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PRACTITIONER'S PERSPECTIVE

Determining appropriate goals for restoration of imperilled communities and species

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Summary

1. Conservation and restoration practitioners often struggle to define appropriate targets for restoration. Frequently, 'pre-settlement conditions' (the conditions that are believed to have existed prior to European settlement) are used. In this review, we draw on our experiences working with land-managers to restore native ecosystems in the Pacific Northwest (USA) to discuss some of the challenges in using pre-settlement conditions as a restoration target.

2. We have found that information on the structure and composition of pre-settlement communities does not exist in sufficient detail to set quantitative restoration targets.

3. The systems we work in have been so altered from the historic condition (as we best understand it), that mimicking the anthropogenic and 'natural' disturbances that shaped these communities is both difficult and unlikely to guarantee success.

4. Furthermore, the pre-settlement condition may not be an appropriate restoration goal given ongoing global changes, including species invasions, habitat loss, and climate change.

5. *Synthesis and applications*. We suggest that rather than focusing on historic benchmarks, restoration goals should be based on ecological principles that will lead to resilient, functioning ecosystems. We provide real-world examples for how scientists and managers can work together to define and test appropriate and effective restoration methods and targets.

Key-words: global change, historic conditions, historic disturbances, pre-settlement, restoration, restoration goals, targets

Introduction

Our natural landscapes face challenges that require innovative solutions. Habitat loss, invasive species, climate change and other factors put much of our biological heritage at risk. One recurring problem that permeates most conservation and restoration efforts is defining appropriate goals and restoration targets (Hobbs 2007). Many restoration plans, including those developed by private and governmental organizations, state that a primary goal of restoration is to replicate historic plant communities and disturbances (Harris *et al.* 2006, and references therein). Other plans state the goals more ambiguously as increasing the abundance of native species and habitats. Although this goal does not define historic conditions as the benchmark, re-establishing historic disturbances and habitats is seen as necessary to preserve native species. Unfortunately, we rarely have a clear picture of the particular historic condition that is our target. In lieu of detailed historical records (e.g. Chambers, Mauquoy & Todd 1999; Hanley *et al.* 2008), remnant populations and communities are used as a proxy for describing the historic condition, despite recognition that these systems and species are dynamic and were likely to be quite different prior to recent human activities. There is often great reluctance to deviate from these known conditions for fear of making matters worse.

Under such circumstances, we question the appropriateness of the historic condition as a restoration target, even if we could accurately quantify it, given pressures such as continued invasions of exotic species, disruption of natural processes and the anticipated impacts from projected climate change (Harris *et al.* 2006). We find these two problems – how to describe accurately the historic condition, and its relevance in the face of global change – are at the heart of many difficult decisions in both large-scale restoration of whole plant communities and

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fine-scale recovery activities for rare species. Here, we discuss some of the challenges that we have faced as practitioners when defining conservation and restoration goals, how we have co-operated with managers to conduct research to inform these issues, and we suggest directions for future work. We illustrate our points using examples from our experience as researchers at the Institute for Applied Ecology (http://appliedeco.org/), a non-profit organization with the mission to conserve native species and habitats through restoration, research and education. We work closely with land managers on conservation and restoration projects throughout Oregon and Washington States, USA, in a variety of habitats, with activities ranging from large-scale restoration to detailed population ecology of rare plants.

Historical conditions as restoration targets

Many of our conservation and research projects are focused on restoring lowland prairies and oak savannas in the Willamette Valley/Puget Trough/Georgia Basin Ecoregion and the rare species that live in these habitats. This ecoregion extends from west-central Oregon to south-western British Columbia in the Pacific Northwest of North America. Less than 2% of the historic prairie and oak savanna habitat remains, and the majority of these remnants are small and fragmented. The quality of these prairies has been degraded by over 150 years of fire suppression, subsequent encroachment by woody species and invasion of non-native plants (Floberg *et al.* 2004). The common goal for restoration of these habitats is that we should restore natural processes and communities such as they existed prior to European settlement (approximately the early 1800s). The pre-settlement goal is also very commonly used in other ecoregions throughout North America. While a number of sources for pre-settlement descriptions of our ecoregion are available, such as historic diaries, artwork and surveyors notes, these sources generally only provide information on the general appearance of the landscape. For example, the frontiersman, hunter and trapper, James Clyman, noted in his diary in 1845, 'prairie all luxuriantly clothed in a rich and heavy coat of vegetation, the upland in yellow and the valleys in purple. The quantity of small flowering vegettiles is very remarkable and beyond conception' (Hasselstrom 1984). Other explorers noted the prairie plants that formed the bulk of the diet of Native Americans, and records of the Hudson's Bay Company documented prairie fires almost every year in western Washington. However, detailed information on historical plant composition and abundance is mostly lacking. The famed botanist David Douglas may have collected detailed information on the flora of the prairies in the region in the mid-1800s, but sadly his journals and specimens were lost in a canoeing accident. Other early botanical surveys have incomplete records (e.g. no location information) or took place after the turn of the century, after major changes had already occurred to the landscape (Dunwiddie *et al.* 2006).

