Ecosystem stewardship as a framework for conservation in a directionally changing world

T.R. Seastedt, K.N. Suding and F.S. Chapin III

“The first law of intelligent tinkering is to save all of the parts.” – Aldo Leopold

Abstract  The realities of a rapidly changing world demand that successful conservation activities accommodate uncertainties and exploit the opportunities imposed by directional environmental changes. A consensus among researchers is emerging behind the conceptual framework offered by ‘ecosystem stewardship’, aimed at sustaining the structure and function of biological communities under stressors induced by directional change. Both novel ecosystems and proactive conservation efforts are an important and compatible component of this framework. Here, we show how forward-looking management activities that seek to maintain biological diversity might be enhanced by applying concepts developed under the umbrella of ecosystem stewardship.

Introduction

Scientists and advocates have acknowledged the need for actions that contribute to local, regional and global sustainability (Clark and Dickson 2003; Rockström et al. 2009). Most agree that the challenges to sustainability are immense. Within the next forty years the human population will increase from seven to nine billion individuals, which hopefully will be accompanied by programs that enhance the quality of life for those individuals. Historically,

1. All authors contributed equally to this essay.
human population and economic growth initiatives have generally superseded or trumped ecological concerns, but current global-scaled impacts of past and current human activities now dictate that sustainability issues become an essential part of debates on maintaining and improving human welfare (MEA 2005; Rockström et al. 2009). Enlightened societies recognize that human welfare and the welfare of other organisms are linked, but these links range from being obvious to unknown (Raudsepp-Hearne et al. 2010).

The recognizable presence of human legacies resulting in new biotic and abiotic characteristics of landscapes has resulted in labels such as ‘degraded’, ‘adventive’, ‘altered’ or the more value-neutral term, ‘novel,’ for these systems (Hobbs et al. 2006). Using the definitions provided in this book, hybrid and novel ecosystems provide the brunt of the earth’s biotically active layer that must provide the ecosystem services (supporting, provisioning, regulating, and cultural services; Chapin et al. 2009) required for sustainability.

That these systems are different or new is undeniable. However, although the ecosystems are different, the living ‘pieces’ previously found in these areas – the biota – usually persist, albeit in numbers that differ from historical reference values. Conservation efforts therefore need to find ways to best exploit novel ecosystems to enhance opportunities for biological diversity. Recognizing ‘win-win’ scenarios and incorporating these into management and policy actions are logical goals that can be shared by all concerned. Here, we explore how ecosystem stewardship can contribute to conservation efforts, and how accepting and exploiting the reality of novel ecosystems may facilitate these activities.

Ecosystem stewardship is defined as “a strategy to respond to and shape social–ecological systems under conditions of uncertainty and change to sustain the supply and opportunities for
use of ecosystem services to support human well-being” (Chapin et al. 2010, pg 241). This program requires a global perspective to be successful and therefore must address changes that occur at scales ranging from local to global. In many respects the strategy continues the concepts developed for adaptive ecosystem management (e.g., Christensen et al. 1996). What is ‘new’ about this program is that it accepts directional environmental change as the reality, and this reality requires a more proactive focus in management activities. While single environmental drivers such as climate change may not affect the majority of ecological communities in major ways over the next few decades, climate interactions with disturbances such as fires or the ongoing pine beetle epidemic in the forests of western North America are changing ecosystems now. Specifically, the ecological stewardship agenda emphasizes the need to develop resilient communities that can withstand or buffer the impacts of the drivers of environmental change to enhance ecosystem resilience and human well-being. Ecosystem stewardship also explicitly considers humans as ‘keystone species’ at regional and global scales, and often at local scales. The stewardship focus broadens the land ethic espoused by Aldo Leopold and recognizes a responsibility to sustain future options for both biota and resources (Chapin et al. 2010).

**Ecosystem Stewardship addresses both physical and biological issues**

Environmental scientists and biogeochemists view ecosystems as functional biophysical units that interact with climate and atmospheric chemistry drivers to produce feedbacks in terms of the forms and amount of energy, water, and other materials that affect future climates. This focus differs dramatically from the view of ecosystems as described by those whose interests are on the species found within these communities. When the species become the focus of concern, the
ecosystem blurs to become ‘the environment and the species with which they interact’.
Historically, such a view was perfectly adequate for conservation and restoration purposes.
Restore the environment and you restore the appropriate home for the species. However, the
current dilemma is that the historical environment cannot be restored to generate a previous
biotic configuration, or, if it is maintained in some historical state, that state becomes
increasingly out of equilibrium with the directionally changing climate and therefore becomes
increasingly fragile and non-resilient. Such systems can be viewed as the equivalent of farms,
zoos or arboreta, which are sustainable only with constant human intervention. The environment
of the organisms has been changed, perhaps permanently, and therefore the procedures for
successful conservation and restoration must address these new realities.

