680c26f6237b62b19484dcb8bf03c8f9
ebrary

Chapter 3

Evolving Ecological Understandings: The Implications of Ecosystem Dynamics

RICHARD J. HOBBS, ERIKA S. ZAVALETA, DAVID N. COLE, AND PETER S. WHITE

680c26f6237b62b19484dcb8bf03c8f9
ebrary

> But if getting older has taught me anything it is the paradoxical certainty that one shouldn't be certain about anything.
>
> —*Stephanie Dowrick*

The science of ecology and the movement to designate national parks and other protected areas began in the nineteenth century, maturing and evolving over the last 100 years. Ecological thinking changed greatly in the last century, and new theories about how ecosystems work have profound implications for the management of protected areas. In particular, an improved understanding of the dynamic nature of ecosystems suggests important changes to the ways protected area managers think about ecological values at risk, the need for management intervention in ecosystem processes, the desired outcomes of those interventions, and the specific techniques used to achieve objectives. In particular, as discussed in Chapter 2, park stewardship continues to be guided to a substantial degree by naturalness, a concept that appears less useful through the lens of modern ecology.

Although initially focused primarily on individual species and ecological phenomena in isolation, ecologists increasingly study systems, all species, their interactions, and the external and internal processes that drive ecosys-

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Cole, David N., and Yung, Laurie, eds. Beyond Naturalness : Rethinking Park and Wilderness Stewardship in an Era of Rapid Change. Washington DC, USA: Island Press, 2010. ProQuest ebrary. Web. 11 January 2016.
Copyright © 2010. Island Press. All rights reserved.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

tems. Ecologists have expanded the spatial and temporal scales of phenomena they examine. By studying ecosystems at different scales, researchers have gained new insights about how such systems are organized, how they operate, what drives them, and how they might be managed. Ecologists increasingly understand that the structure and function of ecosystems reflect complex interactions of environmental and biotic processes at many scales, including longer-term and larger scales than the age and extent of parks. Analogous to this expanded ecological focus, notions of conservation have evolved to embrace a broad range of biodiversity and ecological processes, both of which are now seen as key values of protected areas.

Arguably the most important advance in ecological understanding, in terms of managing protected areas, has been recognition of the inherent dynamism of ecosystems and the importance of disturbance processes. A number of authors have written about a paradigm shift in ecology, from the old "balance of nature" perspective to the modern perspective of nature in flux. Pickett and Ostfield (1995: 274) describe the old paradigm as one that "assumed that ecological systems were closed, self-regulating, possessed of single equilibrium points reached by deterministic dynamics, rarely disturbed naturally, and separate from humans." Today, ecologists recognize that ecological systems are "open, regulated by events arising outside of their boundaries, lacking or prevented from attaining a stable point equilibrium, affected by natural disturbance, and incorporating humans and their effects" (Pickett and Ostfield 1995: 275). The fact that ecological systems are complex, dynamic, chaotic, and inevitably affected by human activity increases the challenge of protected area stewardship and exposes some of the contradictions inherent in the varied meanings of naturalness, the traditional goal of protected area stewardship.

In this chapter, we outline recent advances in ecological thinking that revise or challenge earlier understandings of ecosystems. We offer suggestions about what these advances mean for protected area management, particularly implications for the traditional concept of naturalness, alternative goals for ecosystem interventions, and various management practices. We begin by discussing the rise of biodiversity conservation as a central goal of park management. The remainder of the chapter explores the dynamism of ecosystems. As the pace of biophysical and sociocultural change accelerates, effective management more than ever requires clear enunciation of goals and strategies, design and implementation of suitable interventions, and the capacity to monitor key ecosystem attributes to detect change and determine whether interventions were successful.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Cole, David N., and Yung, Laurie, eds. Beyond Naturalness : Rethinking Park and Wilderness Stewardship in an Era of Rapid Change. Washington DC, USA: Island Press, 2010. ProQuest ebrary. Web. 11 January 2016.
Copyright © 2010. Island Press. All rights reserved.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Biodiversity and Conservation Goals

