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Identifying Rangeland Restoration Targets: An Appraisal of Challenges and Opportunities

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Abstract

Restoration activities are directed toward a broad spectrum of targets. Identifying a restoration target entails defining an ecosystem state and its desired functioning that can be attained through managerial interventions. First, we discuss how restoration targets must integrate economic, social, and ecological considerations in order to be feasible. Primary challenges to identifying realistic restoration targets include long-term managerial and fiscal commitments as well as the accommodation of inherent rangeland complexities stemming from social and ecological factors. Second, we illustrate how the existing tools of ecological site description, rangeland health assessment, and state-and-transition modeling present opportunities to identify flexible restoration targets. Last, we describe how to refine these targets using adaptive management in order to cope with constraints and to reduce the uncertainty of ecosystem dynamics typical of complex systems. Restoration should be viewed as both a rangeland management activity and a means to inform and guide interventions within a specific site.

Resumen

Las actividades de rehabilitación están dirigidas hacia un amplio espectro de objetivos. La identificación de un objetivo de rehabilitación implica la definición del estado del ecosistema y el funcionamiento deseado que puede alcanzarse a través de intervenciones de manejo. Primero, discutimos cómo los objetivos de rehabilitación deben integrar factores económicos, sociales y ecológicos, con el fin de ser factibles. Los principales desafíos para la identificación de objetivos realistas de rehabilitación incluyen compromisos de manejo y económicos a largo plazo. Así también deben incluirse otros elementos innatos de los pastizales derivados de los factores sociales y ecológicos. Segundo, ilustramos cómo la existencia de herramientas para descripción ecológica de los sitios, evaluación del bienestar del pastizal, y el modelado del estado y transición representan oportunidades para identificar objetivos de rehabilitación. Finalmente, describimos cómo redefinir estos objetivos usando manejo adaptativo con el fin de hacer frente a limitaciones y reducir la incertidumbre de la dinámica de los ecosistemas típicamente de los sistemas complejos. La rehabilitación debe ser vista tanto como una actividad del manejo de pastizales como de un medio para informar y guiar las mediaciones en un sitio especifico.

Key Words: adaptive management, conservation planning, ecosystem services, historic benchmarks, novel ecosystems, rangeland monitoring

INTRODUCTION

Restoration is broadly defined in the scientific literature as an intervention designed to facilitate ecosystem or landscape repair (Hobbs et al. 2011), i.e., "the process of assisting the recovery of damaged, degraded, or destroyed ecosystems" (SERI 2004). Restoration objectives may range from reestablishing the dominance of species that characterize a desired plant community (Young 2000) to improving foundational ecosystem attributes such as soil and site stability, hydrologic function, and biotic integrity (Herrick et al. 2006). However, because of differing perceptions of what constitutes a realistic or meritorious target, identifying a target restoration state or defining "proper" ecosystem functioning at the ecosystem level stimulates vociferous debate among the general public and stakeholders. Although the spectrum of restoration targets typically encompasses a historic ecosystem state believed to be characteristic of the site, it also includes ecosystem states that provide high-priority ecosystem services, such as soil conservation, watershed protection, or forage, regardless of plant origin (Hobbs 2007).

Rangeland ecosystems require intervention because a large percentage of the world's rangelands are degraded (Asner et al. 2004; Archer and Predick 2008; Han et al. 2008), thereby diminishing their delivery of ecosystem services (Briske and Heitschmidt 1991; Falkenmark and Rockstrom 2006; Havstad et al. 2007). Self-perpetuating degradation processes, such as accelerated erosion or breakdown of water and nutrient cycling, increase the urgency of intervention. Rangeland productivity is typically erratic, so benefits may be small or slow to appear. Low human-population densities associated with rangelands also hinder investment in rangeland restoration (FAO 2001).

Rangeland management must embrace the evolving science of restoration ecology to repair past and ongoing degradation (Hobbs et al. 2011). To strengthen the restoration component of rangeland management, we first acknowledge the legitimacy of a broad spectrum of prospective restoration targets and outline the challenges to identifying them. Next, we illustrate how recent advances in rangeland ecology and management assist in identifying restoration targets and in monitoring restoration success. Successful integration of ecological resto-

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ration into rangeland management in the near future will largely determine the fate of rangelands on a global scale.

CHALLENGES TO RANGELAND RESTORATION

Restoration Takes Time and Money

Rangeland degradation occurs over extensive time periods. Consequently expectations that immediate and permanent restoration of ecosystem functioning will ensue from improved policy and management must be tempered with the reality of a long and perhaps continual investment of time and resources (Pickett and Parker 1994). The complexity of restoring ecological processes often means that research and management must be simultaneously implemented on an ongoing basis (Boyd and Svejcar 2009). This twin effort is essential to minimize the uncertainty of restoration outcomes, to test underlying assumptions of ecosystem dynamics, and to reduce the gap between theory and practice (Suding and Hobbs 2008). Because restoration is a long-term commitment, attempts that are insufficient in duration and magnitude, that do not provide for flexibility over time, or that cannot respond to inherently unpredictable drivers (e.g., climate) will likely fail. The necessity for an ongoing restoration commitment represents a consummate challenge for policy makers because of inevitable changes to planning and budgeting. By their nature, restoration projects rarely conform to predetermined time frames commonly used to allocate funding.

