Adapting to global change by expanding conservation management goals beyond endpoints: towards the development of a natural practice.

Running head: Practice-based conservation goals

Nicole E. Heller¹ & Richard J. Hobbs²

1 Nicholas School of the Environment, Duke University, Durham, NC 27708
2 School of Plant Biology, University of Western Australia, Crawley, WA 6009, Australia

Communicating author: Nicole E. Heller, heller.nicole@gmail.com
Nicholas School of the Environment, PO BOX 90328, Durham NC 27708 – 0328

Keywords: ecosystem management, climate change, sustainability, naturalness, adaptation, resilience, human behavior, ethics.

Word count: 6221
Abstract

Conservation management at the start of the 21st century reflects a combination of contrasting ideas: Ideal nature is something that is both historically intact and futuristically flexible. Ideal nature is independent from humans, but because of the pervasiveness of human impacts, can only reach expression through human management. These tensions emerge in current management rationales because scientists and managers are struggling to accommodate old and new scientific and cultural thinking with the stresses of global change, while also maintaining legal mandates from the past and commitments to preservation of individual species in particular places. Here we explore how particular ideas about nature are deeply embedded in common management goals whether they are forward- or backward-looking, and show how these goals tend to create essentialisms which limit options to accommodate the dynamic response of ecosystems to global change. As an alternative we propose greater attention to the practice of management intervention, rather than to idealized ecosystem states. We suggest that more attention to the character of human interactions with other species in management is vital to increase the success of the conservation enterprise in the face of global change.
Goal setting is an integral part of conservation management. Any effort at management demands some valuation about desired conditions – a vision of how a place should be ecologically - in order to evaluate interventions or lack thereof. At the same time, conservation goals reflect varied and competing normative concepts leading to debate (Callicott et al. 1999). For example, there has been much written about the ambiguities of naturalness as a conservation objective, the appropriate metrics to evaluate naturalness, the logic of different temporal and spatial benchmarks, the categorization of different human cultures and behaviors as natural or artificial, and the legitimacy of nativeness as a category of difference (e.g. Haila 1997; Angermeier 2000; Callicott et al. 1999; Ridder 2007; Davis et al. 2011; Siipi 2011; Shackleford et al. 2013; and earlier papers). Recently, a growing number of studies are expressing additional concerns about conservation goals in light of global change. Questions have been raised as to whether commonsense concepts of nature in conservation are logical or desirable given knowledge of past variations and expected future change (e.g. Millar & Brubaker 2006; Cole & Yung 2010; Hobbs et al. 2010).

Critical inquiry into the philosophy and the feasibility of conservation goals has been influenced by at least three trends in the late 20th and early 21st century. First, there has been a progressive development of non-equilibrium concepts since the 1970s (Wallington et al. 2005). Theories about ‘the balance of nature’,
steady states, and homogenous, closed systems have been replaced with
dynamism, multiple stable states, and heterogeneous, open systems (Botkin
1990). This shift has challenged the use of historic ecosystem states as a
normative standard. Second, the increase in global anthropogenic climate
change, urbanization, and other large scale transformations of land, energy and
species have created a picture of the earth in the 21st century that is human-
dominated, uncertain, and in flux (Vitousek et al. 1997). Concerns about
ecological collapse and the role of nature in the sustainability of human societies
have provoked interpretations of conservation goals that are more functionalist
than compositional (Callicott et al. 1999). Third, increasing human population
size and economic demands has engendered greater interest in the inclusion of
humans in the production of biodiversity, and in a systems-view of the landscape
that sees humans as parts of ecosystems (Berkes 2004). This has translated into
greater inclusion of non-Western cultural knowledge, community development,
and stakeholder participation into conservation objectives. Concurrently, there
has been an increase in research devoted to improving human practices to
lessen the impacts on biodiversity outside of nature parks (e.g. Daily 2001),
especially as part of a climate adaptation strategy (Heller & Zavaleta 2009).

Our analysis here focuses on human management behavior in conservation
practice as a component of adaptation to global change. Conservation goals vary
widely and orient differently in time (Fig. 1). The juxtaposition illustrates how
conservation has come to reflect, at the start of the 21st century, a combination of
contrasting ideas. Management rhetoric seems paradoxically to ask that managers allow for change so that ecosystems can adapt, while at the same time not permit change so that systems can remain intact (i.e. not damaged or impaired). Indeed, climate change adaptation recommendations suggest that biodiversity managers intervene dramatically to resist change and maintain species populations, while at the same time broaden their notions of what belongs and what is resilient (Heller & Zavaleta 2009). Conservation managers may increasingly find themselves having to choose or find a balance between future-looking management emphasizing change, and past-looking management emphasizing persistence. Is a balance possible in practice?