Protected areas are increasingly viewed as strongholds and refuges for native biological diversity (biodiversity). But the meaning of biodiversity conservation has expanded along with the field of ecology. Sometimes biodiversity is defined narrowly as a list of native species. Other times it is defined so broadly as to lose its meaning, as when it refers to everything from ecological processes to aesthetics. The Convention on Biological Diversity defines biodiversity (or biological diversity) as "the variability among living organisms from all sources, including, inter alia, terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems" (Article 2, www.cbd.int/convention/articles.shtml?a=cbd-02). We view this definition as a useful start to explore what *native biodiversity*, in practice, can usefully mean.

The Earth Summit definition emphasizes the value of biodiversity at a range of scales, including genes, populations, species, patches, ecosystems, and landscapes. Part and parcel of this cross-scale definition is the recognition of the interdependence of different scales via the processes that maintain biodiversity (Noss 1990). For example, without genetic and population diversity, species persistence is compromised because of the loss of the variability that permits evolutionary adaptation. Ecosystem and landscape diversity depend on large regional species pools to provide the raw materials of succession and assembly of the biotic community in any given area, and the maintenance of regional species pools depends on ecosystem and landscape diversity to support a wide range of species through time. Therefore, much more than just species and the assemblage in any given location must be conserved.

In the definition of goals for biodiversity conservation, special emphasis has been placed on the species most critical to ecosystem function, which could include keystone species and ecosystem engineers (Mills et al. 1993; Wright and Jones 2006). For example, sea otters (*Enhydra lutris*) exert tremendous influence over the maintenance of whole kelp forest ecosystems by limiting populations of kelp-consuming urchins (Estes and Duggins 1995). Because of this keystone role, extensive conservation measures have been extended to sea otters, including legislation, enforcement, translocations, and applied research. However, it may not be possible to confidently define a limited set of ecosystem functions that are important or to determine whether the species that contribute to these functions and features of structure (not to mention others inadvertently left out) in one place and

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Cole, David N., and Yung, Laurie, eds. Beyond Naturalness : Rethinking Park and Wilderness Stewardship in an Era of Rapid Change. Washington DC, USA: Island Press, 2010. ProQuest ebrary. Web. 11 January 2016.
Copyright © 2010. Island Press. All rights reserved.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

time are sufficient over larger temporal and spatial scales. The "insurance hypothesis" suggests that retaining all species, even rare ones, in a system provides resilience in the face of changing environmental conditions (Yachi and Loreau 1999). For instance, a recent long-term study in a California grassland showed that a plant species that was rare for 20 years made up a significant proportion of the plant community in years with a particular climatic signature (Hobbs, Yates, and Mooney 2007). Thus, a rare species played a more dominant role during times of drought.

Finally, the concept of ecosystem services has recently grown in popularity and been linked to biodiversity, with implications for how to manage and what to protect. Through the way they function, ecosystems provide services that are essential for human well-being and survival, such as provision of water, food, and fiber, aesthetic beauty, and recreation opportunities (Daily 1997). Conservation efforts targeting ecosystem services can shift priorities from protecting all the constituent parts of biodiversity toward protecting the landscapes, watersheds, or aspects of ecosystem structure and function that are most critical to the provision of ecosystem services. From a protected area perspective, the addition of ecosystem structure, functioning, and services broadens the set of goals for management and the set of reasons for protecting native biodiversity. It also makes protected area stewardship more challenging because the means of optimizing one goal may be detrimental to another goal. For example, desired fire regimes for maximizing forest carbon storage and old-growth–dependent species populations might differ from the optimal fire regimes for maintaining landscape-scale forest and habitat diversity. Moreover, this expanded set of goals means that managers need to be explicit about goals and their relative priority.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

