Managing the whole landscape: historical, hybrid, and novel ecosystems

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The reality confronting ecosystem managers today is one of heterogeneous, rapidly transforming landscapes, particularly in the areas more affected by urban and agricultural development. A landscape management framework that incorporates all systems, across the spectrum of degrees of alteration, provides a fuller set of options for how and when to intervene, uses limited resources more effectively, and increases the chances of achieving management goals. That many ecosystems have departed so substantially from their historical trajectory that they defy conventional restoration is not in dispute. Acknowledging novel ecosystems need not constitute a threat to existing policy and management approaches. Rather, the development of an integrated approach to management interventions can provide options that are in tune with the current reality of rapid ecosystem change.

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As the rate and extent of environmental change increases, traditional perspectives on ecosystem management and restoration are being juxtaposed with approaches that focus on the altered settings now being encountered or anticipated. We suggest that a combination of traditional and emerging frameworks is necessary to achieve the multiple goals of ecosystem management, including biodiversity conservation and provision of other ecosystem services such as food and fiber production, recreation, and spiritual enrichment.

In a nutshell:

- Landscapes are increasingly composed of ecosystems that are altered to different degrees; decisions on when and how to intervene in varying situations need to be made on the basis of the degree of alteration, likelihood of success, and landscape context
- Intervention in systems that are now radically altered from historical configurations needs to take into account their current values (particularly for ecosystem functions, services, and conservation outcomes) and the full range of options available, rather than being limited to traditional conservation or restoration measures
- Instead of posing a threat to existing practice, expanding the options available provides a more robust and comprehensive toolkit for intervening in rapidly changing landscapes

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An effective approach entails a move away from partitioning the environment into dichotomous categories (eg natural/unnatural, production/conservation, intact/degraded). Instead, landscapes are increasingly characterized by a complex mosaic of ecosystems or "patches" in varying states of modification, each of which delivers various combinations of services and presents assorted management challenges and opportunities. These patches interact and affect broader-scale processes (such as water flows and animal migrations), necessitating the urgent development of a conservation and restoration strategy that recognizes these rapid spatial changes.

Here, we focus on an emerging framework that differentiates patches according to the degree of change from a historical state (resulting from altered abiotic factors and biotic compositions), the likely extent to which such changes are reversible, and the effect of altered patches on other patches within the landscape (WebPanel 1). This framework, derived from recent research on novel ecosystems (Hobbs *et al.* 2009, 2013), helps to identify the relative values of ecosystems in different conditions and the management options available in each case. As seen from a landscape perspective, this framework provides a comprehensive approach to decision making and management, including much-needed prioritization of resource allocations.

Managing the whole landscape

Recent analyses have highlighted the need for management and restoration efforts to go beyond site-focused interventions and to consider landscape and regional scales (Mentz *et al.* 2013). Ecosystem managers increas-

