REVIEW

Habitat Restoration—Do We Know What We're Doing?

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Abstract

The term "habitat restoration" appears frequently in conservation and landscape management documents but is often poorly articulated. There is a need to move to a clearer and more systematic approach to habitat restoration that considers appropriate goals linked to target species or suites of species, as well as the ecological, financial, and social constraints on what is possible. Recommendations for particular courses of action need to be prioritized so that restoration activities can achieve the best result possible within these constraints. There is unlikely to be a generic set of recommendations that is applicable everywhere because actions need to be matched to the particulars of site and situation. However, there is a generic set of questions that can be asked, which can help guide the process of deciding which restoration actions are most important and contribute most to the reestablishment of desirable habitat characteristics within a given project area.

Key words: financial constraints, goal setting, limiting resources, prioritization, social constraints, target species.

Introduction

"Habitat restoration" is a frequently used term that appears in a variety of arenas. The term covers the general topic of restoring ecosystems for the specific purpose of providing habitat—either for the individual species or for the entire suite of species likely to be found in an area. It is also used more broadly to represent the restoration of native plant communities (e.g., Gilbert & Anderson 1998). Increasing the amount of habitat present in a given area is often a primary motivation for undertaking restoration, particularly where extensive ecosystem fragmentation and modification have taken place (e.g., Hobbs & Lambeck 2002; Lambeck & Hobbs 2002). However, in many cases, little attention is given to deciding what restoring "habitat" actually means: what constitutes habitat and what are its essential components? There appears to be a continuum of expectations around this issue, with some projects aiming at, for instance, restoring "forest," and others focusing on specific structural elements of the forest, on important forest processes, or on factors that benefit target species.

Interestingly, the idea of "habitat restoration" is less prevalent within the broader thinking of restoration ecologists; for instance, the Society for Ecological Restoration (SER) Primer (SER International Science & Policy Working Group 2004) only mentions the word habitat three times. In the introduction to a special section on "Wildlife Habitat and Restoration," Morrison (2001*a*) noted that the application of principles from wildlife ecology to restoration has lagged behind advances related to plant ecology.

In this article, we suggest that, to date, there has been relatively little attempt to clarify exactly what is meant by the term "habitat restoration." How is habitat defined and described, how do we set goals in relation to habitat restoration, and what is possible in the face of biophysical, financial, and social constraints? We first discuss the habitat concept and ways that the definition of habitat affects the restoration process. We then describe a general process of habitat restoration that focuses on goal setting, linking goals to target species, and prioritizing actions based on the goals that have been set and the constraints that are in place.

The Habitat Concept

Two distinct usages of the term habitat have emerged in recent decades, one that is organism specific and another that is land based (Corsi et al. 2000; Miller 2000; Morrison 2001*b*). In the first instance, habitat is typically defined as an area containing the particular combination of resources and environmental conditions that are required by individuals of a given species or group of species to carry out life processes (Hall et al. 1997; Morrison et al. 1998; SER International Science & Policy Working Group 2004). Although the focus here has often been restricted to

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vegetation, this need not be the case. Abiotic resources as well as other biotic factors, such as competitors and predators, are also likely to play important roles in determining suitable conditions for a given species in a given location (Mitchell 2005), although these factors are perhaps more difficult to quantify. This definition of habitat has a long history (Hall et al. 1997; Corsi et al. 2000), but in recent decades, a second meaning has become more prevalent, whereby the term has been used to refer to areas of similar vegetation or land cover, as in the notion of "habitat types" (Daubenmire 1968).

The concept of habitat types provides a convenient framework for mapping large areas on the basis of features that are easily discerned in aerial photos or satellite images. Maps of this sort, the stock-in-trade of many projects based on geographic information systems (GIS), tend to focus our attention on the arrangement and size of patches. This may be useful in advancing our understanding of habitat selection at broad scales (Johnson 1980; Hutto 1985) or in identifying potential restoration sites in a landscape. However, attempts to define landscape-scale restoration priorities based on habitat types or vegetation cover, pattern metrics (e.g., fragmentation indices), and vague objectives (e.g., biodiversity conservation) pose real obstacles to effective habitat restoration.

Broad-scale typological characterizations of habitat are of limited use in guiding the particulars of restoration projects. This is because the resources or conditions that directly contribute to the well-being of a species may not exhibit a strong correlation with surrogate variables, such as patch area or dominant vegetation type (Mitchell & Powell 2003). For example, a categorical land-cover map for a landscape in the Midwestern Unites States may depict an extensive patch of grassland habitat but will not provide detailed enough information to tell which grassland-obligate bird species would find suitable conditions there. These species vary in their response to vegetation structure (Fig. 1), yet the vegetation within a given polygon or patch on such a map is treated as though it were uniform. It will also be impossible to tell if prairie-obligate butterflies are likely to occur in such an area because the assumption of uniformity would not reveal the presence, amount, or distribution of host plants or nectar sources on which these species depend.

Thus, when the goal is to improve conditions for one or more species, restoration must be guided by an organism-based consideration of habitat. A land-based conceptualization will not suffice to identify the requisite biotic and abiotic factors that need to be restored.

Goals for Habitat Restoration

Given the above considerations, how might we go about setting appropriate goals for habitat restoration? Habitat restoration projects vary greatly in scale, ranging from small urban restorations aiming to restore patches of native plant species through landscape-scale projects that aim to counteract the impacts of habitat fragmentation by increasing the amount and connectivity of habitat over broad areas (e.g., Dilworth et al. 2000; McDonald 2004). In all cases, however, the level of success achieved will depend on a careful consideration and clear statement of the project's goals.