The study of hybrid and novel ecosystems clearly has at least two distinct dimensions. One
dimension is the rapidity of changes that are altering the composition of local and regional biotic
communities. These include well-researched topics of population and community ecology, as
applied to conservation and restoration management. The second dimension of novel
ecosystems focuses on management of the stabilizing or amplifying feedbacks that affect
regional and global climate and related biogeochemistry. These dimensions of hybrid and novel
ecosystems are two sides of the same coin, yet scientists and advocates often focus on only one
or the other. In order to seamlessly merge the science, it is important to identify when ecosystem
sustainability initiatives are consistent with conservation interests, and whether there are
instances when sustainability goals might conflict with conservation efforts.

**Identifying Conservation Goals in an Ecosystem Stewardship Agenda**
Ecosystem stewardship is a framework for managing resources under the environmental change scenarios predicted for the 21st century (Clark and Dickson 2003; Chapin et al. 2010). The goals of this framework are to sustain required ecosystem services and support human well-being as societies attempt to improve the economic well-being of disadvantaged segments of an ever-growing human population. In contrast to a gloom-and-doom message, ecosystem stewardship looks for opportunities and arenas to improve ecosystem services and human welfare.

Conservationists may rightly look upon a program that emphasizes energy and material cycling as one that may not serve the purposes of species preservation. However, the two seemingly different goals – species conservation versus maintaining ecosystem function – can be compatible when one acknowledges the contributions of the species – via their functional roles – to the characteristics of ecosystems (e.g., Naeem et al. 2009). Although the contribution of rare species to ecosystem services has sometimes been dismissed (c.f., Rider 2008), redundancy in functional attributes of species becomes important when environmentally driven changes in the relative abundances of species create situations where even rare species are functionally critical. If overgrazing eliminates a common grass, for example, an ecologically similar (but grazing-tolerant) grass may increase in abundance and fulfill many of the functions (e.g., prevention of erosion or invasion of exotic species) of the species that disappeared (Walker et al. 1999). If the overarching stewardship goal is to manage for resilience, there are clearly advantages to conserving as much of the resident biodiversity as possible (intelligent tinkering; Leopold 1949) and to adaptively manage over time horizons that allow a range of options to be considered and tested.

The relationship between key features of ecosystem stewardship and their implications to conservation and restoration activities is shown in Table 1. The stewardship framework relies
less on the historical conditions of a community and instead focuses on the dynamics of ecological change and the management options that influence pathways and rates of change. If the current community status is viewed as desirable, then efforts should be made to maintain the components of the current system by increasing those stabilizing feedbacks that contribute to community persistence. There are historical precedents for recognizing that diversity can contribute to those stabilizing feedbacks. For example, redundancy in plant diversity will allow for grasslands experiencing extreme droughts to maintain some cover and some productivity under such events as the ‘dust bowl’ that occurred in the last century. Monocultures of single species designed for maximum productivity are likely to collapse under such conditions (and indeed, many did during that time period). Similar scenarios can be constructed for forests experiencing fire and insect outbreaks.

Ecosystem stewardship makes a major departure from classical resource management in stating that expecting and exploiting disturbances such as fires and floods are superior to management that attempts to prevent such events. Fire prevention in forests characterized by ground fires can lead to catastrophic fire and potentially ecosystem transformation, as in western North America, Australia, and other regions of the world (Schoennagel et al. 2004). Anticipating fire and mitigating the system to preclude the most negative outcomes appears a superior management model. Similarly, the conversion of most of our rivers into channels to maximize water discharge downstream has had catastrophic effects to downstream terrestrial ecosystems, coastal wetlands, and coastal shelf ecosystems. As floodplains are reclaimed by these rivers during extreme events, perhaps the best forward-looking conservation and restoration strategy is to allow at least a portion of these floodplains to function in their historical roles. This seems particularly appropriate in those regions where chronically wetter conditions are likely to cause
more frequent flood events, such as those seen in the North American midwestern rivers during 2011. Finally, exploiting windows of opportunity in habitat reconstruction following extreme events may provide opportunities for ecosystem reconstruction that benefits biological diversity concerns as well as an opportunity to enhance ecosystem services.