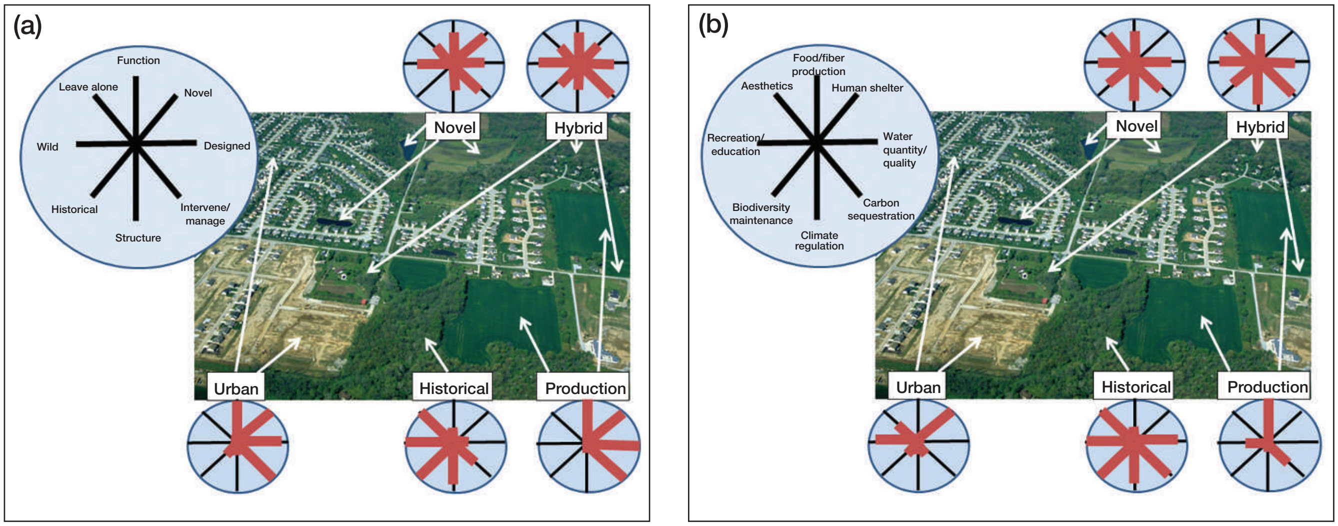

Figure 1. *Two perspectives on a typical landscape found in peri-urban areas worldwide, in which there are various ecosystem states, including those entirely developed for urban use, production areas, and an array of ecosystems modified to a greater or lesser extent spanning the historical–hybrid–novel range. Panel (a) illustrates how diverse landscape elements are differentiated along a range of gradients in characteristics and management emphases (expanded from Kueffer and Kaiser-Bunbury 2014), whereas panel (b) indicates how different elements provide differing combinations of ecosystem services. The opportunities and constraints vary greatly among elements. This type of mixed landscape is increasingly prevalent as urban areas grow and is often the locus for community conservation and restoration projects. Although the landscape depicted is relatively small scale, similar issues can be identified at broader scales incorporating large nature reserves and production landscapes.*

ingly work in heterogeneous, rapidly transforming landscapes, particularly in highly modified areas such as urban and agricultural regions (Figure 1; Ellis 2011; Kowarik 2011). From a biodiversity conservation perspective, landscapes typically consist of multiple ecosystems or patches with distinctive primary characteristics and functions (Kueffer and Kaiser-Bunbury 2014). However, many landscapes are now expected to accommodate the needs of both humans and other species (Foley *et al.* 2011; Sayer *et al.* 2013). The concept of multifunctional landscapes entails considering the complete range of landscape elements and the services they provide (Nelson *et al.* 2009; Jarchow and Liebman 2011; Potschin and Haines-Young 2011). Many landscapes now consist of a diverse array of ecosystems with varying characteristics and management emphases, which provide various services (Figure 1). How can policy be formulated and management guided to more effectively achieve different goals for individual ecosystems and the landscape as a whole?

Accelerating rates of climate and land-use change and species invasions result in rapidly evolving spatial dynamics among multiple landscape patches. These patches have differing sets of services and management challenges, and accounting for these complex dynamics and attributes is essential for effective conservation and restoration planning. Paleoecological and historical studies indicate considerable flux in species distributions and assemblages as a result of climatic and other changes (Jackson *et al.* 2009; Dawson *et al.* 2011). Concepts such as historical range of variation describe the extent of this flux and therefore the degree of variation expected in different ecosystems. Some ecosystems currently remain within this historical range of variation. Recently, however, human-induced changes to many biological and abiotic characteristics have accelerated the rate and complexity of change to such an extent (Steffen *et al.* 2004, 2011; Chapin *et al.* 2008) that systems are being pushed outside their historical ranges.

Conservation planning has long demonstrated the value of systematic prioritization in ensuring the protection of biodiversity, given limited resources and considerable uncertainty (Moilanen *et al.* 2009; Levin *et al.* 2013). The importance of combining strategies that account for multiple ecosystem services (such as carbon–biodiversity; Thomas *et al.* 2013) has also been highlighted recently. In view of the need to prioritize, we argue that assessment of what is possible, where it is possible, and what represents the best use of scarce resources needs to be applied universally, from landscape-scale linkages to protection of hotspots of biodiversity to restoration of greatly altered sites.

Consideration of a fuller set of options regarding how and when to intervene requires assessment of the degree of alteration of particular patches and the intervention options available (Figure 2). Where ecosystems have been pushed beyond their historical range of variability, it may not be practical to maintain or restore them to past conditions. In such cases, new tools and approaches could help guide managers in deciding when and how to intervene. Although most novel ecosystems are the unintended result of human alteration of the environment, that does not mean that those systems cannot be manipulated to meet desired future ecological conditions (WebPanel 1). The simplified schema presented in