The long-term value of restoration activities and the costs entailed in avoiding or delaying action often go unrecognized. Failure to minimize self-perpetuating degradation processes in the short-term entails costs to be borne by future generations that are difficult to quantify. Conventional economic assessments cannot account for the negative impacts avoided by making investments in restoration (Tanaka et al. 2011). Consequently a traditional cost-benefit analysis typically renders an unfavorable assessment of investment in rangeland restoration. Furthermore, many ecological services maintained through restoration activities do not yield direct economic returns to the landowner (e.g., soil formation, nutrient cycling, aesthetics), but support growing environmental markets (e.g., Palmer and Filoso 2009). Consequently, many economists regard the monetary value of restored ecosystems as a poor policy guide (Nelson 1995), even though restoration unarguably proffers an array of high-value goods and services (Hobbs and Harris 2001; Bullock et al. 2011).

Ultimately, uncertain funding scenarios impede restoration success. Furthermore, insufficient funding thwarts full-scale restoration efforts. Partially funded efforts require consideration of tradeoffs among potential restoration benefits. Consequently, identifying which ecosystem services can be enhanced, assessing the value of that enhancement to beneficiaries, and ascertaining their ability to pay are paramount (Bullock et al. 2011).

Rangelands are Complex, Heterogeneous Ecosystems

Social Aspects. Society interacts with ecological restoration at three levels: the citizenry, the stakeholders, and the restoration community. Citizens often possess only a vague understanding of the importance of ecological restoration (Burger 2010). The public is also often unaware of the challenges associated with restoration planning and implementation, and they may not understand the spectrum and magnitude of ecosystem-service tradeoffs that must be considered. Consequently, asking the general public to allocate scarce funds to restoration activities can be problematic.

A diverse set of stakeholders necessitates that restoration planning must consider economic, social, and political values as well as ecological goals (Higgs 1997). Individuals in society impose normative, value-laden, and experience-driven perceptions on rangeland issues. For example, what one person sees as a benefit (e.g., wild horses, wolves), another sees as a conflicting threat to their preferred value (e.g., livestock production) or simply as an unnecessary expense. Engaging stakeholders with opposing priorities into an integrated decision-making process challenges the most conciliatory restoration practitioners (van Marwijk et al. in press). Furthermore, conflicting desires among stakeholders threatens the consensus required to sustain restoration activities (Shore 1997; Shindler et al. 2011). For example, political, social, and economic issues that transcend biophysical considerations have complicated the implementation of restoration goals of the US Endangered Species Act (e.g., how many wolves are enough?).

Restoration practitioners and scientists encompass a broad range of values placed on various aspects of restoration. These values are often presented as scientific arguments (Davis and Slobodkin 2004), but in reality they represent philosophical values (Callicot et al. 1999). For example, the variety of views surrounding the definitions of restoration and restoration targets reflects the diversity within the restoration community. Indeed, such diversity is helpful to avoid the pitfall that only one reference state or system is legitimate (Pickett and Parker 1994). As an example, seeking to "carbon copy" a previous or idealized state has been cited as a myth of restoration ecology because plant community assembly may be unpredictable, leading to any one of multiple endpoints (Hilderbrand et al. 2005). Many restoration ecologists now recognize the possibility of a spectrum of potential restoration targets (Ehrenfeld 2000; Suding 2011). Embracing this broad view has value because restoration outcomes depend on which ecological constraints are identified, prioritized, and addressed in the planning and implementation process (Suding et al. 2004; Hobbs and Cramer 2008).

Ecological Aspects. Integrating restoration ecology into rangeland management is challenging because rangeland ecosystems are expansive, complex, and diverse, making it difficult to prioritize at landscape or regional scales (Hobbs and Norton 1996). Ongoing change also characterizes ecosystems; thus we cannot expect ecological stasis or rely on a predetermined outcome if autogenic processes are to be sustained (Clewell 2000; Hobbs et al. 2010). Consequently the practice of ecological restoration compels the embrace of the dynamic nature of ecological systems (Choi et al. 2008; Bridgewater et al. 2011).

Highly variable abiotic and biotic ecosystem drivers commonly interact with disturbance over time to alter successional trajectories (Pickett and McDonnell 1989) and generate nonequilibrium conditions (Briske et al. 2003; von Wehrden et al. 2012). This perspective of community dynamics is replacing the equilibrium paradigm (Hobbs and Morton 1999) because many ecosystems, including rangelands, can be better described as a series of alternative stable states separated by thresholds (Suding et al. 2004; Briske et al. 2010). In this new paradigm, flux typifies ecosystems rather than stasis, instability characterizes ecosystems rather than permanence, and compounded perturbations lead to ecological surprises (Paine et al. 1998). Given this complexity, restoration practitioners must carefully assess site conditions prior to identifying restoration targets so that interventions address specific ecological processes needing restoration (e.g., Whisenant 1999; Monaco and Sheley 2012).