In the absence of detailed information to reconstruct historic conditions, managers often look to existing prairie remnants in order to set restoration targets and management guidelines, such as which species are suitable for particular sites and the habitat associations of those species. It is highly unlikely that most remnants mimic pre-settlement conditions, given weed invasion, suppression of historic disturbances (e.g. fire) and a probable history of grazing. For example, based on observations that native annual species are very rare in most prairie remnants, seed mixes emphasize perennial forbs and grasses. However, our best records indicate that Native Americans maintained open prairies though the use of fire (Dunwiddie *et al.* 2006). Based on life-history strategies, we would expect there to be a higher abundance of annual species with more frequent disturbance, such as occurred prior to settlement. Indeed, although detailed pre-settlement records are lacking, limited data indicate that native annuals were more abundant in our region in the early to mid-1900s. Furthermore, native annuals are more common (*c.* 30% of the species) in prairie remnants that experience regular fire in the Artillery Impact Area of the Joint Base Lewis–McChord in western Washington state.

To illustrate these issues, we provide brief details of our own experience in this regard as a case study. To develop management strategies for degraded remnant prairies, we tested combinations of burning, herbicide, mowing and over seeding with native species in experimental plots at multiple sites throughout our ecoregion (Stanley, Kaye & Dunwiddie, in press). A component of this study, seeding with natives, was surprisingly controversial. For purposes of experimental design, we wanted to use the same mix of commonly occurring species at all sites. However, even though our native species were common, several species, including *Balsamorrhiza deltoidea* Nutt. (perennial, Asteraceae) and *Plectritis congesta* (Linkl.) DC. (annual, Scrophulariaceae) did not occur at some of experimental sites. This was a particular problem at the 258-ha Mima Mounds Natural Heritage Preserve, which had special protection and restrictions as a Natural Heritage site. Managers there were reluctant to add native species which did not already occur on site. Although we were unable to find any records of these species occurring at the Preserve in historical records (herbarium records, accounts from early botanists, etc.), we were able to document that both species were historically widespread nearby. We found evidence that diversity of native species, and particularly native annuals, declined in remnants throughout the region with decreasing remnant size and increasing thatch and moss cover (a proxy for the time since the last fire). The Preserve had lower native diversity than predicted for its size, probably related to the long period of time since it had last burned. Native annuals in particular were very rare. Given this information, as well as the importance of both *Balsamorrhiza* and *Plectritis* to rare butterflies, Preserve managers actively supported using these species in our experimental plots. While initially the interests of science and management seemed at odds, by focusing on our shared goals – preservation and restoration of these unique habitats – and providing pertinent supporting information to managers, we were able to come to consensus on this issue.

Mimicking historic disturbances

When working under the assumption that remnant prairies represent an appropriate target for restoration and management, an additional challenge is determining effective habitat treatments. Re-creating historic disturbance regimes is seen as key to successful restoration. However as existing prairie remnants lack these disturbance patterns, we have only limited historical information to guide selection and implementation of disturbance for management.

One of the reasons for the pre-settlement goal is that European settlers greatly changed plant communities and disturbance patterns through urbanization and agricultural development. Removing humans from the system is often thought of as one of the goals of successful restoration, in part because there is recognition that 'human arrogance toward nature…has carved deep gashes in the landscape and defined our modern environmental history' (Minteer & Collins 2010). However, the communities that form our pre-settlement goal were heavily shaped by human activities and successful restoration may require perpetual management of these disturbances.

Both historic records and accounts from tribal members indicate that Native Americans frequently burned prairies and oak savannas to increase the abundance of food plants and provide habitat for game (Storm & Shebitz 2006). Soil disturbance from digging for bulbs and roots of edible plants and cultivation of wild plants is also thought to have helped shape these habitats and plant communities (Beckwith 2004). Both of these types of disturbances largely ceased by the mid-1880s. It is unlikely that cultivation/or harvest of native plants will return on similar scales to that which occurred in the past. Although land managers often make a valiant effort to include prescribed burning in management plans, there are multiple issues with this practice.