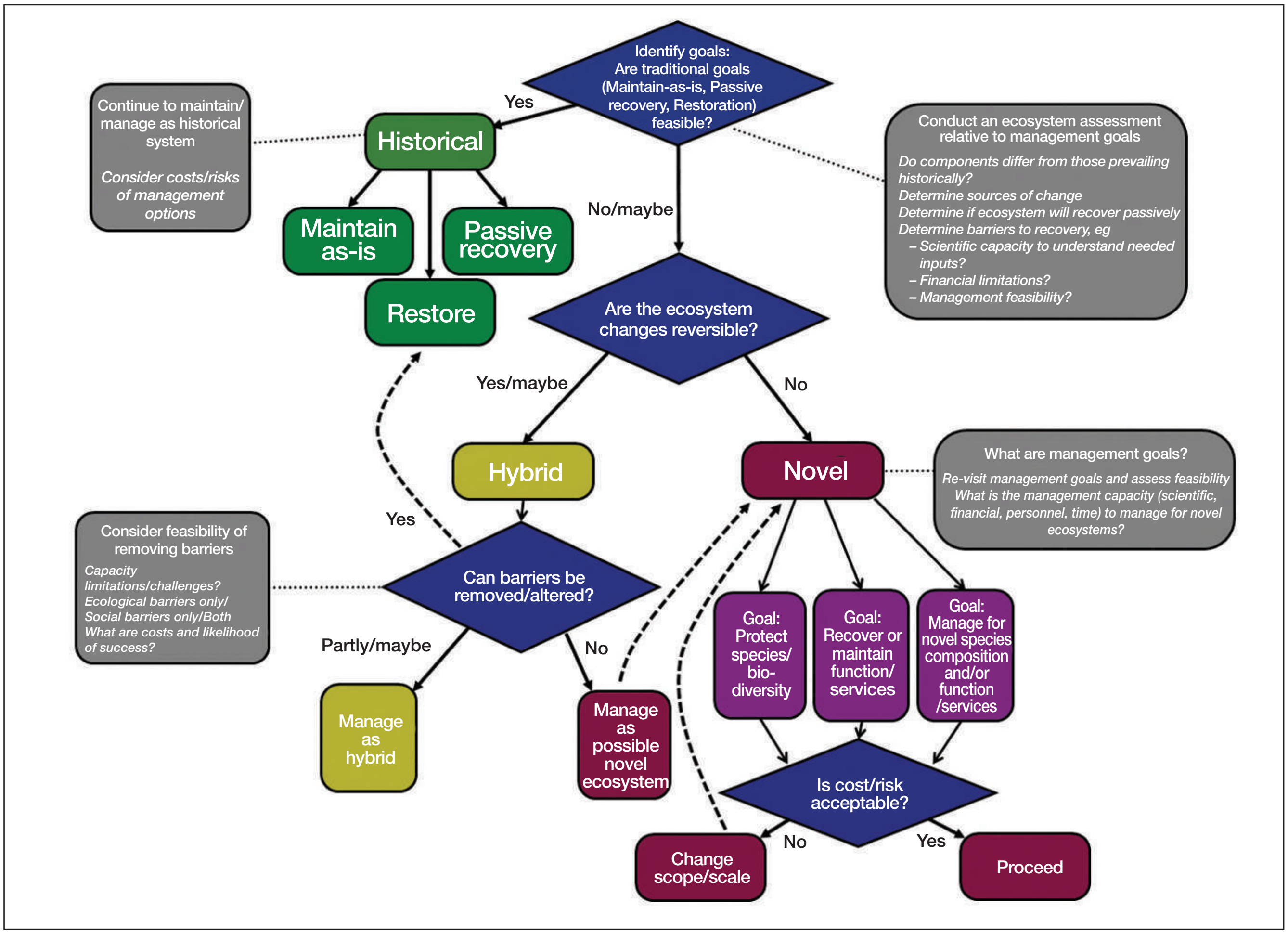

Figure 2. *Flowchart showing a developing framework to guide major decisions regarding interventions in historical, hybrid, and novel ecosystems. This framework has received only preliminary testing (Hobbs* et al. *2013; Trueman* et al. *2014), and an important next step is adequate testing with further real-world examples (eg to characterize reversibility or to effectively implement multiple goals). Modified from Hulvey* et al. *(2013).*

Figure 2 provides an initial tool to help managers weigh options more critically. It is not prescriptive but offers a starting point for what are certain to be complex conversations about how to decide on intervention options. The flowchart highlights assessment and options primarily in relation to conservation and restoration goals; however, the same process can be applied to the full suite of goals for multifunctional landscapes (eg water management and agricultural production).