In this essay, we first consider ways that particular concepts of nature are interwoven into management goals. We then ask whether goals provide sufficient flexibility to accommodate pattern and process and past and future simultaneously. Our analysis suggests that current goals focused on endpoint targets tend to create a set of essentialisms about nature that limit the options of management to accommodate global change and new ecological science. To address this limitation, we introduce a goal focused on the practice of management, which we call “natural practice” (NP). We suggest that this approach may help integrate the need for adaptation with the desire for preservation, and help to prioritize efforts, thus ultimately protecting biodiversity better on long-time scales.
Conservation is a normative discipline, based on philosophical commitments about what is good or bad (Soulé 1985). As systems shift in response to global change, how do we know which changes are “good” and which are “bad”? In the 20th century, when conservation practice was developing there was an expectation that land could be set aside and the same set of species would thrive in perpetuity as long as human disturbance was limited. Under such circumstances one could expect to measure conservation value through species compositional stability and directional succession toward a specified climax state. But this is not the case in a dynamic landscape where multiple disturbances (e.g. non-native species, fire, climate) are re-structuring the relationships among species. In many cases, today, management for particular species in a particular place requires constant human intervention (Scott et al. 2010).

Place-based nature preservation is tricky in the face of global change because the relationship between biotic community and place has become destabilized. Species move. Communities are not coordinated. Rather the parts separate and groupings are re-formed anew. New species arrive, spreading both regionally as well as trans-continentally. Spatial context and disturbance strongly affect the current state of a system and its ecological trajectory, and systems can go through sudden, unpredictable state shifts. In the current century, novelty is
widespread with non-analog climates and assemblages dotting (some would say blanketing) the planet (Hobbs et al. 2006; Williams & Jackson 2007). And while paleoecology has revealed strong turnover in species composition as a pervasive characteristic of ecosystems (Millar & Brubaker 2006; Jackson 2012), the coupled nature of individual biota and place remains a key-organizing element for conservation, restoration, and preservation.

This coupling reflects how conservation science measures valuable “nature.” There is high value placed on the sense of nature and naturalness that forms on evolutionary timescales, and outside of human design and interference (Katz 1997; Ridder 2007). Soulé (1995) distinguishes “Living nature” as “native species of plants and animals in their native settings.” Angermeier (1994) distinguishes natural diversity (naturally evolved) from artificial diversity (human generated, i.e. exotic species). These categories require judgments about species' natural histories – origin and migration stories that define nativeness. Nativeness serves as a proxy for naturalness. The time scale at which nativeness is defined varies for different management goals depending on when human disruption is located in time, but each assumes a historical-based sense of naturalness (Siipi 2004, 2008), namely that there is a period in the past that provides the best approximation of the species that evolved to constitute the natural state of the ecosystem (Fig. 1).
There are also non-historical interpretations of the naturalness concept, including normality, familiarity, and proper function (Katz 1997; Siipi 2008). However, these concepts tend toward historical interpretations as well. Siipi (2004, 2008) discusses how normality and function (similar to health) are measured by the properties of the system in comparison to an ideal; a highly designed ecosystem could be natural if it is similar in components to the ideal.

In conservation, ideal nature is historically based because it relies on concepts of pristine and native (Angermeier 1994). The focus on historical conditions reflects an implied logic between place, health and species composition (Callicott et al. 1999). If historical species assemblages are maintained, the land is healthy. If the land is healthy, historic species assemblages will be maintained. This logic seems distinctly unable to deal with a dynamic system response to global change. Global change demands that species and communities shift in response to new environmental conditions and this means ecosystems may not resemble known historical compositions. This presents a challenge. How can we visualize “intact”, “healthy” nature that does not resemble known natural histories?