When managers are able to use prescribed burning, they also recognize that they are unlikely to mimic accurately the frequency and timing of historic burns. First, despite much anthropological research in this area, there are still few details on the frequency and timing of prairie fires started by Native Americans. Secondly, restrictions often prevent managers from burning at optimal times. At many sites, burning is not possible at all because of urban development or air quality concerns. Even when prescribed burning is scheduled in management plans, it often does not take place due to narrow fire seasons or the lack of fire crews. Finally, because many non-native plants are fire tolerant or fire adapted and now dominate the soil seed bank, prescribed burns often benefit non-native plants as much or more than native plants (Stanley, Kaye & Dunwiddie, in press).

Historic disturbances and land-use patterns probably created a mosaic of patches shaped by different processes and time-since-disturbance that led to high spatial heterogeneity at both the macro- and microscales that may be key for promoting biotic diversity. The majority of remaining prairies are small, fragmented and surrounded by an urban landscape. Most lack essential disturbance events (both anthropogenic and 'natural') that occurred on larger scales and were likely to be important in shaping the structure of the highest quality remnants. For example, channelization of creeks and rivers, increase in impervious surfaces and use of storm sewers has probably decreased flooding and sheet flow over wetland prairies. In addition, post-settlement land use (e.g. ploughing and grading) has removed much of the remaining heterogeneity of remnants and potential restoration sites. Unfortunately, reintroducing large-scale disturbances as management and restoration tools is logistically intractable and some management tools (such as mowing or applying uniform seed mixes over large areas) may actually promote homogenization.

We have found that the success of restoration can be improved when we consider incorporating contemporary tools with historic processes. For example, the combined use of prescribed fire with carefully selected and timed herbicide application can control invasive species while having minimal impacts on native species (e.g. Stanley, Kaye & Dunwiddie, in press). We are also testing various methods of increasing heterogeneity, including using different seed mixes within a site and planting islands of individual species within a matrix of a diverse seed mix. Most land managers have tried multiple management and restoration techniques and in multiple combinations. Their experience, observations and cooperation have proven invaluable in developing experiments to test new treatment regimes rigorously. Collaborative partnerships which combine on-the-ground experience with scientific investigation have been very successful at developing effective management strategies for restoring upland prairies (Stanley, Kaye & Dunwiddie, in press).

Defining appropriate targets for movement of genotypes

Another issue encountered during restoration is determining appropriate targets for the movement of genotypes. Even relatively common prairie species occur in isolated and disjunct populations due to high levels of habitat loss and fragmentation. Since historical records are often lacking or incomplete, we do not know the original distribution, abundance or population structure of many native species. Thus, there is often an assumption that remaining populations are inherently unique and should be maintained in their current state. Defining appropriate restoration targets is particularly problematic with rare species and concerns about mixing genotypes are often greater. When your actions have the potential to affect the fate of an entire species, the concern is understandable. Due to these concerns, there is a general belief that we should be conservative with the movement of genotypes, similar to the first principle of medical ethics, 'first, do no harm'. This point of view assumes that the risk of outbreeding depression and losing presumed locally adapted genotypes outweighs the risk of inbreeding depression and losing genetic diversity through population bottlenecks. The view that the uniqueness of each population must be maintained often prohibits or greatly increases the expense of population augmentation and introduction, and may be detrimental if inbreeding depression is strong.

The Institute for Applied Ecology has been working with multiple managers, agencies and scientists to develop seed transfer zones for both common and rare species. Although, in an ideal world, we would use genetic analyses in order to gain more information about historic gene flow, the expense of this approach is prohibitive given limited funding available for plant conservation. In the absence of this information, seed transfer zones can be determined by evaluating species biology (e.g. pollination and dispersal syndromes) and on-the-ground knowledge of potential hybrid, or otherwise unusual, populations. This approach was used to determine the appropriateness of using the Willamette Valley as a seed transfer zone for common prairie species and to develop guidelines to minimize genetic loss in cultivation (Miller *et al.*, in press; http://www.nativeseednetwork.org).