■ Management alternatives for individual patches

Decisions about when and how to intervene to restore or conserve a particular patch depend on its current state and trajectory (Hulvey *et al.* 2013), as well as on its interactions with other patches. The first requirement is an assessment of whether intervention is needed to achieve the stated goal(s), however these are arrived at. Where degradation is reversible and where historical continuity is possible through management, traditional best practices in conservation and restoration can be used to maintain or recover particular characteristics, such as key species or habitat.

Where the patch is no longer following its historical ecological trajectory, an assessment should be made to see whether the changes are reversible. In some settings, ecological thresholds will clearly have been crossed and a return to a previous state is no longer possible; here, interventions in other patches may be more successful. Usually, this will be the case where notable abiotic change has occurred: for instance, in secondary salinization of wetlands in Australia (Cramer and Hobbs 2002) or the creation of new substrates such as shale-oil spoil heaps in Scotland (Harvie and Hobbs 2013) or imported ballast rock in Wales (Perring 2013). If it can be determined that the ecosystem changes are irreversible (ie a threshold has been crossed), then options for management as a novel ecosystem can be considered. The question of irreversibility is not a simple one, since just about anything other than the stark abiotic changes described above may theoretically be reversible, given enough resources and effort. For example, Ewel (2013) discussed the extensive measures, such as soil removal, that were adopted to restore an area of abandoned agricultural land in Florida's Everglades, much of it deeply plowed, heavily

Figure 3. *Increasingly, historical ecosystems are embedded in a highly altered matrix, even when obvious transformation for urban development or agriculture is absent. This photograph portrays a typical landscape in the Seychelles (Kueffer* et al. *2013). In the foreground, endemic vegetation remains only in small pockets on inselbergs (rocky granite outcrops) in a sea of vegetation dominated by non-native species (in the background; mainly* Cinnamomum verum, Falcataria moluccana, *and* Alstonia macrophylla*).*

fertilized, and dominated by a variety of invasive plants. However, financial, technical, social, and institutional limitations often render such ecosystem changes practically irreversible, at least under prevailing political and economic conditions. Because land use, climate change, and species invasions are all likely to drive the shift from historical toward novel ecosystems, we urgently need further research to identify functional and compositional thresholds (eg by testing the framework in Figure 2 in various landscape types). Beyond that, there is also a pressing requirement to understand social thresholds that might constitute either barriers to, or facilitation of, actions toward or away from novel ecosystems.

A range of options is available for the management of ecosystems identified as historical, hybrid, and novel. The options depend on the goals selected, which may include the protection of biodiversity, conservation of ecosystem functioning and services, maintenance of historical continuity, and provision of natural resources for local human livelihoods. Depending on the portfolio of goals set for individual ecosystems and broader landscapes, management options can be applied preferentially to different ecosystem states. Figure 2 lays out the options for novel ecosystems, depending on whether the primary focus is on species composition and biodiversity or on functional aspects and ecosystem services.

Similarly, for hybrid ecosystems (WebPanel 1) the management goal might be to return the area to its historical trajectory by changing species composition, or to focus more on functional aspects such as forage production or habitat provisioning (Hallett *et al.* 2013). In both novel and hybrid ecosystems, how these interventions are prioritized will depend on social and political perspectives regarding the relative values of distinctive ecosystem states and the desirability, cost, and likelihood of success of different interventions. These considerations are important at both the local level for particular ecosystems, and in the broader landscape context. The latter context is particularly important in light of the spatial and dynamic interconnections that are likely among discrete ecosystems or patches. The framework shown in Figure 2 expands the suite of options available for landscape management, ranging from maintaining and restoring intact natural systems to managing novel ecosystems that have been irreversibly altered but in some cases may provide ecological and social values that need to be preserved.

Placing intervention alternatives in a landscape context

Decisions on what options to pursue may vary depending on what else is happening in the landscape; it makes little sense to consider management of isolated patches. The landscape context of each individual patch is important, and connectivity among historical–hybrid–novel patches may ultimately ensure landscape functionality, especially in situations where historical patches make up only a small portion of the current landscape (Figure 3). In this sense, restoration of every hybrid and novel patch may not be critical, but could be important in ensuring functional connectivity of historical areas through corridors consisting of novel ecosystems. However, not all connectivity is positive: some new connections (eg linking to intensively managed patches such as wastewater treatment facilities, golf courses, or agricultural fields) may ultimately drive historical or hybrid ecosystems to an irreversibly novel state. It is also important to consider the spatial dynamics of patches: if, for instance, a novel patch is dominated by an aggressively spreading invasive plant species, it could be important to prioritize intervention in that patch to prevent the transition of the invasive species to adjacent patches. Management of patches ideally takes place in the context of landscape characteristics such as connectivity or permeability in relation to movement of key species and/or to key processes such as water flow and fire spread (WebPanel 2). This process is often difficult because of incomplete information on past and present patch characteristics, and the difficulty of identifying or monitoring interactions.