PROSPECTIVE RESTORATION TARGETS

Prior to selecting restoration targets, specific ecological problems and constraints should be identified (Suding et al. 2004). However, identifying realistic targets and tracking their success is difficult because the restoration outcomes achieved in one ecosystem may not transfer to another (Hobbs and Morton 1999; Hilderbrand et al. 2005). In addition, comprehensive surveys of restoration successes and failures that might suggest general principles are not available (Suding 2011).

It is imperative to set clear and achievable restoration targets and forecast the best possible restoration outcomes using ecological knowledge and diverse stakeholder perspectives (Higgs 1997; Ehrenfeld 2000). Similarly, site-specific factors strongly influence the selection of a restoration target because they constrain what is ecologically possible, economically viable, and socially acceptable (Hobbs 2007). Scientists, managers, and policy makers need to place strong emphasis on exploring and reconciling the spectrum of potential restoration targets. Two commonly encountered disparate targets are the historical benchmark and a novel ecosystem (Fig. 1). Each target has its own rationale and associated tradeoffs (Fig. 1). We do not intend these examples to be adversarial, but rather to illustrate contrasting prospective targets.

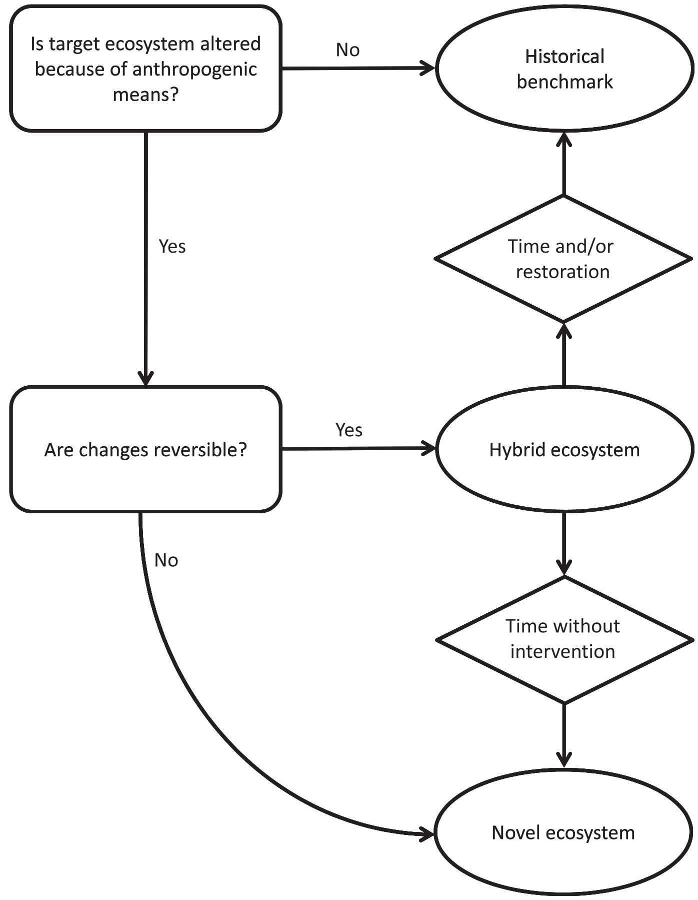

Figure 1. Simplistic decision framework for identifying potential restoration targets among the spectrum ranging from historical benchmarks to novel ecosystems. Adapted with permission from Hobbs (in press).

Historical Benchmark Targets

A historical benchmark, defined as a previous ecosystem state, may serve as a feasible target for smaller-scale projects with exceptional circumstances, e.g., high community volunteerism. Such an approach can be successful for pristine park and wilderness areas with wide buffers and for ecosystems displaying high levels of resilience (Hobbs and Cramer 2008). Setting a historical benchmark as a restoration target implies intact species pools, unaltered abiotic conditions, and the reinitiation of natural successional processes upon removal of the degrading influence (Fig. 1). Under such circumstances, restoration can lead to predictable endpoints that resemble past ecosystem structure and composition within the historical range of variation (Suding 2011).

As indicated above, selection of a historical benchmark as a restoration target applies particularly to the "protected lands" vision, as laid out by Leopold et al. (1963) for national parks (Jackson and Hobbs 2009). Yet historical benchmarks are becoming increasingly difficult to apply, as ecosystems, and rangelands in particular, have become fragmented or otherwise compromised by anthropogenic forces (Jackson et al. 1995; Ellis and Ramankutty 2008). This difficulty explains why the Society of Ecological Restoration International (SERI 2004) has liberalized its definition of ecological restoration by removing any reference to an indigenous state or historical benchmark. Their expanded interpretation increases flexibility for restoration practitioners and hopefully increases the prospect of positive restoration outcomes.