Goals are derived from a complex mix of ecological, social, historical, and philosophical viewpoints (Hobbs 2004, 2007) but, in many cases, are not formulated in such a way as to guide effective habitat restoration. Often, the stated goals relate to restoring a system back to some former structure and/or composition based either on historical information or on nearby reference ecosystems

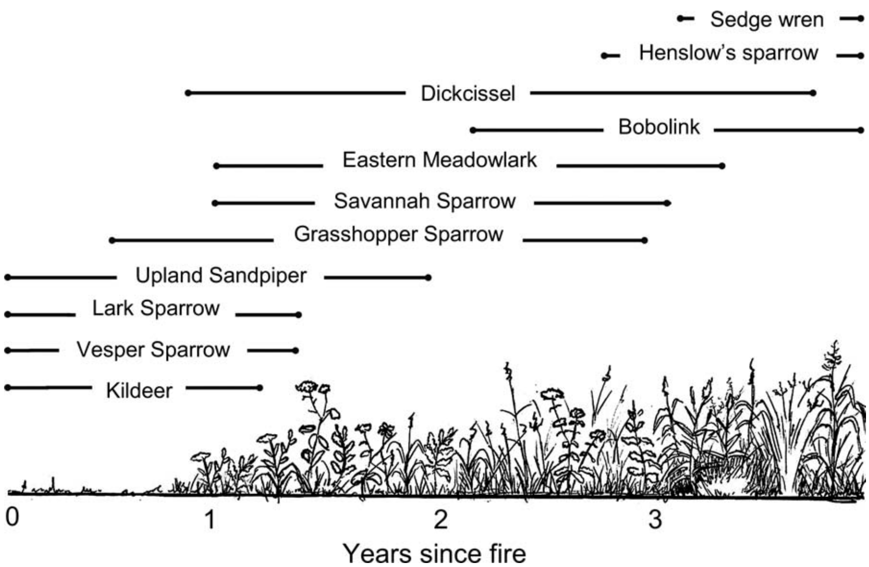

Figure 1. Use of prairie habitats in the central United States by grassland-obligate bird species, based on Poole and Gill (2002).

(e.g., Egan & Howell 2001). Similarly, for broader landscape-scale projects, the goal of restoration is often simply the provision of more of what is already there. Too often, there is not a rigorous assessment of the degree to which "what is already there" (or what we assume was there historically) meets the needs of the species that the restoration is intended to help.

Figure 2 summarizes the key set of considerations that need to be taken into account when embarking on a habitat restoration project. These include determining the target species of the restoration, deciding on the key habitat elements to be restored, and assessing the landscape context. In this article, we focus mainly on the first two of these issues but do not discount the importance of landscape-scale concerns.

Identifying a focal or target species or group of species must necessarily be the first step in habitat restoration; their requirements will thereafter serve to guide the process. This choice will maximize conservation benefits if it is made in the context of regional goals (Dale et al. 2000; Scott et al. 2001; Groves et al. 2002). To do otherwise will likely result in a piecemeal approach that greatly diminishes prospects for population viability of the target species over the long term.

Once an appropriate focal species or group has been identified, the next objective is to identify the biotic and abiotic resources that are required by the species to persist. In some instances, identifying resources must be preceded by deciding on the life stage or process that the habitat restoration is intended to accommodate. Some species may complete their life cycles in one contiguous area, whereas others may breed in one habitat, forage in another, and overwinter in yet another. In either case, it will be necessary to provide enough resources (including space) to support a viable population, whether this is accomplished solely in the area to be restored or in combination with existing habitat (Smallwood 2001).

Ensuring availability of resources through time may also be an issue. The nature of the resource will define the temporal scale that must be considered. Standing dead trees, for example, may serve as suitable nesting and feeding sites for snag-dependent species over several years, providing the trees are of an appropriate size and decay status, and occur at the proper density (George & Zack 2001). In other cases, the duration of availability for a given resource is more fine grained. For instance, the honey possum (*Tarsipes rostratus*), a small nectivourous marsupial in southwestern Australia, requires a constant supply of nectar throughout the year (Wooller et al. 1999). Given the species' small size and lack of long-distance movement capability, meeting this requirement depends on the presence of a suite of plant species that differ in their phenologies so that something is flowering in the area year round.

Resource availability will depend on landscape connectivity for species requiring multiple habitats, and this becomes a key issue, especially in areas dominated by human activities (Beier & Noss 1998; Debinski & Holt 2000; Hobbs 2002). If the distance between habitats is