■ Social dimensions

Because novel and hybrid ecosystems can provide important public goods, such as resources for local livelihoods, abundant clean water, habitat for pollinators, and recreational opportunities, the public has a vested interest in how these ecosystems are managed (Venton 2013). Where novel ecosystems occur on publicly owned lands, democratic principles require that members of the public be involved in decisions about intervention. Even in landscapes of mixed ownership, effective public engagement can yield multiple benefits, including more robust decisions, based on diverse views and local knowledge, broader public support and investment, and careful consideration of trade-offs (Chapin *et al.* 2010; Yung *et al.* 2013). Transparent, inclusive, deliberative processes enable citizens and managers to work together to negotiate between competing goals and prioritize the goods and services that particular novel ecosystems provide, a critical task in the context of limited resources.

Novelty itself demands broad public dialogue. Since restoration to a previous historical trajectory is not typically practical for a novel ecosystem, careful discussion is required on appropriate goals for such systems. Exploring multiple options for intervention opens up social and political "space" for people to engage with the ecosystems they encounter in their own neighborhoods (Standish *et al.* 2013a). The recognition of multiple, legitimate future trajectories, as opposed to one "true" nature that experts can identify, could catalyze public interest in examining a range of management goals and activities (Yung *et al.* 2013).

Novel ecosystems elicit varied responses from ecologists, practitioners, policy makers, and the public. Ecologists increasingly find it a useful framework to test basic ecological theory: for example, the relationship between biodiversity and ecosystem function (Wilsey *et al.* 2009; Mascaro *et al.* 2012) and historical controls on community assembly (Gill *et al.* 2009). Some ecologists and others in the restoration ecology community believe that acknowledging the presence of novel ecosystems is counterproductive and a threat to existing policy and management approaches (Moreno Mateos 2013; Woodworth 2013; Murcia *et al.* 2014). Some see their inclusion in scientific discourse as pulling attention away from high-value conservation assets, whereas others regard it as according undue attention to systems perceived as having no value ("giving legitimacy to the illegitimate"; Woodworth 2013). These are valid concerns (see next section). However, many ecologists recognize that the occurrence of hybrid and novel ecosystems is increasing, and that they may have value in their own right. Novel ecosystems can (but do not necessarily) include many features that society values – from habitat for rare species and green space for children to non-timber forest products for local villagers – without the need for supervision or intervention. Indeed, most people's experience of "nature" today is likely to involve novel or hybrid systems, especially given the increasing size of urban populations (Kowarik 2011; Marris 2013). Because novel and hybrid ecosystems are widespread in populated areas, urban dwellers could be some of the strongest advocates for the aesthetic and other cultural services provided by these systems (eg Mt Sutro in San Francisco; Venton 2013). Novel ecosystems may provide some of the most important opportunities to connect with nature for a wide cross-section of society. Paying particular attention to locally familiar ecosystems could be critical to developing a greater sense of environmental responsibility or stewardship. Novel ecosystems may then cease to be considered in practice as "second-class nature".

By expanding the range of conservation and restoration approaches in instances where ecosystems have been irreversibly altered, the following questions become relevant: what is gained or lost by intervening? What benefits does that system provide? How much will the intervention cost, and are there potential negative outcomes? How resilient will the ecosystem be to future disturbance, and will ongoing intervention be required? Given the need to focus on the overall landscape, these questions take on additional importance.

In short, while managers benefit from improved frameworks, tools, and new information about ecosystem change, decisions about interventions and broader policies are value-laden and require meaningful public dialogue. The framework and approach described above can be integrated into public discussions and engagement exercises, which can then help to chart a course based on scientific knowledge, conservation goals, and human needs and values. Moreover, public dialogue can help address some of the threats and opportunities explored in the next section.

■ Threats, opportunities, or both?

