientific results, but they may lack the ability to identify the mechanisms at play, limiting application across the reserve.

Lack of Incentive and Fears Associated with Failure

As with any endeavor, there are inherent risks associated with restoration (Wyant et al. 1995, DellaSala et al. 2003) and in NROC this is coupled with a lack of incentives for data sharing (Zedler 2007). Practitioners struggle to meet the challenges of preserving and enhancing their lands with meeting expectations of the general public and funding agencies. Currently there is no mandated data sharing tied to funding of restoration projects. Voluntary data sharing labels the task a secondary priority to urgent field tasks faced by practitioners on a daily basis.

There is also a risk to the practitioner and associated agency reputations with a "failed" project. NROC practitioners readily shared successful project data, but were apprehensive about volunteering information on projects they considered failures even though the group as a whole recognized the value of failed projects in guiding future planning. Failure is a natural component of long-term land management and identification of potentials for failure during the restoration planning phase may reduce concerns over risks to reputations and ability to obtain future funding (Wyant et al. 1995, DellaSalla et al. 2003). In NROC, lands are managed over a long time scale. Knowledge gained from a "failure" at one site may lead to greater success across the reserve. Through both successful and failed experiments, it is clear that the current approach to restoration ecology needs to be modified through the use of collaborations (Arlettaz et al. 2010).

No Room for Adaptive or Experimental Management

Unfortunately, the current funding atmosphere does not provide for such a view of failure nor does it support the incorporation of adaptive management. Many funding opportunities for land management in NROC span one to two years. Two years is too short a time to apply an experimental or adaptive management technique and still leave time to change methods if recovery is not occurring before funding deadlines. Trying to stay ahead of plant invasion, for example, often forces practitioners of NROC to stay with methods that they know rather than incorporate experimental approaches to test the efficacy of one method over another. Restoration requires long-term management, awareness of fluctuations and openness to alternative states and flexible management (Halle 2007). The interaction of science and practice to increase research relevance and restoration success takes time but is in progress (Giardina et al. 2007).

Restorations need to account for the process; not only should there be an ultimate goal with clear success criteria, but interim milestones towards an eventual goal. Interim goals act to assess progress and identify when a system is stuck and requires adaptive management that may be outside the original scope of the restoration plan (Palmer 2005). In NROC, interim goals are largely limited to mitigation projects. The pressure to produce visually recognizable improvements is high and expected to occur in a very short period of time. Adaptive management methods have been applied on NROC lands but limited to 20% of sites surveyed and lacked quantifiable measures of success (Figure 1). Practitioners identified the need for research focused on restoration methodology and adaptive management strategies in restoration practice. They additionally voiced support of funding research projects with NROC funds to address method based questions. Changes in policy are necessary to facilitate changes on the ground and increase researcher participation (Palmer 2005, Arlettaz et al. 2010).

Final Lessons from NROC

Now more than ever there is a need to increase collaboration between science and practice. Over the past decade, a movement towards bridging the well-recognized gap has gained momentum. Lessons learned from successful and unsuccessful projects have taught us that progress is possible given open participation and recognition of ideas, needs, and constraints. The next steps are to determine how science can best aid practice by listening to the needs of practitioners.

Gonzola-Turpen and others (2008) determined that their collaborative effort would have been more relevant to restoration if they used a more flexible communication approach involving workshops and open discussion between all stakeholders. The NROC project involved all stakeholders for the majority of the decision making process, especially in determining management needs and potential solutions. This joint approach allowed for full description of problems, limitations, and needs within management and policy. The involvement of all stakeholders was key to developing a plan of action that was relevant to all participants. As restoration ecologists, our ability and willingness to do much of the initial leg work of collecting and analyzing data under this group plan created a unique opportunity to form trusting one-on-one relationships with stakeholders and obtain not only data but the honest opinions of all. While time and labor intensive initially, the interview process was essential to stakeholder support. Feeling validated and heard, valued for the unique knowledge they brought to the table, and inclusion throughout the project was important. However, our partnership was a bit unique as a federal research agency (USDA) funded our efforts and allowed us to do the data collection—this cannot and should not be the only funding mechanism that allows scientists to partner with practitioners.

Conclusions

We found that important steps in the restoration process were missing or rarely addressed with NROC as a result of legitimate information and resource limitations (Figure 1). Identifying solutions to these limitations will require collaborative research between researchers and practitioners along with substantial changes to the current management infrastructure as it pertains to restoration funding, planning and implementation. Collaborations increase the authenticity and rigor of fundamental research and validate the effectiveness of recommended restoration guidelines (Arlettaz et al. 2010). In addition, collaborations allow unparalleled chances of experimentation at the appropriate spatial scale, including cost and methodological constraints as well as landscape-level ecological processes. Agencies funding restoration could recommend or reward the participation of a scientist, particularly in the monitoring and assessment stages. A productive approach to restoration will require substantial changes in the roles of science and other stakeholders so that all parties have equal power (Cabin et al. 2007, Gibbons et al. 2008, Gonzola-Turpin et al. 2008).

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