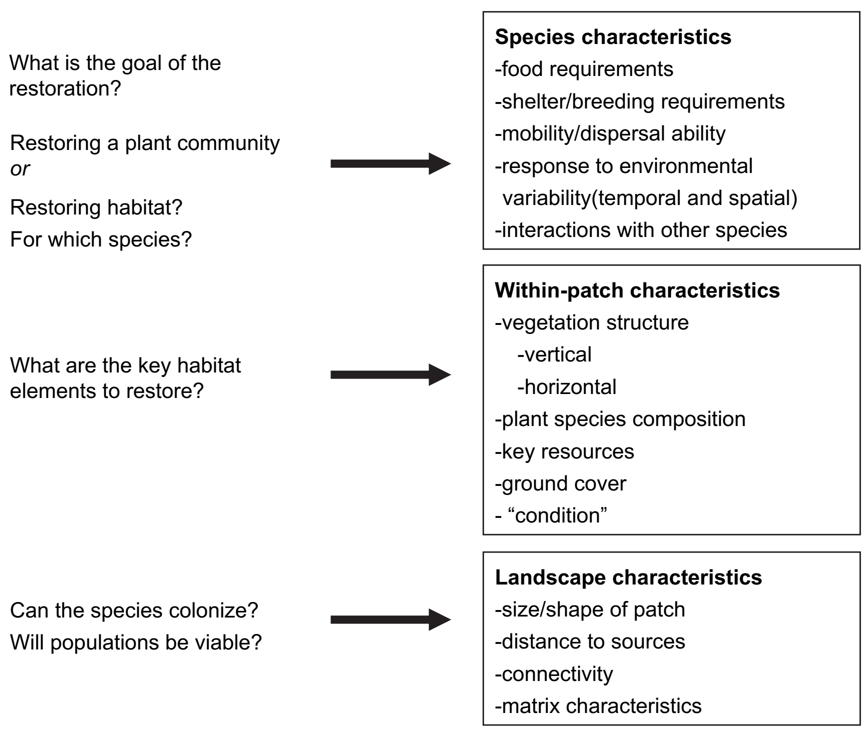

Figure 2. Key considerations when setting goals for habitat restoration projects.

short relative to the dispersal capability of the target species, it may only be necessary to provide structural features that are similar to those in the remnants. Additional resources may also be required if the dispersal capability of the focal species is limited relative to the distance that must be covered.

Constraints on Restoration

The other aspect of setting goals relates to ensuring that they are realistic given the constraints within which the restoration has to take place. Here, we consider these constraints in three categories—ecological, economic, and social (Fig. 3). Ecological constraints set limits on what is possible based on the biophysical realities of the site and its surroundings. Within the broader context of what is physically possible, both financial and social constraints set limits on the scope of work that can be done. Furthermore, available funding will be limited by social constraints and public attitudes in this regard will be influenced by the perceived "payoff" for a given expenditure on restoration.

Ecological Constraints

It is a truism that the distribution of species and ecosystems across the globe is closely linked to an array of climatic, geological, and soil parameters at all scales (e.g., Holdridge 1967; Box 1996; Bailey 1998). Hence, most species and ecosystems occur within relatively well-defined climatic envelopes and are tied either directly or indirectly to particular soil conditions. Restoration generally aims to work within the same set of environmental constraints; for instance, at a crude level, one would not try to restore a rainforest in a desert.

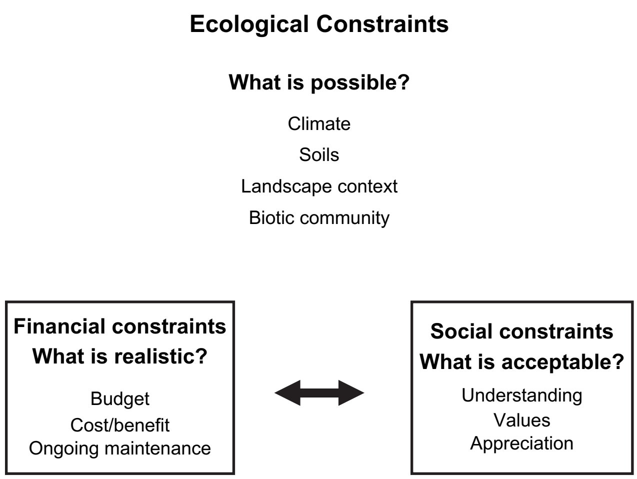

Figure 3. Three types of constraints on habitat restoration. Ecological factors ultimately constrain what is possible, then what is actually achieved becomes a function of financial and social factors, both of which will tend to influence one another.

However, the fact that restoration is generally taking place following some form of environmental degradation means that the original set of environmental conditions has been modified in some way. If the level of degradation is severe, an area may no longer be suitable for species that once occurred there. For example, soils in some parts of Los Angeles have experienced such high levels of heavy metal deposition from automobile exhaust that restoring native plants there is no longer an option (Woodward 2005).

Suitability may also be affected by changes in land use and land cover. As mentioned above, habitat types may be useful in characterizing the surrounding landscape and thus identifying upper constraints on what is actually possible in restoration locally. Such constraints will be a function of the types and juxtaposition of habitats and land use, and the particular sensitivities of the species in question. Landscapes with a higher percentage of natural land cover are in general more likely to support native species that are of conservation concern compared with those in which intensive human land uses predominate (Noss & Cooperrider 1994). Having said this, restorations in areas with relatively little native land cover remaining may still have value for conservation (Miller & Hobbs 2002; Miller 2005, 2006).

It is important to note that the relationship between the amount of suitable habitat present in a landscape and the abundance of a given species may not be linear. Numerous species have been shown to exhibit thresholds in their response to overall habitat area, below which they tend to disappear regardless of the quality of the habitat that remains (Andrén 1994; Bissonette et al. 1997; Mladenoff et al. 1999). Unless such thresholds have been previously detected, however, it will likely be difficult to identify them a priori (Miller et al. 2004). In lieu of empirical data for a given situation, Andrén (1994) has shown that many species tend to be absent in landscapes where habitat loss exceeds 70% and this figure could be used as a general guideline.