**When is change adaptive?**

Given the longstanding interest in preserving natural entities and processes in conservation and the massive investment in resources needed to resist global change, it is productive to pause and ask if the ecological processes occurring on the landscape today in natural areas are the expression of nature’s autonomy?
Do fluxes in species composition observed at local scales represent the transformative evolutionary response of a complex adaptive system (Levin 1998) to global change, rather than system collapse that must be mitigated? When managers try to conserve or eliminate system parts to avoid species loss and preserve conceptual goals (e.g. integrity, naturalness), how does that affect the system dynamics at multiple scales?

We need to ask at what point does the effort to conserve or restore all the parts and relationships, as described by human agents at particular points in time (as for instance recently advocated by Clewell & Aronson 2013), undermine the resilience or self-expression of the whole? In other words, does an approach aiming to maintain current assemblages in a particular place actually militate against the adaptive behavior of individual species and the formation of assemblages that are resilient to ongoing change?

The trouble with endpoints

Goals that are focused on specific endpoints, reference states, and benchmarks create expectations about how and when ecosystems should change. Management requires human agents to work intentionally to control the degree and rate of change. This requirement for control is problematic. Worster (1995) argues that we need to protect nature specifically to preserve a diversity of change, which promotes the coexistence of many beings. He recognizes that we
can observe and record changes, but we don’t have the capacity to know “which changes are vital and which changes are deadly.” Landres (2010) argues that it is the ecosystem left entirely alone to confront global changes that serves as Aldo Leopold’s “base datum of normality, a picture of how healthy land maintains itself as an organism.” On the other hand, a hands-off approach, if applied widely, may well lead to the local or global extinction of species that are now dependent on human management (Scott et al. 2010). Balancing our desire for justice to keep species extant, with the need for humility to let nature respond autonomously to change, and our instinct toward hubris to think that we know how to intervene to protect natural processes, is a key challenge for conservation.

In order to let an ecosystem absorb global change, but remain intact, “intact” needs to be defined broadly, both spatially and temporally. How much space for broad interpretation is embedded into the various goals indicated in Fig. 1? Goals that are orientated toward the recent past are unlikely to accommodate global change if they are narrow in defining the spatial and temporal sense of what is native (Millar & Brubacker 2006; Jackson 2012). For example, the European colonization of North America was just on the heels of the coldest part of the Little Ice Age. This ecological assemblage provides a poor reference for the “natural” or “appropriate” community for the warmer 21st century. Narrow historical benchmarks demand strategies of resistance, which are unlikely to be cost effective or successful (Heller & Zavaleta 2009).
Wilderness (and related wildness) as a goal has the potential to be open-ended in what constitutes “intact” because in theory it allows an ecosystem to evolve however, as long as it is “untrammeled”. However in practice, historical species composition may be prioritized as in other past-looking management goals – in part because of the confusion raised by pervasive human impacts, especially those that are unintentional, like escaped non-native species or climate change. The updated guidelines for Wilderness Area management in the US attempt to balance at least two different ideas of nature, minimal human intervention and maintaining native ecosystems (Landres et al. 2009). This latter quality may not provide freedom to managers to interpret novel expressions of wilderness on the landscape.

At the edges of the temporal spectrum, rhetoric suggests that when scientists think across greater timescales they become oriented toward broad targets. For instance, re-wilding, the perspective that dips farthest back in time, focuses on restoring trophic complexity. Since North American megafauna are extinct, the concept is to restore the ecosystem with proxies from Africa and Asia. This provides spatial flexibility in what constitutes “nativeness” or “appropriateness”. However, there is an essentialist appeal to a particular period in history: paleo-history when large megafauna roamed North America. This period seems incompatible with the social-cultural landscape of the present (Toledo et al.)
Resilience, a common objective of future-looking management, also suggests flexibility. But in practice appeals to resilience may not loosen the grip of the past as much as one might expect. Resilience itself is not a goal. It must be defined with specificity, resilience for what, and for whom (Zavalata & Chapin 2010, Cote & Nightingale 2012)? A resilience goal requires there to be an identifiable “state”, something specific that can be made resilient. This could be a particular community type, species population, measure of diversity, or functional property. The capacity for a system to absorb change and adapt is embedded into the resilience concept providing a sense of an open-ended goal. However in practice, given the small spatial and short temporal scale of most management decisions, and legal constraints from environmental laws (such as the U.S. Endangered Species Act), resilience goals are likely to collapse into management for the persistence of specific assemblages of native biodiversity.