From the Balance to the Flux of Nature

Insights from paleoecology, long-term ecological studies, and ecological modeling have revealed that ecosystems are highly dynamic and that they change in complex, nonlinear, and unpredictable ways. The idea of the balance of nature has been replaced with the flux of nature (Lodge and Hamlin 2006; Pickett and Ostfield 1995). Ecosystems may occur in a number of alternative states, and those states are contingent on many variables, particularly the history of disturbance and human intervention. Given their dynamic nature, ecosystems inevitably change on a number of spatial and temporal scales.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Cole, David N., and Yung, Laurie, eds. Beyond Naturalness : Rethinking Park and Wilderness Stewardship in an Era of Rapid Change. Washington DC, USA: Island Press, 2010. ProQuest ebrary. Web. 11 January 2016.
Copyright © 2010. Island Press. All rights reserved.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

The implications of this paradigm shift for the stewardship of parks and wilderness are profound (Christensen 1988). As threats to biodiversity mount, managers increasingly consider interventions for protected area ecosystems and processes. But the shifting nature of ecosystems suggests that there are many possible desirable outcomes for such interventions; there is no single true natural state. Moreover, the fluctuations themselves matter. The traditional notion of restoring past conditions is often inappropriate because many of the changes in ecosystem state that demand intervention are irreversible. So what criteria should be used to make decisions about where and how to intervene and to define desired outcomes? In the pages that follow, we explore some of what is known about ecosystem dynamics and the implications for such decisions.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Ecosystem Dynamics and Disturbance

Ecologists classify ecosystem dynamics as deterministic or stochastic or as transitions between alternative stable states (multiple equilibria) (Figure 3.1). Understanding how ecosystems actually change through time is essential to management decisions. Assuming one type of dynamics when, in fact, another type is in train may lead to potentially unpleasant surprises and unwanted outcomes. This is particularly true if slow, predictable dynamics are assumed and more stochastic or state-change dynamics are actually in play. Deterministic dynamics assume a predictable path of ecosystem development given any particular starting point, regardless of conditions before or during the development of the ecosystem. This deterministic paradigm is embodied by the traditional Clementsian perspective of succession, which sees plant community development as occurring in a very predictable, repeatable way depending on the local climate and soil type (Clements 1916). Odum (1969) later expanded these ideas to include a wide range of ecosystem properties that could be expected to change in a predictable way through time. In limited cases and contexts, ecosystems do undergo fairly deterministic succession. Old-field succession in eastern North America provides a classic example of predictable succession, where after abandonment the plant community is dominated first by annuals, then herbaceous perennials, then shrubs, and finally a progression of different types of trees (Hobbs and Walker 2006).

Most ecologists now agree that deterministic models are too simple to describe the complexity of dynamics actually observed in most situations and that stochastic (chance, unpredictable) processes play important roles

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Cole, David N., and Yung, Laurie, eds. Beyond Naturalness : Rethinking Park and Wilderness Stewardship in an Era of Rapid Change. Washington DC, USA: Island Press, 2010. ProQuest ebrary. Web. 11 January 2016.
Copyright © 2010. Island Press. All rights reserved.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