Finally, another factor to be considered is the increasing rate of change in environmental parameters caused by human-induced shifts in climate and land use, and the growing number of invasive species present in many ecosystems. Harris et al. (2006) have recently reviewed the likely implications of global climate change for ecological restoration, and several recent accounts highlight the need to consider invasive species as an increasingly integral component of many ecosystems (e.g., Low 1999; Hobbs et al. 2006). These changed conditions present many conundrums for conservation and restoration, exemplified by the current debate in the western United States over the relative risks and values of saltcedar (*Tamarix* spp.), an invasive plant species that disrupts hydrologic and riparian processes on one hand, but provides critical habitat for a threatened species on the other (Anderson 1998; Burrows 1998; Zavaleta 2000; Cohn 2005). In this and similar cases, if restoration requires the removal of the invasive vegetation, mechanisms must also be in place for simultaneously providing alternative resources for species that have come to depend on it.

An across-the-board emphasis on removing exotic vegetation may be counter productive, however, as instances have been documented where the net effects of these species on a given system are neutral or even beneficial. For instance, Thacker (2004) reports that 14 of 32 native butterfly species in Davis, California rely completely on exotic plants as hosts. In fact, such plants provided alternative resources for these species when their ancestral home, a nearby marsh, was converted to human uses. Indirect effects of exotic vegetation must also be considered. Again using the Davis example, one butterfly species exclusively uses the only species of native mistletoe in the area, yet the abundance of this key host plant stems from the fact that many non-native trees planted in the town are particularly susceptible to being parasitized by it.

Financial Constraints

It could be argued that there are many goals that become attainable with enough money, but in the majority of cases, finances are limiting and it is essential to determine the greatest gain per unit of investment. Although ecological constraints ultimately set limits on what is possible, financial constraints set limits on what is realistic. Here, we suggest that it is important to consider not only what can be achieved with different levels of funding but also what the shape of the relationship between costs and gains in habitat quality are under different scenarios (Fig. 4). This clarifies what may or may not be realistic in a given situation and, indeed, may offer opportunities to extend what is realistic by more careful assessment of what needs to be done and when.

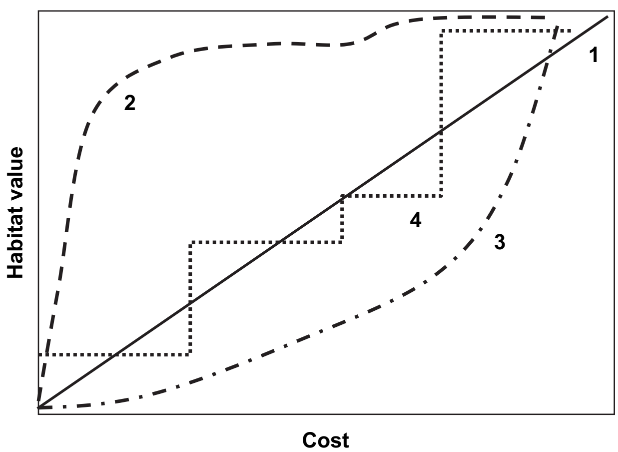

Figure 4. Value of restored habitat versus the financial input to the restoration project for a number of different scenarios. (1) Habitat value increases linearly with the amount spent on the restoration; (2) restoring a high proportion of the desired habitat value is achieved relatively cheaply, but achieving further small additions to habitat value becomes increasingly expensive; (3) relatively little value is restored until considerable expenditure is invested; (4) habitat value increases in a stepwise way in response to the need for expenditure to overcome particular biotic or abiotic thresholds.

An unstated assumption might be that the value of restored habitat increases linearly with the amount spent on the restoration (Fig. 4, line 1). However, it seems more likely that this relationship can assume a number of alternative forms. In some cases, restoring a high proportion of the desired habitat value may be achieved relatively cheaply, but at some point even small improvements become disproportionately expensive (Fig. 4, line 2). An example of this would be where most of the critical resources are provided by a few key plant species, which are relatively easy to reestablish. However, additional species may be more difficult to restore, and hence, any additional habitat value they provide may cost substantially more. Alternatively, relatively few benefits accrue from restoration efforts until considerable expenditure is invested, for instance, in earthworks or soil remediation activities (Fig. 4, line 3; e.g., Zentner et al. 2003). Finally, habitat value may increase in a stepwise fashion in response to the need for expenditure to overcome successive biotic or abiotic thresholds (Fig. 4, line 4; Hobbs & Norton 1996; Whisenant 1999, 2002; Hobbs & Harris 2001). This might be the most realistic scenario in many cases, where a series of relatively discrete management actions is required to achieve the reestablishment of different habitat elements (e.g., fencing out domestic stock, soil conditioning, replanting key species).

Again referring to the earlier example from the Midwestern Unites States, creating suitable vegetation structure for grassland bird species may be relatively inexpensive, whereas restoring the plant compositions of native prairies that some butterfly species require could easily exceed $4000/ha (US dollars; Snyder et al., unpublished data). Grasslands will also require frequent and ongoing management to maintain suitable habitat (Packard & Mutel 1997). Recognizing which of these scenarios applies to a given restoration project is a key step in deciding the types of activities that are required and the level of investment necessary to achieve desired outcomes.

Social Constraints

Whereas ecological constraints define what is possible and financial constraints determine what is realistic, social constraints will determine whether a given habitat restoration project is acceptable. Clearly, social and financial constraints are inter-related. Funding levels may depend on public acceptance of a project, whereas the degree to which the public embraces the restoration is likely to be a function of the ratio between costs and perceived benefits.