In recent years, some past-looking goals are being re-interpreted. For example, Dudley (2011) has redefined the concept of authenticity such that authentic ecosystems can include both the “pristine” and “radically altered,” and are judged as much on response to stress, and function, as on fidelity to historical composition. Jackson (2012) introduced “extended historical range of variation” and Millar and Brubaker (2006) proposed “re-alignment,” both of which seek to
integrate pre-histories with long-term landscape and climate trajectories. These are likely useful strategies, but still they may force more specificity about acceptable targets than is warranted.

We rarely have information to describe the processes that drive ecological and evolutionary trajectories (Fig. 1). In best cases, there is information on temporal variation in systems over long-time scales that can be used to estimate which changes are within the bounds of past ecosystem processes and which are highly unlikely (Safford et al. 2012). Still, historical information is typically coarsely resolved and rare events are likely undetected. Further, changes on the landscape today are unprecedented, and there is large uncertainty regarding future climate and land-use. These unknowns and uncertainties raise cautions about the limits of science to describe historical conditions or future trajectories with specificity.

Natural practice: expanding beyond endpoints to include process

Some key questions emerge from the discussion outlined here. What management goals are flexible enough to be adaptive while specific enough to be protective? How does one define naturalness without appeals to particular, historic species assemblages? And how does one protect individual species populations without limiting the adaptive response of ecosystems to global change? New management paradigms that can hold the differing ideas of
adaptation and preservation together require a metric of intact nature that will not become decoupled as global changes progress.

We suggest such a measure may be articulated through the practice of a relationship. As we argue above, management goals tend to create appeals to essential biotic communities and ecosystem states. This is a form of teleological thinking that forces one to define with specificity the desired state. This requires a reference, which is limited by human experience and shaped predominately through the cultural hegemony of Western science. If idealized models are discarded, this would allow a focus on processes and behaviors that reflect the traits most admired in natural systems. Which human behaviors function as interactions between humans and other biotic agents that would express naturalness? What human management actions would be considered natural processes of adaptation, interaction, and part of an ecosystem resilience cycle? For indeed, if human actors are an embedded part of an ecosystem, agents of selection as well as under selection pressure themselves, rather than agents existing outside natural systems, how do perspective, opportunity and approach in management practice change?

Light and co-authors (2013) discuss the concept of virtue to guide ecosystem management decisions. Environmental virtues can be understood as forms of “human character excellence regarding various relations to the organisms and ecosystems of the biosphere where our specifically human lives unfold.”
ethical stance shifts inquiry away from asking what is the morally right ecosystem
state and toward inquiry into what would the virtuous manager do or what virtues
best express the values of the conservation community? This stance places
emphasis on the character of human behavior in the context of environmental
management, recognizing naturalness as a process and a relationship, not an
intrinsic identity; human behavior may be more or less (un)natural (Haila 1997;
Katz 1997; Siipi 2008).

Tsing (2005) offers an example of integrated human-nature relations in her
description of the “social landscape” (p 196) created by the Meratus Dyak in
Kalimantan, Indonesia, in contrast to what she calls the “non-social spaces” of
the Western imagination. As public commons became enclosed by private elites
in the 19th and 20th century with the expansion of private property regimes, a
particular imagination about natural spaces emerged. “Only by seizing the
forests for elites, thus making forests coercively, off limits for peasant uses, did
European forests become empty and wild. In this state they could be...nonsocial
spaces that haunted European sociality (p 201).” This sense of the forest as
empty and wild was exported with colonization. Natural spaces became either
harvested or protected; either way excluding people. Nature in this view is an
object for management and regulation, with the benefits typically consumed by
populations in distant lands. This stance permeates conservation to this day and
has produced a great deal of critique, mistrust and alienation (Kelly 2011).
In Western conservation philosophy and practice, nature and human daily lives are in opposition. In contrast, in the social landscape, nature is a home - a community of biotic actors with whom to have social life. What is profound about social nature is that human actors are not antagonistic to wild nature preservation, but rather are active participants in creating it. This is similar to concepts of community-based conservation, and protected landscapes. In these forms of conservation the human community and its livelihoods are interwoven with the conservation goals (Berkes 2004; Dudley 2011). Applying the concept of social nature to management goals in conservation suggests that how we behave, and how we view the land and its history, is as important as what we want to protect.