For an increasing number of degraded, human-dominated rangeland ecosystems, then, key ecosystem factors (e.g., climate change, soil loss, biotic invasions) have increasingly modified the foundational ecological-site characteristics (Sanderson et al. 2002; Suding et al. 2004; Seastedt et al. 2008), making restoration to a historical benchmark unlikely. Under these circumstances, pursuing a restoration target that resembles a historical benchmark may be ecologically unrealistic, and the end results will likely disappoint.

Under these increasingly common circumstances, we suggest imitating the structure and function of a desirable existing ecological state as a reasonable alternative to the strict historical benchmark. For example, the US Natural Resources Conservation Service (NRCS) has championed the use of state-and-transition models (STMs) to describe site dynamics within specific ecological site classifications.[1] These conceptual models identify sets of

[1]http://esis.sc.egov.usda.gov

potential restoration targets within the range of existing ecological variation and describe restoration pathways that may lead to a targeted ecological state (Jordan et al. 1987; Bestelmeyer et al. 2003). The assessment of existing restoration targets improves our understanding of the processes and feedbacks that contribute to plant-community composition and dynamics. In addition, when multiple states represent potential restoration targets, STMs assist with "the choice of reference ecosystems, the evaluation of restoration actions, and the identification of priority areas for conservation and restoration" (Cortina et al. 2006). With this knowledge, restoration interventions can better implement practices to influence specific ecosystem processes operating within existing reference sites. These sites, then, serve as time-proven survivors and long-term products of evolution and the environment (Ewel 1999).

Novel Ecosystem Targets

The natural capital of our world, our biotic resource base, is now widely regarded as becoming depleted (Mooney 2010). This depletion has led to the observation that there are now more lemons (damaged ecosystems) than lemonade (pristine ecosystems), and "we need to recognize this and determine what to do with the lemons" (Hobbs et al. 2006). When a historic benchmark cannot serve as a realistic restoration target because of ecological, economic, and/or social constraints (Fig. 1), alternate targets that deliver ecosystem services and ensure ecosystem resilience to perturbation should be sought instead (Seastedt et al. 2008; Suding 2011). Coming to terms with these realities, the restoration profession is now recognizing that so-called novel ecosystems may be a viable option for restoring value to degraded lands (Light and Higgs 1996; Jackson and Hobbs 2009; Marris 2009).

Novel ecosystems result from deliberate or inadvertent human action and exhibit new functions or contain new assemblages of species, yet are self-organizing (Hobbs in press). For example, they may arise from prior land degradation, from weed invasion, and/or from the abandonment of a former land use (Hobbs et al. 2006). Although novel ecosystems do not conform to a historical benchmark (Hobbs et al. 2006), they may still provide ecosystem functions, goods, and services of value to humanity (Palmer et al. 2004; Kareiva et al. 2007; Jackson and Hobbs 2009).

Many rangelands can be categorized as either novel or "hybrid" ecosystems, as described by Hobbs et al. (2009). Hybrid ecosystems retain elements of the natural ecosystem, but species composition or ecosystem properties or functions lie outside its historic range of variability (Fig. 1; Hobbs et al. 2009). Hybrid ecosystems differ from novel ecosystems in that the former may be restored, while truly novel systems have crossed a threshold, rendering restoration unattainable (Hobbs et al. 2009).

Managing novel and hybrid ecosystems requires reconsideration of conservation and restoration norms (Hobbs et al. 2006, 2009). For example, when rangeland ecosystems have been significantly altered by invasive or introduced species, their management will depend on site-specific goals that range from straightforward-certain to complex-uncertain (Belnap et al. 2012 [this issue]). Although novel ecosystems have crossed thresholds that prevent return to a historical benchmark, other prospective targets compatible with conservation and restoration goals may be attainable, while at the same time providing vital ecosystem services (Bridgewater et al. 2011).

OPPORTUNITIES TO IDENTIFY RESTORATION TARGETS AND MONITOR RESTORATION SUCCESS

The uncertain dynamics of complex ecosystems pose significant challenges to understanding potential outcomes, detours, and setbacks from rangeland restoration practices. Nevertheless, recent advancements in ecological theory and the development of practical rangeland management tools make it increasingly possible to define realistic restoration targets. Below we outline how the tools of ecological site assessment, state-and-transition modeling, and adaptive management can help to identify a restoration target and to evaluate restoration success.

Ecological Site Assessment

Reducing uncertainty in restoration requires the identification of constraints to restoring suboptimal processes and/or processes not yielding desired ecological functions (Suding et al. 2004). The adoption of ecological sites as the fundamental land unit for evaluating rangeland condition (SRM 1995) helps to identify appropriate restoration targets and to subdivide the landscape into components that are more homogeneous for management response (Brown 2010). Each ecological site description (ESD) contains a rangeland health indicator worksheet that can be used to develop management options for damaged lands (Pyke et al. 2002; Sheley et al. 2010, 2011). Ecological site descriptions include STMs with graphical/textual descriptions of possible soil:vegetation "states" and transitions among them for the particular ecological site. These models delineate the spectrum of potential plant-community dynamics and ecological processes for the ecological site (Briske et al. 2005). Metaphorically, ESDs and STMs function like maps and compasses, respectively, to chart and explore restoration pathways, thus facilitating a shift from a descriptive understanding of ecology to one with potential predictive value (Hobbs and Morton 1999; Bestelmeyer et al. 2003, 2009). These tools may integrate restoration into rangeland management by detailing flexible and multiple endpoints along with their relative costs and tradeoffs.