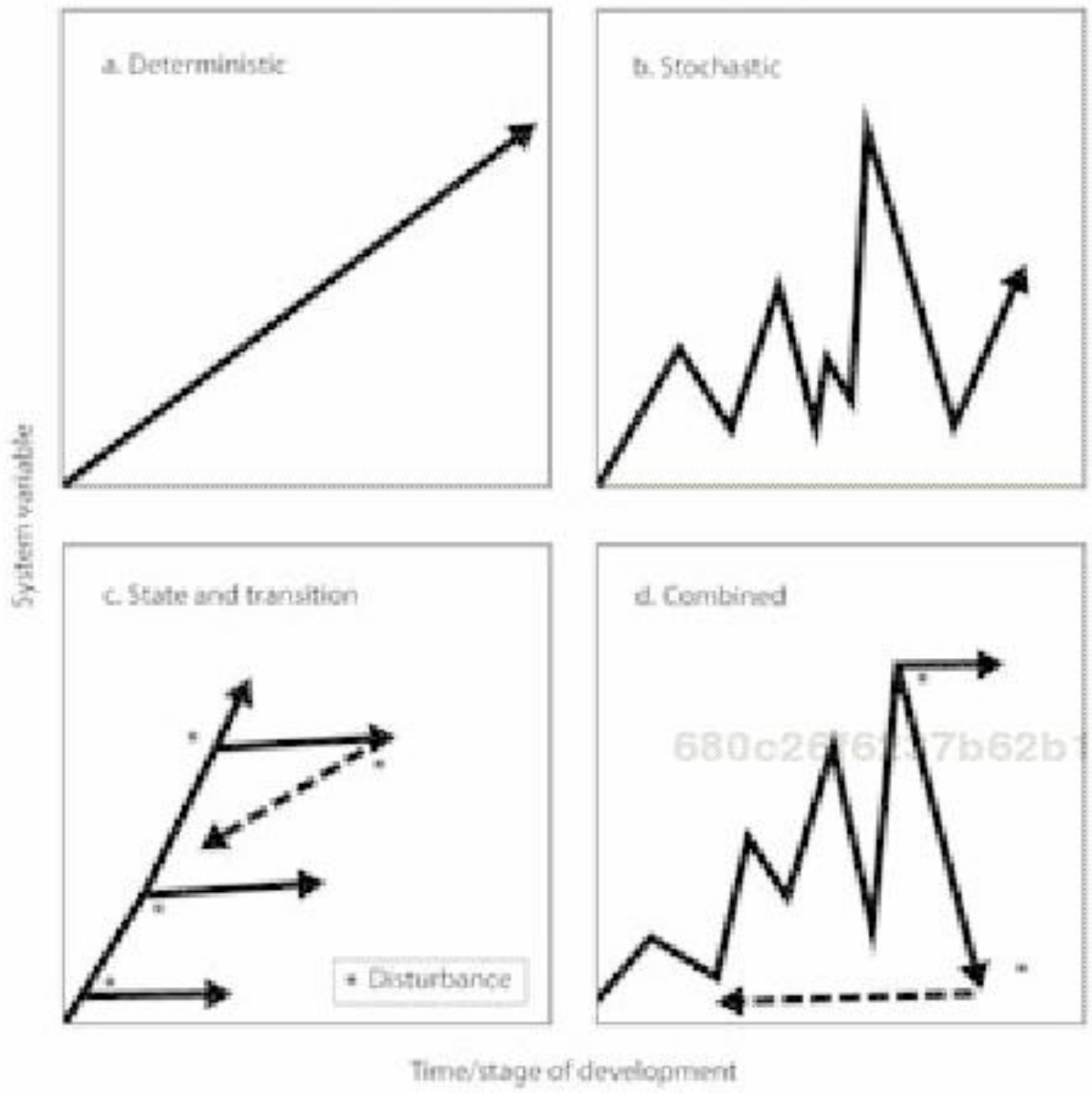

FIGURE 3.1. Ecosystem dynamics can be depicted as (a) deterministic, (b) stochastic, or (c) state and transition. In reality a combination of all three is likely (d). Traditionally, ecosystems have often been managed on the assumption that they are exhibiting deterministic dynamics. However, increasing levels of unexpected ecosystem change and surprise have led to a new understanding that incorporates the potential for both stochastic and state and transition dynamics. Solid lines represent progressive development, and dotted lines represent regressive dynamics. (Hobbs, Jentsch, and Temperton 2007)

680c26f6237b62b19484dcb8bf03c8f9
ebrary

(Temperton and Hobbs 2004). Although some apparently deterministic patterns are observable, there are usually variations around them, and often multiple developmental pathways are possible (Cramer 2006; Hobbs and Walker 2006). These variations often relate to the timing and severity of particular disturbances, climatic events, or soil- and resource-related phenomena. Abiotic disturbances in particular, such as fire, floods, hurricanes, and windthrow events, shape many (if not most) ecosystems. Altered disturbance regimes can profoundly change the structure, composition, and functioning of ecosystems. For example, the removal or reduction through dam building of pulse flood events from many rivers in the western United States has contributed to fundamental ecosystem changes such as widespread dominance by exotic tree species and large reductions in channel volumes (Stromberg and Chew 2002).