Efforts to restore habitat may be seriously hampered by an unanticipated public backlash (Gobster 2000; Van Driesche & Van Driesche 2002). Negative reactions to well-intentioned projects may stem from the failure of environmental scientists to reconcile their own assessment of what actions are necessary with public perceptions and values. As Hull and Robertson (2000) noted, value judgments are inherent in restoration prescriptions, however, strong the underlying science may be, and the "best" course of action is always negotiable. What appears to an ecologist as habitat with the requisite structural and compositional heterogeneity to accommodate a suite of native species may strike a private landowner as messy, weedy, or neglected (Nassauer 1995, 1997). Conversely, an area thick with invasive trees and shrubs of relatively little habitat value may be much appreciated by some urban dwellers for its "natural" or "aesthetic" qualities. In such cases, successful habitat restoration must be predicated on communication of project goals and underlying rationale, as well as open dialogue to gauge public understanding and acceptance.

The importance of public acceptance of habitat restoration increases with the intensity of human settlement in the surrounding landscape. In landscapes dominated by human activity, local support for restoration projects can translate into social buffers (Van Driesche & Van Driesche 2002), which can greatly enhance habitat quality and increase effective habitat area. For example, a community that understands the objectives and merit of a project may be more willing to help reduce deleterious edge effects that often result from human activities, or participate in ongoing stewardship once the project has been completed. Fortunately, ecologists are beginning to recognize the key role that social values play in determining the outcomes of restoration (Davis & Slobodkin 2004; Hobbs et al. 2004). Social scientists and design professionals have much to offer in developing frameworks for involving the public in goal setting and enhancing the prospects for acceptance and support of restoration projects.

Setting Priorities

Once a restoration goal is agreed upon, how can it be best achieved? The above set of considerations implies that a clear prioritization of activities is required, both in terms of what is possible ecologically, most efficient financially, and socially acceptable. However, this appears to be largely missing from recent attempts to identify key activities in habitat restoration, or more generally in conservation management of altered landscapes (e.g., Recher 1993; Fischer et al. 2006). As one example, Marzluff and Ewing (2001) posed a set of key considerations in habitat restoration aimed at avian conservation in urbanizing landscapes. These included a mixture of within-patch and landscape concerns, as well as socioeconomic factors, and ranged from relatively straightforward prescriptions such as increasing foliage height diversity within fragments to suggestions relating to very complex regulatory and educational programs.

We applaud efforts to provide guidance by constructing such lists, which can be helpful in pointing out the array of factors, which need to be considered. Nevertheless, they can also be quite confusing and lacking utility to managers dealing with on-ground decision-making. To-do lists may ultimately be counter productive if there is not an attempt to prioritize actions or differentiate activities that fall within the sphere of influence of managers from those that are more appropriately addressed by policymakers or at different organizational levels. For instance, it may be relatively easy for local managers to institute a habitat restoration program within particular fragments, but it would be unrealistic to expect them to develop a whole new educational paradigm. Unrealistic expectations of what is possible may lead to disenchantment among practitioners or the general public and make further restoration actions less likely.

Prioritization is thus a key element in developing effective habitat restoration programs, spawning a number of questions that need to be asked, as follows:

(1) What is the range of potential management options available?
(2) Which options are essential, which are desirable, and which are unnecessary?
(3) What is it most important to do first?
(4) Are there some things, which need to be done, without which it is not worth doing any of the others? This is particularly relevant when considering whether biotic or abiotic thresholds have been crossed, which require active intervention.
(5) Will some recommendations cost a lot more than others?
(6) Are some actions likely to be seen in a negative light by neighboring landowners, thus requiring additional communication in advance?
(7) What are the consequences of partial fulfillment of the recommendations (either the individual recommendations or the full set)?
(8) If partial fulfillment of recommendations will not actually achieve the goals set for the restoration project, is there any point in embarking on it in the first place?

The answers to these questions are likely to be highly context specific and there may be no generalizable list of recommendations possible beyond the broad set provided, for instance, by Recher (1993) and Fischer et al. (2006). However, we suggest that trying to answer this set of preliminary questions as rigorously as possible will provide a useful framework for assessing what needs to be done and how best to use available resources. This may be more useful than attempting to produce a generic "laundry list" of important things to do.

The process of habitat restoration can be viewed as an attempt to move a given area from a degraded state of relatively low habitat quality toward a target of improved condition (Fig. 5). Assessment of the current condition

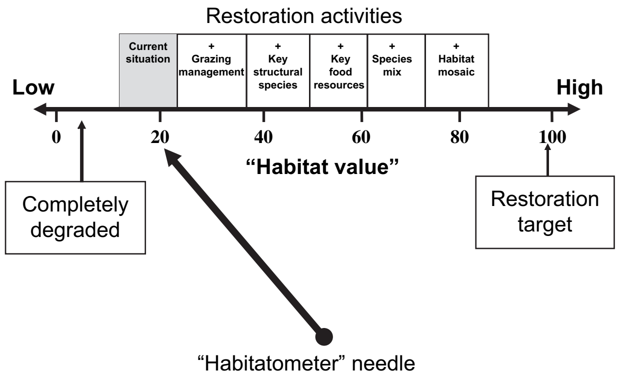

Figure 5. Habitat restoration entails assessing the current status and moving the "habitatometer"needle progressively toward higher habitat quality. This involves identifying the types of restoration/management actions required and the order in which these need to be carried out, in the light of the ecological and financial constraints in place. Hypothetical examples of possible restoration activities are given here.

relative to the target is followed by consideration of which management options are likely to increase habitat quality. The question of how habitat quality is measured is, of course, a key concern. As indicated earlier, this usually has to be related to the requirements of the particular species of concern, although indices such as habitat complexity scores (Catling & Burt 1995) could be used where it has been established that these provide meaningful insights into an area's suitability for a particular set of species.