There is increasing evidence for the existence of a range of ecosystems that have departed so extensively from their historical trajectory that they defy conventional restoration. The implications of the broader concept of novel ecosystems invoke a variety of concerns (Standish *et al.* 2013b; Woodworth 2013). Part of the reason there is controversy about novel ecosystems may be that those undertaking management/restoration actions (and their motivations) vary so widely. Some worry that acknowledging novel ecosystems will allow corporations and governments to continue to degrade and abandon lands. Others are concerned about prioritization, effective use of limited resources, and the likelihood of successful interventions: for example, is it useful for community groups to expend limited resources on futile battles with nonnative species? Different experiences affect biases one way or the other, and the initial entry point into the decision process in Figure 2 will vary according to the identity of the decision maker and their social, cultural, economic, and organizational context.

There are valid concerns about novel ecosystems. For some, the term "novel" has positive connotations based on contemporary consumer culture. Might a widespread commitment to ecosystem services lock onto novel ecosystems as an expression of such broader cultural commitments to products, services, and innovation? What will become of people's attachment to these changing ecosystems? Will increased novelty lead to greater engagement with highly altered ecosystems that have traditionally eluded conservation and restoration action, or will such systems be spurned as less important? Novel ecosystems are certainly making conservation and restoration decisions more complex, and in this respect more difficult to understand and undertake. Finally, will the concept of novel ecosystems promote overconfidence in terms of development and management, leading to overly human-centered ambitions for ecosystems? There are no easy answers to these questions, but at the same time it can be argued that a conscientious land manager could consider accepting and working with novelty, both as a fundamental moral responsibility and in acknowledgement of "the world as we find it" (Thompson and Jackson 2013).

Perhaps the biggest concern is that accepting the reality of novel ecosystems represents a slippery slope in our commitment to conservation and restoration. Accepting novel ecosystems leads to the recognition that some ecosystems may be more effectively managed for goals other than a return to the ecosystem's historical trajectory, and acknowledges that drivers of novelty are intensifying. In some cases this may mean that the management emphasis shifts over time from intact, historically continuous, and rare ecosystems and landscapes to those that are heavily altered. This is undoubtedly already happening, but need not diminish ongoing efforts to conserve and restore particular ecosystems and species; indeed, as discussed above, these efforts may depend on the effective management of landscape mosaics with many different ecosystem states. Furthermore, many novel ecosystems are directly associated with human settlements, and are therefore likely to be experienced more regularly and to be subject to greater interest, scrutiny, and investment of resources (eg Venton 2013).

The "slippery slope" argument also pertains to the policy realm, which has largely focused on protection of individual species and notions of static, stable ecosystems. Policy makers and legislation are only just beginning to acknowledge the dynamic nature of ecosystems and the emergence of novel ecosystems (Bridgewater and Yung 2013). Will embracing novel ecosystems erode hard-won progress in establishing protected-area networks, or lead to management trade-offs that favor specific ecosystem services over protection of rare species? These concerns merit discussion, and guidance will be required to navigate the increasingly complex policy debates. By acknowledging the concept of novel ecosystems, and more explicitly incorporating management goals around these systems, there is an opportunity for a more dynamic and flexible approach that recognizes the benefits of novel ecosystems without compromising conservation and management goals at a larger scale (Bridgewater and Yung 2013). This will lead to a more productive dialogue that explores the problems as well as possible solutions and trade-offs, and weighs the consequences of various management actions, preferably in an overtly experimental framework (Yung *et al.* 2013).

The way forward

There are no definitive answers to most of the concerns raised above, but acknowledging them and exercising caution are a good first step (Standish *et al.* 2013b). Regardless of terminology used – novel, emerging, recombinant, no-analog – ecosystems that challenge conventional conservation and restoration are a present reality. Managing for the whole landscape – mosaics of historical, hybrid, and novel ecosystems – allows for a comprehensive and transparent approach to managing for a range of goals. Novel systems will almost certainly cover a larger fraction of Earth's surface in the future. Ignoring them or describing them with heavily value-laden language will increasingly marginalize conservation and restoration in the public realm, whereas in fact there is no either/or dichotomy. This argument is reminiscent of the early attempts at ecological restoration being regarded as having the potential to reduce conservation efforts and provide a rationale for ecosystem destruction. Given the finite nature of Earth's ecosystems, we emphasize the need to value all ecosystems in some way and to conserve nature in its many forms, including entirely unprecedented patterns, and to consider different ways of managing ecosystems. How novel ecosystems are perceived and whether and how they are managed will clearly vary among managers and among ecosystem types. However, acknowledging and becoming involved in novel ecosystems has the potential to increase the profile of an integrated approach to conservation, restoration, and intervention ecology. In doing so, rare and historically continuous ecosystems and landscapes are likely to be the focus of more, not less, conservation interest and activity. This more integrated approach will allow managers to consider options across all landscapes and enable them to make more effective decisions that are rooted in the current reality of rapid ecosystem change.