As ecosystems transition to new states, as species abundance is altered due to the suite of directional environmental drivers, conservationists may want to focus on direct and indirect mechanisms to allow for ‘unassisted’ species redistributions. The conversion of closed-canopy forests to savannas and shrublands, a phenomenon that appears to becoming more common in semiarid zones, makes life much more difficult for some species but offers opportunities to others that may have historically been rare or found only in adjacent areas. Concurrently, other communities may be transforming in an opposite direction. For example, much of the eastern grasslands remnants in North America have or will transform to woodlands provided these lands are not used for conventional agriculture purposes. If species have corridors that allow for movement, the systems can reform, potentially keeping most species and ecosystem services, at least at a regional scale. While the debate on assisted migrations is ongoing (McLachlan et al. 2007), natural corridors can be viewed as compatible components of both ecosystem stewardship and forward-looking conservation efforts. The new focus recognizes spatial scale issues that need to be considered now and in the future that previously could be ignored for most conservation efforts (e.g., Ervin et al. 2010; Worbys et al. 2010).

This framework has been applied to the National Wildlife Refuge System in the United States to develop a continental-scale conservation strategy (Magness et al. in press). Across the 540 refuges that comprise this system, the rate of historical temperature changes ranges from negligible to substantial. The sensitivity of each refuge was estimated based on whether it was
close to a biome boundary, because species responses to climate change are often associated with
biome boundaries (e.g., presence or absence of trees at a forest-grassland boundary) (Hampe and
Petit 2005). Finally, the capacity of a refuge to adapt to climate change depends on factors that
influence opportunities for migration and adjustment (e.g., elevational/latitudinal range within
the refuge, road density and proportion of protected lands adjacent to the refuge). The analysis
suggested the following conservation strategy to maximize continental-scale species
conservation:

1. Refuges that are not currently exposed to rapid climate change and have low sensitivity
   (are distant from a biome boundary) and have high adaptive capacity can serve as species
   refugia, and management need not be intensive might be focused on addressing non-
   climatic threats such as invasive species.

2. Refuges that are not currently exposed to rapid climate change and have high sensitivity
   and/or low adaptive capacity warrant management that mitigates conservation threats
   using tested conservation methods to maintain or restore historic conditions.

3. Refuges that are exposed to substantial climate change but have high adaptive capacity
   provide opportunities to learn about processes important to adaptation through natural
   species adjustments and warrant management of conservation of corridors and other
   features that facilitate this adjustment.

4. Refuges that are exposed to substantial climate change but have high sensitivity and/or
   low adaptive capacity may require management that facilitates transformation to novel
   ecosystem types that support novel species assemblages or that manages refuges as
   stepping stones for species migration at larger scales.
The first and second approaches are largely reactionary, aimed at maintaining current ecosystem and species composition. The third and fourth require anticipatory efforts that would benefit from adaptive management. Such a framework provides only rough guidance to local managers and must be integrated with local and regional conservation goals. However, it illustrates the value of considering a multi-faceted strategy that views novel ecosystems as potential opportunities under certain circumstances.

Another example of this framework is the management of the Tahoe National forest administered by the USDA forest Service (Stephens et al. 2010, Joyce et al. 2008). In Tahoe National forest, as with many forest systems in the Western United States, drought concerns, amplified by rising temperatures and lowered snowpacks, interact with dense forest structure from fire suppression policies to create severe forest hazards, extreme flood events and new opportunities for invasive species spread. On the Tahoe National Forest, several general principles were recognized as opportunities for stewardship in the face of rapidly changing climate: (1) managing for drought- and heat-tolerant species and ecotypes, (2) reducing the impact of current anthropogenic stressors, (3) managing for diverse successional stages, (4) spreading risks by including buffers and redundancies in natural environments and plantations, and (5) increasing collaboration with interested stakeholders. They considered alternative species mixes and germplasm choice for reforestation, and prioritized sensitive-species management actions at the ‘leading edge’ of species ranges (likely favorable future habitats) rather than ‘trailing edges.’ They prioritized projects that were projected to adapt to climate change projections, and put fewer priorities on restoration of systems that had an uncertain future.