Virtue ethics and social nature can be used to re-think the role of “managers” in cultivating biodiversity. The primary role of managers may not be to cut, burn, and poison to hold biotic communities stable, but rather to behave as compassionate, humble, loving biotic agents interacting in a diverse and social home. This distinction is important with regards to interventions. Management intervention itself, regardless of how noble its aim, potentially acts as a pervasive and persistent form of human disturbance and manipulation, the same kind of disturbance that is causing biodiversity loss. Intervention often has unintended consequences (Zaveleta et al. 2001; Landres 2010). It can reflect hubris when there is an excessive presumption that we understand the dynamics of complex systems. Many species considered invasive thrive because
they have traits compatible with human disturbance. If interventions select for weedy traits, one can expect repeat invasions (Buckley et al. 2007), where the effort to remove one non-native only results in the invasion of another.

Intervention increasingly employs technological, modern broad-scale approaches, such as the use of prolonged, aerial broadcasts of toxic chemicals, and the use of heavy machinery: behaviors viewed by some as the most-unnatural and oppressive (Katz 1997; Angermeier 2000). In an estimated 26% of Wilderness areas in the US, non-native species are controlled through culling, chemical and biotic control programs, and for most of this work there is no submission of NEPA documents or other formal consideration of less invasive strategies or risks (Tempel et al. 2004). Fifty years after the publication of Rachel Carson’s “Silent Spring”, there are now thousands of chemicals distributed liberally into the environment, including into national parks and nature reserves. Yet little information is available on the likely impacts of all but a few of these on non-target organisms and in the ecosystem as a whole. Recent findings on the implication of low-dose pesticides in declines in bee populations (Henry et al. 2012) provide a timely warning that Rachel Carson’s message is as if not more relevant today than it was 50 years ago. When Sisyphean effort or heavy-handed, extreme (e.g. oppressive, polluting, risky) interventions are the only imagined roads to meeting conservation goals, this signals that new methods and goals are needed.
Toward developing a natural practice

Hobbs et al. (2011) describe a new science called intervention ecology --- this is not a call for intervention per se, but rather a thoughtful consideration of when and how, given these paradoxes we face. Scott et al. (2010) discuss the need for prioritization of conservation interventions given the increasing number of species at risk. In considering intervention and prioritization, we suggest using process goals to establish how, when and where. An intervention decision should include the question: What species assemblages are compatible with an appropriate set of practices? This shifts the methods from defining static endpoint targets and using almost any means possible to try to establish targets, to defining broad goals and the pursuit of human-non-human interactions that are deemed consistent with the natural processes that are to be honored in conservation.

Ecological science provides many clues about how biotic agents behave within ecological communities, the scale and impact of behavior, and what behaviors tend to produce diversity. Conservation policy and ethics provides clues about human character traits that are desirable and conducive to conservation (i.e. humility, respect, restraint, care, reflection). These traits are important because they are distinctly different than the traits commonly expressed toward nature in modern industrial development that are at the root of biodiversity decline.
Clues from ecology and ethics serve as guidelines for questions to be asked in defining a natural practice (NP) (Table 1).

Just as in current practice, the status of rare, threatened species, or a visible change in the ecosystem, such as encroachment by woody plants, might instigate the question of intervention. Guiding questions, such as in Table 1, could be used to design a process of debate and reflection. If the answers to many of the questions indicate that the intervention methods are comparatively different than the processes engendered by biotic agents in ecosystems, and not in line with espoused conservation virtues, this would indicate a need for alternative methods or that intervention should not be practiced.

For example, the fern *Pteridium aquilinum* (bracken) is considered an invasive weed in places and control methods have been studied extensively (e.g. Alday et al. 2013). Because of the plant's extensive underground rhizome system, effective control requires ongoing treatment with cutting and herbicide. An alternative method has recently been suggested. The wild boar *Sus scrofa* target their rooting behavior towards bracken rhizomes (Sandom et al. 2013). Re-introduction of this extirpated animal in controlled rotations could achieve sustained results with low cost and impact. In applying the NP criteria to this case, herbicide treatment appears problematic because of rate, scale, technology, effectiveness and possibly selective pressure. The re-introduction of boar suggests a more suitable method.
In some cases alternative methods may not be known at the time of decision-making. A lack of knowledge would justify increased research to develop appropriate methods or provide the rationale for no intervention. For instance, in removing invasive ant populations, managers have relied on what are often ineffective and impactful pesticide programs, but with additional research, non-toxic methods are emerging (Diaz et al. 2013). Alternatively, sometimes the impacts of invasive ants decrease over time with no control measures (Morrison 2002; Cooling et al. 2012).