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WebPanel 1. Why historical–hybrid–novel?

Novel ecosystems have been described in a variety of ways, and have also been referred to as "emerging" and "no-analog". There is debate over the utility of the term "novel ecosystem" and whether it adds anything beyond existing constructs in restoration ecology (Moreno Mateos 2013; Van Andel 2013), and this remains an ongoing dialogue. Most recently, Hobbs *et al.* (2013) discussed the difficulties involved in settling on a definition and provided the following working definition: "A novel ecosystem is a system of abiotic, biotic, and social components (and their interactions) that, by virtue of human influence, differ from those that prevailed historically, having a tendency to self-organize and manifest novel qualities without intensive human management. Novel ecosystems are distinguished from hybrid ecosystems by practical limitations (a combination of ecological, environmental, and social thresholds) on the recovery of historical qualities" (Figure 2).

The question of whether there is a categorical difference between historical, hybrid, and novel systems remains contentious (Moreno Mateos 2013), and centers on both the degree of departure from a system's historical range of variation and the likelihood that intervention could reverse a current trajectory. Historical ecosystems retain historical continuity, and their current state lies within their known or assumed historical range of variation. Hybrid systems have moved out of this range, often because of the arrival of novel elements, such as non-native species that interact and form assemblages not previously present; they therefore constitute a mixture of historical and novel elements. However, it is thought that these systems could be returned to their historical state and trajectory with appropriate intervention, although some may have social and ecological values that warrant managing them as hybrid ecosystems. Novel systems have moved so far away from their historical range, through on-site and off-site biotic, abiotic, and functional changes, that they retain very few of their historical characteristics. They are likely to be relatively resistant to intervention that attempts to return them to their historical state and trajectory.

The ability to identify clear breakpoints or boundaries between categories – particularly between novel and hybrid systems – depends on the recognition of ecological or management thresholds. This is frequently a challenge in practice and also raises the question of reversibility. The characterization of novel ecosystems above suggests there should be clear breakpoints or thresholds that differentiate between novel and hybrid ecosystems in terms of their potential for restoration. Theoretically, novel ecosystems have little potential for restoration to the historical state. This hypothesis remains to be tested empirically. While the idea of threshold dynamics has proven very useful in considering ecosystem management choices and techniques (eg Suding and Hobbs 2009), the presence of ecological thresholds has remained difficult to demonstrate in all but a few terrestrial systems (Andersen *et al.* 2008; Samhouri *et al.* 2010; Bestelmeyer *et al.* 2011). Although there is clear utility in differentiating systems that may have crossed a threshold of one type or another that then presents a barrier preventing the return of the system to a historical state and trajectory, for some purposes it may be better to consider novelty as a continuum, thus avoiding the need to differentiate categories. As in physics, where light is simultaneously viewed as waves and particles, it is useful to retain a dual view of novelty as continuous or discrete.

Is the characterization of different ecosystem states as historical, hybrid, or novel a valid and useful way to proceed? A legitimate question is whether "novel" is just another word for "degraded", given that this term is usually applied to systems that have lost particular structural or functional characteristics. Yet we believe that the distinction lies in the recognition that altered systems, although changed, may still retain important values and therefore cannot necessarily be characterized as degraded relative to those particular values, even though they may be degraded relative to other values. The problems with blanket assumptions about altered systems being degraded have recently been explored in the context of secondary and human-inhabited forest systems (Hecht *et al.* 2014). Because all ecosystems are dynamic and are therefore changing, a further question is whether calling some systems novel is actually useful (Moreno Mateos 2013). This characterization provides a framework for considering a wider range of management approaches given an unprecedented rate of ecosystem change. Indeed, the term "novel" raises the public and policy profiles of the consequences of rapid anthropogenic changes. Certainly, several important questions arise. For instance, should historical conditions continue to be used as the baseline or reference state for assessing novelty (ie a departure from baseline or reference state)? The role of historical knowledge in informing decisions around novel ecosystems, as with decisions on ecosystem management, is increasingly being dismissed as irrelevant as rapid environmental change pushes systems into new configurations that have diminishing connection with past conditions. The term "historical" is often used in a vague and unreferenced way and can refer to anything in the past, contributing to confusion and a sense that history is no longer relevant. On the other hand, some argue that historical configurations still yield the best information on how systems work and provide guidance and limits to management endeavors. At this juncture, both perspectives are relevant and an important task is to try to find a resolution to this apparent contradiction (Jackson and Hobbs 2009).