Clearly, we will not always have a good understanding of the precise relationship between the particular management actions and the degree of increase in habitat quality. However, thinking about things in this way at least provides a logical method for sorting out what might be useful to do. In addition, cost factors may render some actions unrealistic or unachievable under current conditions. In the case where essential actions are unachievable, it is probably best not to embark on the restoration effort at present, recognizing that circumstances may change and technological or other advances may render the action more achievable in the future.

Considerations and Caveats

Changing climatic conditions and biotic communities pose complex challenges to efforts aimed at restoring habitat. Increasing evidence indicates that some species are almost certainly not in equilibrium with the current climate (e.g., Davis 1986; Campbell & McAndrews 1993; Swetnam 1993; Johnstone & Chapin 2003). Although it would seem that local conditions must have been suitable for the establishment of a species if it currently occurs there, it does not necessarily follow that conditions remain suitable, especially for very long-lived species. For example, adult persistence of a given tree species in an area is not necessarily a reliable indicator of ongoing potential to include them in a restoration.

Further, when identifying specific habitat features to restore, one must be mindful of the fact that some faunal species may currently occupy suboptimal habitat. Animal species may be excluded from their preferred habitats by a range of factors such as competition from other species (native or non-native), predation by introduced predators, or simple lack of preferred habitat. For example, numerous species that were once common in the highly productive grasslands of North America were displaced by conversion to agriculture uses and now tend to occur on expansive, but relatively unproductive lands in the semiarid west and southwest (Huston 2005). Conversely, human-influenced shifts in biotic communities often result in novel combinations of species or elevated numbers of predators or competitors. Such biotic mixing may, in turn, constrain some species in their use of particular habitats. For example, in Australia, the Eastern Bristlebird (*Dasyornis brachypterus*) was once thought of as a forest specialist, but following predator removal programs in some areas is now thought of as a generalist species (D. Lindenmeyer, The Australian National University, personal communication, 2005). Therefore, caution is warranted when inferring habitat requirements or quality from current population densities (Van Horne 1983; Bock & Jones 2004).

Given the dynamic nature of habitats, it will also be necessary to provide for population movement as resources diminish locally, as successional dynamics come into play, or in the event of disturbance. In this same vein, unless the target species is translocated to the restored habitat, a key consideration will be the landscape context of the site and how that might influence passive dispersal (Scott et al. 2001). The wide range of factors that can potentially affect colonization of a restored habitat and the persistence of the target species underscores that one of the key objectives in the planning process is ensuring that a well-designed monitoring program can be implemented once the actual restoration is complete. To be truly effective, such a program must focus on the most direct measure of the status of the target species population dynamics (Block et al. 2001).

Conclusions

In the title of this article, we asked the question "Do we know what we are doing?" in relation to habitat restoration. We suggest that the answer in many situations is "Not really." What can we do to improve matters? The caveats discussed in the previous section indicate that there are never simple answers to questions surrounding habitat restoration. Further, we maintain that there is unlikely to be a generic set of recommendations, which is applicable everywhere, but rather that actions need to be matched to the particulars of site and situation. Having said this, however, we feel that there is a general process that can help to identify which restoration actions are most important and have the greatest potential to contribute to the return of desirable habitat conditions within a given project area. The process we have proposed involves setting appropriate goals, linking these to target species, and taking into account the ecological, financial, and social constraints that are in place. Our approach focuses on setting priorities for action based on a systematic assessment of what is best to do where and in what order. If this type of approach is adopted, we argue that we will be in a much better position to "know what we are doing."

The need for effective habitat restoration is growing, but we must move beyond simply drawing lines on maps and calling the spaces "restored habitat"—we need to give much greater consideration to how we actually fill in these spaces to achieve the goals that are set. Our article represents an attempt to provide a means to do this, and we welcome further discussion and development of these ideas in the spirit of achieving increased restoration capability in the future.

Implications for Practice

- The first step in habitat restoration is identifying the target species that the effort is intended to benefit.
- Once the target species is identified, habitat restoration focuses on the conditions, including key resources, necessary for the species to persist.
- Setting realistic restoration goals must be predicated on consideration of ecological, financial, and social constraints that are in place.
- There is unlikely to be a generic set of restoration actions that is applicable everywhere.

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LITERATURE CITED

Anderson, B. 1998. The case for salt cedar. Restoration & Management Notes **16:**130–134.

Andrén, A. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. Oikos **71:**355–366.

Bailey, R. G. 1998. Ecoregions: the ecosystem geography of the oceans and continents. Springer-Verlag, New York.

Beier, P., and R. F. Noss. 1998. Do habitat corridors provide connectivity? Conservation Biology **12:**1241–1252.

Bissonette, J. A., D. J. Harrison, C. D. Hargis, and T. G. Chapin. 1997. The influence of spatial scale and scale-sensitive properties on habitat selection by American marten. Pages 368–385 in J. A. Bissonette, editor. Wildlife and landscape ecology: effects of pattern and scale. Springer-Verlag, New York.

Block, W. M., A. B. Franklin, J. P. Ward, J. L. Ganey, and G. C. White. 2001. Design and implementation of monitoring studies to evaluate the success of ecological restoration on wildlife. Restoration Ecology **9:**293–303.

Bock, C. E., and Z. F. Jones. 2004. Avian habitat evaluation: should counting birds count? Frontiers in Ecology and the Environment **2:**403–410.