With these advancements, rangeland restoration projects may operate as proving grounds to inform basic research and acquire site-specific knowledge as reassembly and/or interventions are implemented (Jordan et al. 1987). Accordingly ecological restoration efforts serve as excellent sources of information that can refine STMs, e.g., by describing biotic and abiotic thresholds (Bestelmeyer 2006; Hobbs 2007). This justifies the increased use of ESDs and STMs to identify appropriate restoration targets. To facilitate development of this analytical approach, both reference and restoration sites must be carefully examined to elucidate their dynamics and structure in time and space (White and Walker 1997), to suggest management practices for restoration targets, and to assess the efficacy of the restoration plan (Hobbs and Harris 2001; Ruiz-Jaen and Aide 2005). Updating ESDs and STMs with the outcomes of restoration projects can enhance future restoration success in similar ecological situations.

Monitoring Success With Adaptive Management

We subscribe to the idea that ecological restoration is a process rather than an endpoint (Pickett and McDonnell 1989). Therefore, defining restoration targets and monitoring success can benefit from the application of adaptive management principles (Morghan et al. 2006). Adaptive management entails active updating of how a site or system responds to management actions (Williams 2011; Williams et al. 2011). It also involves systematic monitoring and assessment to detect surprises and integrate new information into the restoration process to improve success and reduce uncertainty (Lee 1999). Fortunately rangeland assessment and monitoring tools for gathering this critical information have been defined, providing a systematic tool for monitoring rangeland dynamics and restoration success (e.g., Karl and Herrick 2010; Karl et al. 2011).

Because of diverse stakeholder values and uncertain rangeland dynamics, surprise and conflict are inevitable when adaptive management is practiced in rangeland restoration. When they commit to the adaptive management process, stakeholders must understand that unpredictable problems with the initial plan are to be expected. Therefore, adaptive management must require long-term commitment to a process that will involve compromise. Addressing complex rangeland problems requires exceptional collaboration among stakeholders to achieve consensus on a strategy capable of succeeding within the ecological, economic, and social constraints of the site (Boyd and Svejcar 2009). Thus, restoration success depends not only on what is recognized as ecologically feasible, but also whether stakeholders can agree on restoration targets. Adaptive management is a vital component of rangeland restoration because a mechanism needs to be in place to quickly recognize unanticipated threats to success and to adapt accordingly. When ecosystem resilience or provision of ecosystem services is not forthcoming, adaptive management must allow for midcourse refinements.

IMPLICATIONS

Restoration success urgently needs adaptive management, wherein ecosystem functioning is continually monitored to better inform intervention activities and adjusted over time to enhance the probability of long-term success. The lack of a comprehensive understanding of potential restoration targets and what it will take to achieve them has inhibited the routine implementation of adaptive management by restoration practitioners and policy makers. Application of the ecological site concept and a functional STM can address this barrier. Restoration can almost never be accomplished through a single intervention; thus intervention activities essentially serve as mechanistic trials, generating site-specific information to adaptively refine ongoing management and to calibrate expectations of associated costs and benefits. Application of ESDs and STMs has the potential to reduce the uncertainty involved in restoration. This will enhance the discussion between stakeholders and policy makers regarding tradeoffs among management options and will further the formulation of realistic policy. In addition, the union between rangeland management and restoration ecology will be strengthened as practitioners identify feasible restoration target ecosystem states, closely monitor outcomes to determine whether specific targets are reached, and build up a database on process-based responses to restoration treatments.

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LITERATURE CITED

Archer, S. R., and K. I. Predick. 2008. Climate change and ecosystems of the southwestern United States. *Rangelands* 30(3):23–28.

Asner, G. P., A. J. Elmore, L. P. Olander, R. E. Martin, and A. T. Harris. 2004. Grazing systems, ecosystem responses, and global change. *Annual Review of Environment and Resources* 29:261–299.

Belnap, J., J. A. Ludwig, B. P. Wilcox, J. L. Betancourt, W. R. J. Dean, B. D. Hoffmann, and S. J. Milton. Introduced and invasive species in novel rangeland ecosystems: friends or foes? *Rangeland Ecology & Management*. 65:569–578.

Bestelmeyer, B. T. 2006. Threshold concepts and their use in rangeland management and restoration: the good, the bad, and the insidious. *Restoration Ecology* 14:325–329.

Bestelmeyer, B. T., J. R. Brown, K. M. Havstad, R. Alexander, G. Chavez, and J. E. Herrick. 2003. Development and use of state-and-transition models for rangelands. *Journal of Range Management* 56:114–126.