If novelty is measured against some reference, how should that reference be determined? When are historical references valid or possible, and are modern analogues or current reference states more appropriate? These alternatives have advantages and limitations, and are complicated by questions of temporal and spatial uncertainty. While new approaches may be needed, current best practices that are based on years of successes and failures have much to offer and should be considered first, especially in the face of uncertainty over the current state and trajectory of the system. In all cases, reference ecosystems, however determined, are not meant to be a rigid template toward which the system should be managed or restored: rather, they act as a guide and need to be considered in tandem with current and projected conditions and dynamics. In addition, phrases such as "historical condition" or "reference state" should be viewed as shorthand encompassing dynamics; past, present, and future states should be considered more as trajectories of change. It is perhaps most important to consider when novelty actually matters: what degree of difference from a past or present condition either triggers the need for management intervention or dictates the type of intervention that might be appropriate?

WebPanel 2. The landscape context: necessary but challenging

A landscape perspective provides the opportunity to ensure that patch-based interventions are planned and designed to be effective, and to identify where and what type of broader-scale interventions are necessary. A key challenge in implementing the approaches outlined here is the identification of critical patches and critical scales for interventions, particularly in landscapes characterized by multiple uses and ownerships (Figure 1). Landscapes vary in terms of what these critical scales might be, from relatively fine grained (as in Figure 1) to much coarser grained for extensively managed systems such as rangelands. Management units often equate to patches used in different ways (Figure 1), and goals for individual patches often differ substantially. Broader landscape goals frequently relate to the "bundles" of ecosystem services expected from the area, and this commonly involves an examination of potential trade-offs and synergies among different services. Local intervention may be appropriate in some instances but ineffective in others, particularly where broader landscape processes such as regional hydrology have been drastically altered (Cramer and Hobbs 2002). Determining the appropriate locations and scale of intervention is often difficult because of incomplete information on past and present patch characteristics, and lack of ability to identify or monitor interactions and flows among patches. In addition, the scale of restoration interventions is frequently determined more by budgets, interests, and jurisdictions than by ecological considerations alone.

There are, nevertheless, promising recent approaches to addressing management challenges arising from novel ecosystems at both local and landscape scales. For instance, Zedler *et al.* (2012) highlighted the need to accommodate irreversible landscape alterations by relating management approaches to the extent and nature of these changes. The authors suggested, for example, that the potential for wetland restoration depends on the position of the wetland in the broader landscape. Wetlands lower in the watershed are more likely to have been affected by inflows of sediment and nutrients, and are therefore unlikely to be easily restored to a historical state. Conversely, upstream wetlands, which are likely to be less substantially altered, could still be considered legitimate targets for restoration of historical assemblages. Zedler *et al.* (2012) also advocated an experimental and adaptive approach to managing individual wetlands so that a clearer picture emerges of which management/restoration targets are achievable and which are not.

Recent work on the altered ecosystems of the humid highlands in Galapagos National Park has also illustrated how a consideration of landscape context can assist with prioritizing interventions (Trueman *et al.* 2014). This study examined transitions from the original vegetation to a series of altered vegetation states, measured the degree of novelty of these states, and considered the ecological and practical limitations to restoration, using the decision tree in Figure 2 (modified from Hulvey *et al.* 2013). Invasions by a variety of plant species were primarily responsible for the development of altered states, and the major practical barriers to restoration were identified for most of these states, being largely due to the difficulties involved in adequately controlling invasive species over large areas. It was, however, possible to identify potential priorities for action: for instance, two states (grassland and avocado-dominated forest) that occupied relatively small isolated patches but were actively spreading could be targeted for intervention (WebFigure 1). Direct intervention to control the invasive species and reinstate native species in those patches could be an appropriate priority. In other cases, creating buffers to limit further outward spread could also be appropriate.

WebFigure 1. *Grassland dominated by the non-native grass* Pennisetum purpureum *in humid highland areas within the Galapagos National Park on Santa Cruz Island, Galapagos. Patches of this altered vegetation type are relatively small but are increasing in size. Unlike more widespread plant invasions, it may be possible to control and/or isolate the invasive species and restore the patch to a less novel configuration.*

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