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Cole, David N., and Yung, Laurie, eds. Beyond Naturalness : Rethinking Park and Wilderness Stewardship in an Era of Rapid Change. Washington DC, USA: Island Press, 2010. ProQuest ebrary. Web. 11 January 2016.
Copyright © 2010. Island Press. All rights reserved.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Managing disturbance regimes is often seen as a way to modify community assembly and succession. However, human disturbance regimes (such as altering grazing or fire regimes) must be tested for their historic bounds of variation. Disturbances that are within the historic bounds of variation for an ecosystem may produce different responses, or serve different management goals, than disturbances that are novel or create conditions that are outside those bounds. Altered fire regimes in western North American forests provide a vivid example of how ecosystems can change dramatically if historic disturbance regimes are altered (Arno and Fiedler 2005). Fire suppression during the twentieth century moved the forests away from their historic state and allowed a buildup of fuel that resulted in catastrophic wildfires in many areas. Stochastic dynamics suggest a less orderly development, with the path of development constantly being affected by a variety of factors, each working on a range of different temporal and spatial scales and resulting in an apparently random path.

Alternatively, the notion of transitions between alternative stable states suggests that an ecosystem can exist in a number of different configurations and can be driven from one state to another by particular disturbance, climate, or management events (Hobbs and Suding 2009; Suding et al. 2004; Suding and Gross 2006). In other words, development of an ecosystem is punctuated and characterized by sudden changes from one stable state to another. Such dynamics are being increasingly proposed to explain changes in ecosystems, originally in arid and freshwater systems but more recently across a wide range of different systems (Hobbs and Suding 2009). For example, the removal of perennial vegetation in arid regions can trigger positive feedbacks that lead rapidly to a stable sandy desert condition. Nutrient loading in lakes can produce little visible change until a threshold is crossed, rapidly rendering a clear lake turbid and dramatically changing its species composition (Scheffer et al. 2001).

Disturbance events of extreme magnitude, such as tsunamis or catastrophic fires, can cause deterministic and stochastic dynamics to be nonlinear in the sense that no near-term return to prior reference conditions or reference dynamics is possible. For example, landslides on Hawaii that remove ash-derived soils can alter forest successional trajectories and generate persistent changes, such as reduced biomass and increased exotic species dominance (Restrepo et al. 2003). State and transition dynamics also include the idea of thresholds where sudden changes in ecosystem properties occur.

It is thus increasingly clear that no one model of ecosystem dynamics is completely appropriate in all situations and for all systems (Cramer et al.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Cole, David N., and Yung, Laurie, eds. Beyond Naturalness : Rethinking Park and Wilderness Stewardship in an Era of Rapid Change. Washington DC, USA: Island Press, 2010. ProQuest ebrary. Web. 11 January 2016.
Copyright © 2010. Island Press. All rights reserved.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

2008). As indicated in Figure 3.1, the same system may exhibit all three types of dynamics at different times, at different phases of development, or under different conditions. Assuming that one type of dynamics is in play when in fact another or a mix of dynamics is prevalent can lead to serious management problems. For example, assuming that a eutrophied lake can be restored simply by returning lake nutrient levels to pre-eutrophication levels could easily lead to a costly failure.