Bestelmeyer, B. T., A. J. Tugel, G. L. Peacock, D. G. Robinett, P. L. Shaver, J. R. Brown, J. E. Herrick, H. Sanchez, and K. M. Havstad. 2009. State and transition models for heterogeneous landscapes: a strategy for development and application. *Rangeland Ecology & Management* 62:1–15.

Boyd, C. S., and T. J. Svejcar. 2009. Managing complex problems in rangeland ecosystems. *Rangeland Ecology & Management* 62:491–499.

Bridgewater, P., E. S. Higgs, R. J. Hobbs, and S. T. Jackson. 2011. Engaging with novel ecosystems. *Frontiers in Ecology and the Environment* 9:423.

Briske, D. D., S. D. Fuhlendorf, and F. E. Smeins. 2003. Vegetation dynamics on rangelands: a critique of the current paradigms. *Journal of Applied Ecology* 40:601–614.

Briske, D. D., S. D. Fuhlendorf, and F. E. Smeins. 2005. State-and-transition models, thresholds, and rangeland health: a synthesis of ecological concepts and perspectives. *Rangeland Ecology & Management* 58:1–10.

Briske, D. D., and R. K. Heitschmidt. 1991. An ecological perspective. *In:* R. K. Heitschmidt and J. W. Stuth [eds.]. Grazing management: an ecological perspective. Portland, OR, USA: Timber Press. p. 11–26.

Briske, D. D., R. A. Washington-Allen, C. R. Johnson, J. A. Lockwood, D. R. Lockwood, T. K. Stringham, and H. H. Shugart. 2010. Catastrophic thresholds: a synthesis of concepts, perspectives, and applications. *Ecology and Society* 15(3):37. Available at: http://www.ecologyandsociety.org/vol15/iss3/art37/.

Brown, J. R. 2010. Ecological sites: their history, status, and future. *Rangelands* 32(6):5–8.

Bullock, J. M., J. Aronson, A. C. Newton, R. F. Pywell, and J. M. Rey-Benayas. 2011. Restoration of ecosystem services and biodiversity: conflicts and opportunities. *Trends in Ecology and Evolution* 26:541–549.

Burger, J. 2010. Public perceptions of natural resource damages and the resources that require restoration. *Journal of Toxicology and Environmental Health Part A* 73:1325–1336.

Callicot, J. B., L. B. Crowder, and K. Mumford. 1999. Current normative concepts in conservation. *Conservation Biology* 13:22–25.

Choi, Y. D., V. M. Temperton, E. B. Allen, A. P. Grootjans, M. Halassy, R. J. Hobbs, M. A. Naeth, and K. Torok. 2008. Ecological restoration for future sustainability in a changing environment. *Ecoscience* 15:53–64.

Clewell, A. F. 2000. Restoring for natural authenticity. *Ecological Restoration* 18:216–217.

Cortina, J., F. T. Maestre, V. R. Vallejo, M. J. Baeza, A. Valdecantos, and M. Pérez-Devesa. 2006. Ecosystem structure, ecosystem function, and restoration success: are they related? *Journal for Nature Conservation* 14:152–160.

Davis, M. A., and L. B. Slobodkin. 2004. The science and values of restoration ecology. *Restoration Ecology* 12:1–3.

Ehrenfeld, J. G. 2000. Defining the limits of restoration: the need for realistic goals. *Restoration Ecology* 8:2–9.

Ellis, E. C., and N. Ramankutty. 2008. Putting people in the map: anthropogenic biomes of the world. *Frontiers in Ecology and the Environment* 6:439–447.

Ewel, J. J. 1999. Natural systems as models for the design of sustainable systems of land use. *Agroforestry Systems* 45:1–21.

Falkenmark, M., and J. Rockstrom. 2006. The new blue and green water paradigm: breaking new ground for water resources planning and management. *Journal of Water Resources Planning and Management* 132:129–132.

[FAO] Food and Agriculture Organization. 2001. Pastoralism in the new millennium. Rome, Italy: Food and Agriculture Organization of the United Nations. Animal Production and Health Paper 150. 93 p. Available online: http://www.fao.org/DOCREP/005/Y2647E/y2647e00.htm#toc. Accessed 10 January 2012.

Han, J. G., Y. J. Zhang, C. J. Wang, W. M. Bai, Y. R. Wang, G. D. Han, and L. H. Li. 2008. Rangeland degradation and restoration management in China. *Rangeland Journal* 30:233–239.

Havstad, K. M., D. P. C. Peters, R. Skaggs, J. Brown, B. Bestelmeyer, E. Fredrickson, J. Herrick, and J. Wright. 2007. Ecological services to and from rangelands of the United States. *Ecological Economics* 64:261–268.

Herrick, J. E., G. E. Schuman, and A. Rango. 2006. Monitoring ecological processes for restoration projects. *Journal for Nature Conservation* 14:161–171.

Higgs, E. S. 1997. What is good ecological restoration? *Conservation Biology* 11:338–348.