While a practice-based approach may sometimes diminish the justification for management actions aimed at maintaining particular species in particular places, we argue that the implications of this approach are likely positive for biodiversity at large. The hypothesis here is that less extreme methods will provide ecosystems the opportunity to adapt to global change and maintain evolutionary processes in the long-term (e.g. local diversification, specialized species interactions). To provide more evidence for this hypothesis greater research is needed to monitor under-studied dimensions of biodiversity (e.g. microbial, genetic, insect) in addition to the common conservation targets. We need to study the patterns of species at fine spatial gradients over time in response to global change and to variation in intervention methodology.

There are possible risks in moving away from management with firm endpoint targets. In some cases, policy mandates to protect individual species may be the
only teeth an agency has to allocate resources toward conservation. If the endpoint target is not firm, might some regulatory frameworks for conservation become ineffective? This is an important concern with varying relevance to different agencies depending on how they get their authority and funding. Exploration of how NP can be incorporated into existing policy frameworks without undermining conservation mandates is an important area for further consideration.

NP may be best suited for conservation areas committed the preservation of holistic nature and wilderness rather than single species targets, as well as those areas where the human disturbance is especially pervasive, such as urban fragments, or areas that are recovering and have a low biodiversity base (Hughes et al. 2011). NP is not equivalent to a hands-off approach. For conservation to continue to justify its funding allocations and relevance politically, it will be important to monitor ecosystem changes and practice interventions. To gain support for new goals such as these, the conservation community will need to measure and communicate about biodiversity in ways that are more complex than the current focus on particular species populations and richness. It will be vital to demonstrate and advocate how this biodiversity and its management is vital to ecosystem services, community development, and has intrinsic value.
NP is directly relevant to human practices in the matrix as well. If the behaviors of human agents outside preserve boundaries continue to drastically modify the landscape, the climate, and regional species pools, it is unlikely that sensitive native species will survive, even if we continue expensive and targeted measures to keep them viable. Similarly, parks will be jeopardized if their policies continue to antagonize the options for local communities to sustain a livelihood (Kelly 2011; Cote & Nightingale 2012). There is a deep literature working to understand how variation in human behavior affects species diversity, such as countryside biogeography (Daily 2001), urban ecology (Cooper et al. 2007), and agroecology (Perfecto & Vandermeer 2008). More direct community engagement in restoration (Higgs & Hobbs 2010) and science production (Cooper et al. 2007) provides a potential path for the cultivation of a social nature ethos in industrialized communities that may ultimately aid in promoting species conservation within converted lands. Increased native species survival in converted lands will increase the abundance of native populations and decrease propagule pressure of non-native species into conservation areas. Our argument is that softening our interactions with other species is essential across the entire landscape.

In conclusion, conservation management challenges are wicked, complex problems. We face undesirable tradeoffs. Here we argue that change is increasingly the norm, so management for specific visions of what nature should be are becoming increasingly unwise and unattainable. In order to better
accommodate global change and the dynamic response of ecosystems,
management goals should expand from static endpoint targets to include norms
of practice. Focusing on practice can contribute to a framework for prioritizing
and formulating how, when and where to intervene.

Acknowledgements
This essay was inspired by discussions at the ESA conference “Developing
Ecologically-Based Conservation Targets Under Global Change,” held February
27 – March 1, 2012. Thank you to T. Matza, P. Angermeier, and three anonymous
reviewers for constructive feedback, and to A. Thompson for helpful discussions
on virtue ethics. R.J.H. acknowledges financial support via an ARC Australian
Laureate Fellowship, the ARC Center of Excellence for Environmental Decisions
and the NERP Hub for Environmental Decisions.