The Institute for Applied Ecology has also used common garden and reciprocal transplant experiments to test for differentiation between populations (Kaye *et al.* 2009; Miller *et al.*, in press; Thorpe & Kaye 2010). For example, we have incorporated studies of population differentiation into reintroductions of the endangered *Erigeron decumbens* Nutt. (Willamette daisy, Asteraceae). There are currently fewer than 40 populations of this species in the Willamette Valley. The majority of *Erigeron* populations number fewer than 100 flowering individuals and have low rates of seed viability (Thorpe & Kaye 2010). *Erigeron* occurs in prairie habitats ranging from wetland to well-drained upland prairies and it was unknown if plants exhibit local adaptation to hydrologic conditions (ecotypic differentiation). If the species exhibits local adaptation, reintroductions or augmentations might need to match carefully seed sources to recovery sites. By contrast, if the species has a wide ecological niche, careful matching would not be necessary and the limited seed sources could be used with more flexibility. We used reciprocal transplant techniques to test for ecotypic differentiation in seeds collected from wetland and upland prairie sites. Although we found some evidence for ecotypic differentiation, it did not occur consistently across habitats or time. For example, at a moderately dry site, plants from an upland source tended to be larger, but plants from a wet prairie source produced more inflorescences. These differences were only found at certain plant ages and for a single planting year. The only consistent effects were in a wetland prairie site where overall survival was low. Here, surviving plants from the wetland prairie source were larger and produced more inflorescences. Thus, patterns of success in *Erigeron* vary depending on interactions between planting year, age of individuals, source population and recipient habitat types. As these patterns are not always predictable, we suggest that future introduction efforts include seed from a variety of sources to maximize establishment.

These types of experiments may be particularly useful to test for differences in populations of rare species, as small population sizes and low rates of seed viability may make it difficult to collect sufficient seed for restoration within narrowly defined transfer areas (Thorpe & Kaye 2010). In summary, we recommend that rather than relying on limited information about pre-settlement conditions and assumptions based on remnant populations, targets for the movement of genotypes should be based on population genetic theory, species biology and careful experimentation.

Defining restoration targets in the face of global change

In the absence of using historic conditions as the target in management and restoration, what should our target be? We advocate the development of appropriate restoration and management goals based on quantifiable ecological objectives (e.g. Martin, Moloney & Wilsey 2005). These could include percent native species, diversity metrics (total diversity, patch diversity, beta diversity), abundance of focal species (rare species, keystone species, etc.) and ecological processes (nutrient cycling, water infiltration). Clear and quantifiable goals are more straightforward and make progress easier to track than a nebulous plan of returning to a mostly unknown pre-settlement condition.

We also advocate that we should look towards restoring systems that will be resilient in the face of continued global change. Harris *et al.* (2006) suggested that a key question in restoration is the proper balance between rebuilding past systems and attempting to build resilient systems for the future. Even if we could work out all the issues with using pre-settlement conditions as a restoration target, we question whether it is relevant to do so in the face of global changes, including climate change, invasive species and continued anthropogenic influences (e.g. agricultural and urban development), which may fundamentally alter species interactions and ecosystem processes. Indeed, this is not a new idea; Heller & Zavaleta (2009) identified articles suggesting changes in restoration and conservation actions to accommodate climate change from as early as 1987. They suggested that although these articles make numerous recommendations for action, none actually defined how, by whom, or under what conditions these actions could be implemented. We see this as a critical need to address the effects of global change in restoration and rare species management.

Including resilience as a restoration target may require considering novel, and potentially controversial, approaches. For example, there is increasing recognition that building 'resilient systems for the future' will probably require assisted migration, particularly to minimize extinction risk of some rare species (e.g. Kramer & Havens 2009; Minteer & Collins 2010). Despite acknowledging this in theory, a recent survey found that few managers are willing to move species outside of their known habitats or home-ranges in practice (T.N. Kaye, unpublished data), due to the uncertainties associated with such actions, including the potential of creating a new invasive species, the genetic effects associated with outbreeding depression, and altering ecosystem processes and interactions (Ricciardi & Simberloff 2009; Minteer & Collins 2010). Unfortunately, there is currently little information to determine the risk of assisted migration. Despite these ongoing debates, some groups are beginning to explore the viability of assisted migration, including the movement of the endangered *Torreya taxifolia* by the Torreya Guardians and a large-scale experiment of the success of several tree species moved outside of their range by scientists in British Columbia (Minteer & Collins 2010; http://torreyaguardians.org).

We believe that to resolve these types of issues, scientists and managers should work together to test the effects, costs and benefits of novel restoration and management approaches using a careful experimental and adaptive management approach. We recommend that managers and scientists look for opportunities to test new approaches during restoration. In addition to the research value, using multiple techniques within an experimental framework can be a way to 'hedge your bets' and ensure success of a project.

In moving forward with such an approach, we suggest that three issues be considered. First, while managers can rarely justify funds for research alone, research can frequently be incorporated into management actions. Secondly, land managers have important on-the-ground knowledge and experience. We recommend that scientists and managers work together from the onset of a project; while scientists can provide important ecological framing and experimental design, managers can often provide unique ideas for experimental treatments, interpretation of results and trouble-shooting if problems arise (Hulme 2011). Finally, it is important to maintain good relationships with all partners. Focusing on shared goals and common concerns can go a long way towards alleviating any areas of conflict. Collaborative projects between managers and scientists can greatly enhance the quality of research and advance our knowledge of ecological theory.

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