Thresholds and Alternative States

An important insight in ecology from the last 50 years is that nonlinear threshold changes can occur in ecological processes, species interactions, and population sizes in which there is a sudden switch from one state to a markedly different one (Walker et al. 2004). This switch can result from a particular event (such as a climatic extreme or major storm), management activity (such as the application of fire or changes in the grazing regime), or a nonlinear response to environmental change (such as pollution in a river reaching toxic concentrations). Crossing some thresholds may produce changes that are either irreversible or extremely difficult to reverse. For instance, too frequent fire can shift a shrub-dominated plant community to a herbaceous community that appears resistant to further change, particularly redevelopment of the previous shrub community (Keeley 2006). Consequently, understanding thresholds is critical to the development and evaluation of management actions.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Invasive Species and Rapid Evolution

Another factor affecting ecosystem dynamics and notions of naturalness is the increasing role that species not originally native to the locality have in ecosystems, as discussed in detail in Chapter 10. Today's conditions increasingly challenge managers to consider how to define and tackle invasive species. For example, where climate change is forcing species to migrate to new areas or other stressors have eliminated formerly dominant native species, nonnative species can meet important habitat needs for native species or perform useful ecosystem functions (Graves and Shapiro 2003). For instance, tamarisk invades riparian areas in western North America and alters ecosystem processes such as sedimentation, but some argue that, in the absence of native riparian tree species, it now provides habitat for

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Cole, David N., and Yung, Laurie, eds. Beyond Naturalness : Rethinking Park and Wilderness Stewardship in an Era of Rapid Change. Washington DC, USA: Island Press, 2010. ProQuest ebrary. Web. 11 January 2016.
Copyright © 2010. Island Press. All rights reserved.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

threatened bird species (Cohn 2005). Therefore, efforts to remove tamarisk must be accompanied by the restoration of native riparian species. Where nonnative species have come to support native biodiversity in the absence of some now-missing species, ecosystem structure, or function, managers may decide to tolerate, retain, or even actively encourage clearly exotic species (such as Aldabran tortoises, *Geochelone gigantea*, in Mauritius) (Zavaleta et al. 2001). The pace and extent of change at scales far beyond individual protected areas challenge managers to think carefully about how to define *native* and *invasive* for practical purposes and about whether and when to accept the presence of a species even when it is recognized as an invader. The ecological and management implications of novel species assemblages have only recently begun to be considered seriously in the ecological literature (Hobbs et al. 2006; Seastadt et al. 2008).

As a final twist in how ecological systems are changing in ways that challenge traditional management approaches, there are increasing reports of species evolving rapidly in their new habitats (Thompson 1998), especially in the context of invasive species and pathogens (Strayer et al. 2006). Invasive species sometimes show a remarkable ability to evolve rapidly and adapt to their new habitat or biotic assemblage. A recent dramatic example of this is the Gough Island mouse (Wanless et al. 2007). The common house mouse *Mus musculus* was thought to have been inadvertently transported to the sub-Antarctic island by British whalers around 150 years ago. The mouse now appears to have evolved to two to three times the size of ordinary British house mice and from eating predominantly insects and seeds to eating the chicks of large birds, changes that may be causing problematic population declines. Therefore, it becomes increasingly important not to assume that a particular species will continue to behave in a similar manner to that found in its previous habitat. This implies the need for ongoing monitoring efforts to be robust enough to detect such changes and impacts.

The potential for rapid evolution is also an important factor in likely biotic responses to climate change. A range of species have already shown the capacity to undergo genetic change in the face of rapidly changing climates (Bradshaw and Holzapfel 2006), and yet this has rarely been factored into attempts to understand and predict biotic response to climate change.

Dynamic Ecosystems Challenge Notions of Naturalness

What do the recent developments in thinking about ecosystem dynamics mean to the concept of naturalness? The old "balance of nature" perspec-

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Cole, David N., and Yung, Laurie, eds. Beyond Naturalness : Rethinking Park and Wilderness Stewardship in an Era of Rapid Change. Washington DC, USA: Island Press, 2010. ProQuest ebrary. Web. 11 January 2016.
Copyright © 2010. Island Press. All rights reserved.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

tive on the world was consistent with notions of naturalness: Nature existed apart from humans and was largely predictable and static except when recovering from infrequent disturbance. These assumptions have slowly been pulled apart. Ecosystems are only seldom predictable and are in a constant state of dynamism, with individual species and biotic communities constantly changing in abundance through space and time. Furthermore, science has revealed that humans have been part of most ecosystems for millennia.