Box, E. O. 1996. Plant functional types and climate at the global scale. Journal of Vegetation Science **7:**309–320.

Burrows, C. 1998. The case for wholesale removal. Restoration & Management Notes **16:**135–139.

Campbell, I. D., and J. H. McAndrews. 1993. Forest disequilibrium caused by rapid Little Ice Age cooling. Nature **366:**336–338.

Catling, P. C., and R. J. Burt. 1995. Studies of the ground-dwelling mammals of eucalypt forests in south-eastern New South Wales: the effect of environmental variables on distribution and abundance. Wildlife Research **22:**669–685.

Cohn, J. P. 2005. Tiff over tamarisk: can a nuisance be nice, too? BioScience **55:**648–656.

Corsi, F., J. de Leeuw, and A. Skidmore. 2000. Modeling species distribution with GIS. Pages 389–424 in L. Boitani and T. K. Fuller, editors. Research techniques in animal ecology: controversies and consequences. Columbia University Press, New York.

Dale, V. H., S. Brown, R. A. Haeuber, N. T. Hobbs, N. Huntly, R. J. Naiman, W. E. Riebsame, M. G. Turner, and T. J. Valone. 2000. Ecological principles and guidelines for managing the use of land. Ecological Applications **10:**639–670.

Daubenmire, R. 1968. Plant communities. Harper & Row, New York.

Davis, M. B. 1986. Climatic instability, time lags and community disequilibrium. Pages 269–284 in J. Diamond and T. J. Case, editors. Community ecology. Harper & Row, New York.

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

Debinski, D. M., and R. D. Holt. 2000. A survey and overview of habitat fragmentation experiments. Conservation Biology **14:**342–355.

Dilworth, R., T. Gowdie, and T. Rowley. 2000. Living landscapes: the future landscapes of the Western Australian wheatbelt? Ecological Management and Restoration **1:**165–174.

Egan, D., and E. A. Howell, editors. 2001. The historical ecology handbook: a restorationist's guide to reference ecosystems. Island Press, Washington, D.C.

Fischer, J., D. B. Lindenmayer, and A. D. Manning. 2006. Biodiversity, ecosystem function, and resilience: ten guiding principles for commodity production landscapes. Frontiers in Ecology and Environment **4:**80–86.

George, T. L., and S. Zack. 2001. Spatial and temporal considerations in restoring habitat for wildlife. Restoration Ecology **9:**272–279.

Gilbert, O. L., and P. Anderson. 1998. Habitat creation and repair. Oxford University Press, Oxford, United Kingdom.

Gobster, P. H. 2000. Restoring nature: human actions, interactions, and reactions. Pages 1–20 in P. H. Gobster and R. B. Hull, editors. Restoring nature. Island Press, Washington, D.C.

Groves, C. R., D. B. Jensen, L. L. Valutis, K. H. Redford, M. L. Shaffer, J. M. Scott, J. V. Baumgartner, J. V. Higgins, M. W. Beck, and M. G. Anderson. 2002. Planning for biodiversity conservation: putting conservation science into practice. Bioscience **52:**499–512.

Hall, L. S., P. R. Krausman, and M. L. Morrison. 1997. The habitat concept and a plea for standard terminology. Wildlife Society Bulletin **25:**173–182.

Harris, J. A., R. J. Hobbs, E. Higgs, and J. Aronson. 2006. Ecological restoration and global climate change. Restoration Ecology **14:**170–176.

Hobbs, R. J. 2002. Habitat networks and biological conservation. Pages 150–170 in K. J. Gutzwiller, editor. Applying landscape ecology in biological conservation. Springer-Verlag, New York.

Hobbs, R. J. 2004. Restoration ecology: the challenge of social values and expectations. Frontiers in Ecology and the Environment **2:**43–44.

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

Hobbs, R. J., S. Arico, J. Aronson, J. S. Baron, P. Bridgewater, V. A. Cramer, et al. 2006. Novel ecosystems: theoretical and management aspects of the new ecological world order. Global Ecology and Biogeography **15:**1–7.

Hobbs, R. J., M. A. Davis, L. B. Slobodkin, R. T. Lackey, W. Halvorson, and W. Throop. 2004. Restoration ecology: the challenge of social values and expectations. Frontiers in Ecology and the Environment **2:**43–48.

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., and R. J. Lambeck. 2002. Landscape management and restoration: new models for integrating science and action. Pages 412–430 in J. Liu and W. W. Taylor, editors. Integrating landscape ecology into natural resource management. Cambridge University Press, Cambridge, United Kingdom.

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

Holdridge, L. R. 1967. Life zone ecology (revised edition). Tropical Science Centre, San Jose, Costa Rica.

Hull, R. B., and D. P. Robertson. 2000. The language of nature matters: we need a more public ecology. Pages 97–118 in P. H. Gobster and R. B. Hull, editors. Restoring nature. Island Press, Washington, D.C.

Huston, M. A. 2005. The three phases of land-use change: implications for biodiversity. Ecological Applications **15:**1864–1878.

Hutto, R. L. 1985. Habitat selection by nonbreeding, migratory land birds. Pages 455–476 in M. L. Cody, editor. Habitat selection in birds. Academic Press, Inc., San Diego, California.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology **61:**65–71.

Johnstone, J. F., and F. S. Chapin. 2003. Non-equilibrium succession dynamics indicate continued northern migration of lodgepole pine. Global Change Biology **9:**1401–1409.