Efforts to mitigate vegetation changes due to increased atmospheric deposition of plant-available forms of nitrogen (N) also provide another example of stewardship activities. Several
management techniques have proven successful to mitigate effects of N deposition on ecosystems: biomass removal, prescribed fire or control of invasive grasses by mowing, selective herbicides, weeding or domestic animal grazing. However, the efficacy of these techniques vary based on public acceptance and ecosystem type. For instance, 54% of the coastal sage scrub ecosystem is estimated to be in exceedence of the critical load for nitrogen deposition. Although the most effective large-scale method for controlling annual exotic grasses that invade the coastal sage scrub is burning in the spring before seeds have shattered (Gillespie and Allen, 2004), fire has not been used in remnant coastal sage areas because managers are understandably reluctant to burn remnant stands of shrubs. In grasslands, selective grazing on N-rich exotic grasses has been used with success to combat effects of N deposition (Weiss 1999; Marty 2005); however this same method in Coastal sage scrub is less effective because sufficient grass forage only occurs in very wet years. Thus, a good management technique (grazing or mowing) has successful used to mitigate for N deposition in grasslands, but in coastal sage scrub there is little evidence that management options will be effectively implemented in ecosystems impacted by excess N because they are not technically feasible or cost effective, and in many protected areas site manipulations are prohibited.

Researchers need to partner with managers on all aspects of resource and conservation management. Resource managers have spent millions of dollars in efforts to get rid of species they don’t want in their semi-natural ecosystems. These efforts have been unsuccessful in many areas, because either the target species (the ones the managers don’t want) come back immediately, or they are replaced with other species that are equally or even more undesirable in terms of both ecological services and conservation values (Reid et al. 2009). A recent meta-analysis by Kettenring and Adams (2011) attests the the generality of these observations. While
control of invasives in heavily impacted areas might be possible with infinite funding, the focus and resources might be better spent on conserving and enhancing the species of concern and interest (Davis et al. 2011; Wardle et al. 2011). Ecosystem stewardship focuses on maintaining and enhancing species that are viewed as important for a variety of ecosystem services, including cultural services, and a common feature is that these species maintain conditions favorable to native communities. Within this framework, species removal would be most appropriate where it maintains native communities with a reasonable expenditure of funds.

Fire management is also at a crossroads. The economic realities of the current fire control efforts are viewed as unsustainable (Pyne 2004). While we may not want fire, ongoing climatic changes are likely increase the extent of fire, regardless of the suppression effort applied (Westerling et al. 2011). Further, fire management now emphasizes protection of human-modified landscapes (i.e., the protection and promotion of hybrid or novel ecosystems) in addition to its role as a restoration tool (Schoennagel and Nelson 2011). Given this reality, it is important to rethink where and how to manage for the provision of the ecological services and conservation values provided by both fire-prone and fire-sensitive ecosystems and to manage development in ways that allow adequate protection of life and property.

**Conclusion**

Hybrid and novel ecosystems have a dual role. By default they have become the most widespread terrestrial ecosystems and are therefore important in providing ecological goods and services to society in an era of rapid environmental change. They also provide the most widespread arenas for conservation action. The good news - and it is good news - is that “many orthodox conservation practices…will continue to increase species and ecosystem adaptive
capacity to climate change” (Dawson et al. 2011, pg 57), and these practices are largely compatible within an ecosystem stewardship framework. Hybrid and novel ecosystems also provide opportunities for cautious experiments that may foster species conservation in new assemblages that have greater likelihood of persistence under projected environmental conditions.

References


Pyne, S. 2004. Tending fire: coping with America’s wildland fires. Island Press,


Table 1. Approaches and goals of ecosystem stewardship differ from traditional resource management (modified from Chapin et al. 2010), and benefits to biological conservation efforts are identified.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Ecosystem Stewardship Focus</th>
<th>Value to Conservation</th>
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<tbody>
<tr>
<td>Reference point</td>
<td>Trajectory of change¹</td>
<td>Resilience focus slows rate of biotic change</td>
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<tr>
<td>Central goal</td>
<td>Sustain social-ecological system and the delivery of ecosystem services</td>
<td>Diversity is a recognized component of services</td>
</tr>
<tr>
<td>Approach</td>
<td>Manage desirable feedbacks</td>
<td>Diversity compatible and contributes to focus</td>
</tr>
<tr>
<td>Role of uncertainty</td>
<td>a) Exploit opportunities generated by disturbances</td>
<td>Proactive: maximize ‘unassisted’ migration of desired biota</td>
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<td></td>
<td>b) Maximize flexibility and have multiple acceptable outcomes</td>
<td>Emphasis on heterogeneity, promote landscape diversity</td>
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<tr>
<td>Role of research</td>
<td>Researchers and managers partner in programs</td>
<td>Biodiversity focus can be part of management goals</td>
</tr>
<tr>
<td>Resources of primary concern</td>
<td>Biodiversity, well-being and adaptive capacity</td>
<td>Maintenance of biodiversity explicit</td>
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¹. Ecosystem stewardship might be considered adaptive ecosystem management for the Anthropocene, i.e., adaptive management that recognizes the significance of directional environmental drivers.