Literature cited
Alday, J.G., Cox, E.S., Pakeman, R.J., Harris, M.P.K., LeDuc, M.G., and R.H. Marrs. 2013. Overcoming resistance and resilience of an invaded community is
necessary for effective restoration: a multi-site bracken control study. Journal of
Applied Ecology 50: 156-67
Angermeier, P.L. 1994. Does biodiversity include artificial diversity?
Conservation Biology 8: 600 - 602
Conservation Biology 14: 373 – 381
Biology 18: 621 – 634
Oxford University Press, Oxford


Levin, S.A. 1998. Ecosystems and the Biosphere as Complex Adaptive Systems,
Ecosystems 1: 431 - 436


Table 1: Example of ecological dimensions and virtues to consider in evaluating management interventions. Different virtues are listed in italics within each ecological dimension but this is illustrative only; virtue questions should be considered for all ecological dimensions.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Examples of questions to be considered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale</td>
<td>How big an area is impacted?</td>
</tr>
<tr>
<td></td>
<td>How long does the intervention last?</td>
</tr>
<tr>
<td></td>
<td>Is the disturbance consistent with the scale of natural biotic agent-driven disturbance events?¹</td>
</tr>
<tr>
<td></td>
<td><em>Is it humble?</em></td>
</tr>
<tr>
<td>Rate</td>
<td>How frequently will it be applied?</td>
</tr>
<tr>
<td></td>
<td>Is it at a rate that is likely to facilitate diversity (i.e. along the lines of the intermediate disturbance hypothesis)?</td>
</tr>
<tr>
<td></td>
<td><em>Is it restrained?</em></td>
</tr>
<tr>
<td>Technology</td>
<td>What tools are involved?</td>
</tr>
<tr>
<td></td>
<td>Does it use locally available, non-synthetic, non-polluting materials or activities?</td>
</tr>
<tr>
<td></td>
<td>Are effects targeted or broad-scale?</td>
</tr>
<tr>
<td></td>
<td><em>Is it cautious? Is it loving?</em></td>
</tr>
<tr>
<td>Efficiency</td>
<td>Is “waste” generated (i.e. animal, plant bodies)?</td>
</tr>
<tr>
<td></td>
<td>Are waste products cycled back into the local system, as typical in non-human ecosystems?</td>
</tr>
<tr>
<td></td>
<td>Can waste be productively used in neighboring systems or for other purposes?</td>
</tr>
<tr>
<td></td>
<td><em>Is it thrifty? Is it respectful?</em></td>
</tr>
<tr>
<td>Selective pressure</td>
<td>How does the intervention act as a selective pressure on biotic populations?</td>
</tr>
<tr>
<td></td>
<td>Does the intervention select for weedy traits?</td>
</tr>
<tr>
<td></td>
<td><em>Is it careful? Is it social?</em></td>
</tr>
<tr>
<td>Effectiveness</td>
<td>Does the intervention shift the conditions of survival for native species populations so that populations will become self-sustaining?</td>
</tr>
<tr>
<td></td>
<td>Or is it a temporary fix that will need to be applied continuously?</td>
</tr>
<tr>
<td></td>
<td><em>Is it reflective?</em></td>
</tr>
</tbody>
</table>

¹ Natural biotic agent includes humans (e.g. starting a fire could be consistent with a natural practice. Putting out a wildfire may be considered inconsistent because of the answers to questions about scale, technology, selective pressure, efficiency, and effectiveness).
Figure 1: Some examples of common management goals are shown with their orientation in time and examples of typical approaches. Past-looking orientations search for earlier times when nature was more fully expressed on the landscape. Industrial human activity (pre-European) is often seen as a critical break in nature. Authenticity, ecological integrity, and historical fidelity focus on pre-industrial ecological conditions and the historical range of variability in recent centuries to situate nature (Cole and Young 2010; Safford et al. 2012). Recognition of the transformative effect of indigenous humans on ecosystems motivates some to find nature further back in time (pre-history). Re-wilding promotes the introduction of exotic animals from Africa to function as proxies for extinct mega-fauna in North America (Donlan et al. 2005). Present-focused biological management tends to focus on ecosystem health. This translates into controlling the most pressing threats to keep systems providing ecosystem services (Palmer and Febria 2012) and reference states are found in the present. For example, the Index of Biotic Integrity assesses a site’s status relative to a similar undisturbed or the least-disturbed reference community in a region. Future looking orientations tend to focus on near-term sustainability and promote goals like resilience to diminish the possibilities for maladaptation through the manipulation of systems to mimic the past when the environmental and social context of places has changed dramatically (Zavaleta and Chapin 2010). The bottom of the graph shows a hypothetical line depicting the level of knowledge about ecosystem states across time. Knowledge about past conditions decays slowly at first, and then rapidly further into the past. Future projections show average regional trends, but local realizations and rates of change are highly uncertain in the near and distant future.