Hilderbrand, R. H., A. C. Watts, and A. M. Randle. 2005. The myths of restoration ecology. *Ecology and Society* 10(1):19. Available at: http://www.ecologyandsociety.org/vol10/iss1/art19/.

Hobbs, R. J. 2007. Setting effective and realistic restoration goals: key directions for research. *Restoration Ecology* 15:354–357.

Hobbs, R. J. Novel ecosystems: intervening in the new ecological world order. Hoboken, NJ, USA: Wiley-Blackwell, 392 p.

Hobbs, R. J., S. Arico, J. Aronson, J. S. Baron, P. Bridgewater, V. A. Cramer, P. R. Epstein, J. J. Ewel, C. A. Klink, A. E. Lugo, D. Norton, D. Ojima, D. M. Richardson, E. W. Sanderson, F. Valladares, M. Vila, R. Zamora, and M. Zobel. 2006. Novel ecosystems: theoretical and management aspects of the new ecological world order. *Global Ecology and Biogeography* 15:1–7.

Hobbs, R. J., D. N. Cole, L. Yung, E. S. Zavaleta, G. H. Aplet, F. S. Chapin, P. B. Landres, D. J. Parsons, N. L. Stephenson, P. S. White, D. M. Graber, E. S. Higgs, C. I. Millar, J. M. Randall, K. A. Tonnessen, and S. Woodley. 2010. Guiding concepts for park and wilderness stewardship in an era of global environmental change. *Frontiers in Ecology and the Environment* 8:483–490.

Hobbs, R. J., and V. A. Cramer. 2008. Restoration ecology: interventionist approaches for restoring and maintaining ecosystem function in the face of rapid environmental change. *Annual Review of Environment and Resources* 33:39–61.

Hobbs, R. J., L. M. Hallett, P. R. Ehrlich, and H. A. Mooney. 2011. Intervention ecology: applying ecological science in the twenty-first century. *Bioscience* 61:442–450.

Hobbs, R. J., and J. A. Harris. 2001. Restoration ecology: repairing the Earth's ecosystems in the new millennium. *Restoration Ecology* 9:239–246.

Hobbs, R. J., E. Higgs, and J. A. Harris. 2009. Novel ecosystems: implications for conservation and restoration. *Trends in Ecology and Evolution* 24:599–605.

Hobbs, R. J., and S. R. Morton. 1999. Moving from descriptive to predictive ecology. *Agroforestry Systems* 45:43–55.

Hobbs, R. J., and D. A. Norton. 1996. Towards a conceptual framework for restoration ecology. *Restoration Ecology* 4:93–110.

Jackson, L. L., N. Lopoukhine, and D. Hillyard. 1995. Ecological restoration: a definition and comments. *Restoration Ecology* 3:71–75.

Jackson, S. T., and R. J. Hobbs. 2009. Ecological restoration in the light of ecological history. *Science* 325:567–569.

Jordan, W. R., III, M. E. Gilpin, and J. D. Aber. 1987. Restoration ecology: ecological restoration as a technique for basic research. *In:* W. R. Jordan III, M. E. Gilpin, and J. D. Aber [eds.]. Restoration ecology. Cambridge, UK: Cambridge University Press. p. 3–21.

Kareiva, P., S. Watts, R. McDonald, and T. Boucher. 2007. Domesticated nature: shaping landscapes and ecosystems for human welfare. *Science* 316:1866–1869.

Karl, J. W., K. Colson, and H. Swartz. 2011. Rangeland assessment and monitoring methods guide. *Rangelands* 33(4):48–54.

Karl, J. W., and J. E. Herrick. 2010. Monitoring and assessment based on ecological sites. *Rangelands* 32(6):60–64.

Lee, K. N. 1999. Appraising adaptive management. *Ecology and Society* 3(2):3. Available at: http://www.ecologyandsociety.org/vol3/iss2/art3/.

Leopold, A. S., S. A. Cain, C. M. Cottam, T. L. Gabrielson, and T. L. Kimball. 1963. Wildlife management in the national parks. *Transactions of the Twenty-eighth North American Wildlife and Natural Resources Conference* 28:28–45.

Light, A., and E. S. Higgs. 1996. The politics of ecological restoration. *Environmental Ethics* 18:227–247.

Marris, E. 2009. Ecology: ragamuffin earth. *Nature* 460:450–453.

Monaco, T. A., and R. L. Sheley. 2012. Invasive plant ecology and management: linking processes to practice. Wallingford, Oxfordshire, UK: CAB International. 204 p.

Mooney, H. A. 2010. The ecosystem-service chain and the biological diversity crisis. *Philosophical Transactions of the Royal Society B* 365:31–39.

Morghan, K. J. R., R. L. Sheley, and T. J. Svejcar. 2006. Successful adaptive management—the integration of research and management. *Rangeland Ecology & Management* 59:216–219.

Nelson, R. H. 1995. Sustainability, efficiency and god: economic values and the sustainability debate. *Annual Review of Ecology and Systematics* 26:135–154.