Lambeck, R. J., and R. J. Hobbs. 2002. Landscape and regional planning for conservation: issues and practicalities. Pages 360–380 in K. Gutzwiller, editor. Concepts and applications of landscape ecology in biological conservation. Springer Verlag, New York.

Low, T. 1999. Feral future. Viking, Ringlwood, Victoria, Australia.

Marzluff, J. M., and K. Ewing. 2001. Restoration of fragmented landscapes for the conservation of birds: a general framework and specific recommendations for urbanizing landscapes. Restoration Ecology **9:**280–292.

McDonald, T. 2004. The Wilderness Society's WildCountry program. Ecological Management and Restoration **5:**87–97.

Miller, C. J. 2000. Vegetation and habitat are not synonyms. Ecological Management and Restoration **1:**102–104.

Miller, J. R. 2005. Biodiversity conservation and the extinction of experience. Trends in Ecology & Evolution **20:**430–434.

Miller, J. R. 2006. Restoration, reconciliation, and reconnecting with nature. Biological Conservation **127:**356–361.

Miller, J. R., and R. J. Hobbs. 2002. Conservation where people live and work. Conservation Biology **16:**330–337.

Miller, J. R., M. G. Turner, E. A. H. Smithwick, L. C. Dent, and E. H. Stanley. 2004. Spatial extrapolation: the science of predicting ecological patterns and processes. Bioscience **54:**310–320.

Mitchell, M. S., and R. A. Powell. 2003. Linking fitness landscapes with the behavior and distribution of animals. Pages 93–124 in J. A. Bissonette and I. Storch, editors. Landscape ecology and resource management. Linking theory with practice. Island Press, Washington, D.C.

Mitchell, S. C. 2005. How useful is the concept of habitat?—a critique. Oikos **110:**634–638.

Mladenoff, D. J., T. A. Sickley, and A. P. Wydeven. 1999. Predicting gray wolf landscape recolonization: logistic regression models vs. new field data. Ecological Applications **9:**37–44.

Morrison, M. L. 2001*a*. Introduction: concepts of wildlife and wildlife habitat for ecological restoration. Restoration Ecology **9:**251–252.

Morrison, M. L. 2001*b*. A proposed research emphasis to overcome the limits of wildlife-habitat relationship studies. Journal of Wildlife Management **65:**228–240.

Morrison, M. L., B. G. Marcot, and R. W. Mannan. 1998. Wildlife-habitat relationships. University of Wisconsin Press, Madison.

Nassauer, J. I. 1995. Messy ecosystems, orderly frames. Landscape Journal **14:**161–170.

Nassauer, J. I. 1997. Cultural sustainability: aligning aesthetics with ecology. Pages 65–83 in J. I. Nassauer, editor. Placing nature: culture and landscape ecology. Island Press, Washington, D.C.

Noss, R. F., and A. Y. Cooperrider. 1994. Saving nature's legacy. Island Press, Washington, D.C.

Packard, S., and C. F. Mutel. 1997. The tallgrass restoration handbook. Island Press, Washington, D.C.

Poole, A., and F. Gill, editors. 2002. The birds of North America. Academy of Natural Sciences, Philadelphia, Pennsylvania, and The American Ornithologists Union, Washington, D.C.

Recher, H. F. 1993. The loss of biodiversity and landscape restoration: conservation, management, survival—an Australian perspective. Pages 141–151 in D. A. Saunders, R. J. Hobbs, and P. Ehrlich, editors. Nature conservation 3: reconstruction of fragmented ecosystems. Surrey Beatty & Sons, Chipping Norton, New South Wales, Australia.

Scott, T. A., W. Wehtje, and M. Wehtje. 2001. The need for strategic planning in passive restoration of wildlife populations. Restoration Ecology **9:**262–271.

SER (Society for Ecological Restoration International Science & Policy Working Group). 2004. The SER International Primer on Ecological Restoration. Society for Ecological Restoration International, Tucson, Arizona (available from www.ser.org) accessed April 2005.

Smallwood, K. S. 2001. Linking habitat restoration to meaningful units of animal demography. Restoration Ecology **9:**253–261.

Swetnam, T. W. 1993. Fire history and climate change in giant sequoia groves. Science **262:**885–889.

Thacker, P. D. 2004. California butterflies: at home with aliens. Bioscience **54:**182–187.

Van Driesche, J., and R. Van Driesche. 2000. Nature out of place. Island Press, Washington, D.C.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management **47:**893–901.

Whisenant, S. G. 1999. Repairing damaged wildlands: a process-orientated, landscape-scale approach. Cambridge University Press, Cambridge, United Kingdom.

Whisenant, S. G. 2002. Terrestrial systems. Pages 83–105 in M. R. Perrow and A. J. Davy, editors. Handbook of ecological restoration, volume 1: principles of restoration. Cambridge University Press, Cambridge, United Kingdom.

Woodward, J. 2005. Letting Los Angeles go: lessons from feral landscapes. Landscape Review **2:**59–69.

Wooller, R. D., K. C. Richardson, and G. O. Bradley. 1999. Dietary constraints upon reproduction in an obligate pollen- and nectar-feeding marsupial, the honey possum (*Tarsipes rostratus*). Journal of Zoology, London **248:**279–287.

Zavaleta, E. 2000. Valuing ecosystem services lost to Tamarix invasion in the United States. Pages 261–302 in H. A. Mooney and R. J. Hobbs, editors. Invasive species in a changing world. Island Press, Washington, D.C.

Zentner, J., J. Glaspy, and D. Schenk. 2003. Wetland and riparian woodland restoration costs. Ecological Restoration **21:**166–173.