Paine, R. T., M. J. Tegner, and E. A. Johnson. 1998. Compounded perturbations yield ecological surprises. *Ecosystems* 1:535–545.

Palmer, M., E. Bernhardt, E. Chornesky, S. Collins, A. Dobson, C. Duke, B. Gold, R. Jacobson, S. Kingsland, R. Kranz, M. Mappin, M. L. Martinez, F. Micheli, J. Mose, M. Pace, M. Pascual, S. Palumbi, O. J. Reichman, A. Simons, A. Townsend, and M. Turner. 2004. Ecology for a crowded planet. *Science* 304:1251–1252.

Palmer, M. A., and S. Filoso. 2009. Restoration of ecosystem services for environmental markets. *Science* 325:575–576.

Pickett, S. T. A., and M. J. McDonnell. 1989. Changing perspectives in community dynamics—a theory of successional forces. *Trends in Ecology and Evolution* 4:241–245.

Pickett, S. T. A., and V. T. Parker. 1994. Avoiding the old pitfalls: opportunities in a new discipline. *Restoration Ecology* 2:75–79.

Pyke, D. A., J. E. Herrick, P. Shaver, and M. Pellant. 2002. Rangeland health attributes and indicators for qualitative assessment. *Journal of Range Management* 55:584–597.

Ruiz-Jaen, M. C., and T. M. Aide. 2005. Restoration success: how is it being measured? *Restoration Ecology* 13:569–577.

Sanderson, E. W., M. Jaiteh, M. A. Levy, K. H. Redford, A. V. Wannebo, and G. Woolmer. 2002. The human footprint and the last of the wild. *Bioscience* 52:891–904.

Seastedt, T. R., R. J. Hobbs, and K. N. Suding. 2008. Management of novel ecosystems: are novel approaches required? *Frontiers in Ecology and the Environment* 6:547–553.

[SERI] Society for Ecological Restoration International Science Policy Working Group. 2004. The SER international primer on ecological restoration. Tucson, AZ, USA: Society for Ecological Restoration International. Available at: http://ser.org. Accessed 25 May 2012.

Sheley, R., J. James, B. Smith, and E. Vasquez. 2010. Applying ecologically based invasive-plant management. *Rangeland Ecology & Management* 63:605–613.

Sheley, R. L., J. J. James, E. A. Vasquez, and T. J. Svejcar. 2011. Using rangeland health assessment to inform successional management. *Invasive Plant Science and Management* 4:356–367.

Shindler, B., R. Gordon, M. W. Brunson, and C. Olsen. 2011. Public perceptions of sagebrush ecosystem management in the Great Basin. *Rangeland Ecology & Management* 64:335–343.

Shore, D. 1997. The Chicago wilderness and its critics. II. Controversy erupts over restoration in the Chicago area. *Restoration and Management Notes* 15:25–31.

[SRM] Society for Range Management. 1995. New concepts for assessment of rangeland condition. *Journal of Range Management* 48:271–282.

SUDING, K. N. 2011. Toward an era of restoration in ecology: successes, failures, and opportunities ahead. *Annual Review of Ecology and Systematics* 42:465–487.

SUDING, K. N., K. L. GROSS, AND G. R. HOUSEMAN. 2004. Alternative states and positive feedbacks in restoration ecology. *Trends in Ecology and Evolution* 19:46–53.

SUDING, K. N., AND R. J. HOBBS. 2008. Threshold models in restoration and conservation: a developing framework. *Trends in Ecology and Evolution* 24:271–279.

TANAKA, J. A., M. BRUNSON, AND L. A. TORRELL. 2011. A social and economic analysis of rangeland conservation practices. *In:* D. D. Briske [ED.]. Conservation benefits of rangeland practices: assessment, recommendations, and knowledge gaps. Washington, DC, USA: USDA-NRCS. p. 371–422.

VAN MARWIJK, R. B. M., B. H. M. ELANDS, J. K. KAMPEN, S. TERLOUW, D. G. PITT, AND P. OPDAM. Public perceptions of the attractiveness of restored nature. *Restoration Ecology* (in press).

VON WEHRDEN, H., J. HANSPACH, P. KACZENSKY, J. FISCHER, AND K. WESCHE. 2012. Global assessment of the non-equilibrium concept in rangelands. *Ecological Applications* 22:393–399.

WHISENANT, S. G. 1999. Reparing damanged wildlands: a process-oriented, landscape-scale approach. Cambridge, UK: Cambridge University Press. 312 p.

WHITE, P. S., AND J. L. WALKER. 1997. Approximating nature's variation: selecting and using reference information in restoration ecology. *Restoration Ecology* 5:338–349.

WILLIAMS, B. K. 2011. Passive and active adaptive management: approaches and an example. *Journal of Environmental Management* 92:1371–1378.

WILLIAMS, B. K., M. J. EATON, AND D. R. BREININGER. 2011. Adaptive resource management and the value of information. *Ecological Modelling* 222:3429–3436.

YOUNG, T. P. 2000. Restoration ecology and conservation biology. *Biological Conservation* 92:73–83.