As discussed in Chapter 2, increased understanding of the widespread influence of indigenous humans on ecosystems around the world and the likelihood that indigenous people were keystone species exerting a strong influence on many environments necessitates rethinking how we view the past and plan for the future. If ecosystems evolved with human input, the absence of all human influence may not be desirable in some cases. For example, intentional burning could be necessary to maintain the open, parklike conditions of ponderosa pine forests and montane meadows in parts of the western United States. Instead, protected area managers may strive to minimize certain types of human effects. When managers determine whether a particular change is good or bad, they should no longer view human-induced change as necessarily bad, as implied by naturalness. Rather, criteria for what is good and bad should focus on various ecosystem attributes, such as species preserved, ecological integrity, historical fidelity, or resilience, as discussed in subsequent chapters. Another way of saying this is that the criteria for deciding whether to intervene and the desired outcomes of intervention should be shifted substantially from cause to effect. Whether or not the characteristics of the ecological system are acceptable or desirable is more important than whether or not change is human induced.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

New ways of thinking about ecosystem dynamics lead further away from the old ideas about the balance of nature and the existence of one true "natural" state. If ecosystems are dynamic, the "natural state" is a moving target. What is natural may encompass many different potential states in any particular place though time and is likely to change as a result of climatic and disturbance events and changing management regimes.

Putting Ecosystem Dynamism into Practice

Ecosystem dynamism presents both challenges and opportunities for protected area managers. On one hand, confronting this level of complexity can be quite paralyzing because of the number of decisions to be made, the range of options that might be available, and the difficulty in monitoring

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Cole, David N., and Yung, Laurie, eds. Beyond Naturalness : Rethinking Park and Wilderness Stewardship in an Era of Rapid Change. Washington DC, USA: Island Press, 2010. ProQuest ebrary. Web. 11 January 2016.
Copyright © 2010. Island Press. All rights reserved.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

simple cause-and-effect responses in an ecosystem. There may not be one correct state to aim for, and even without considering human effects on ecosystems, there is no single definable baseline. In addition, managers and society are faced with the possibility that certain introduced species might even be good (if they promote desirable goals and objectives).

Setting management goals is further complicated by the need to allow for natural disturbance processes. Historical range of variability (HRV) (Landres et al. 1999) can account for variation associated with disturbance (although directional change makes even this problematic). However, using HRV in a management context means that only conditions within the historic range are considered desirable. Applying HRV also entails arbitrary decisions about scale, place, and time. If scale, place, or time becomes too broad, almost anything is within the bounds of HRV, and the concept no longer provides practical guidance to the manager. Thus, maintaining historic species assemblages may not be the only valid management goal in protected areas. Novel species assemblages arising through species migration and invasion are increasingly inevitable as climate change and species movement increase; some of these novel assemblages might be desirable. Furthermore, as demonstrated by new ecological thinking about ecosystem dynamism, there are many possible desirable future states that are best considered in terms of ecosystem attributes (e.g., resilience, biodiversity) rather than degree of historic fidelity.

If the concept of naturalness is no longer a useful guide to developing goals for management interventions, what might replace or supplement it? Recognizing complexity in dynamics does not necessarily mean increased difficulty in deciding on management options. Despite the challenges described here, the dynamic nature of ecosystems may mean that a greater variety of valid management responses are available. In other words, one consequence of the new understanding of ecosystem dynamics is the expanded range of possible desirable outcomes. This means that there is less reason to seek the precise, correct future trajectory or endpoint. For example, intensive management to secure a particular mix of species and proportions of forest patches in a landscape could shift to a focus on maintaining disturbance dynamics and the ability for species to move across the landscape. It also means there is more need to make choices with little guidance regarding how to choose between alternatives. Managers will have to "play God" to a greater degree, and more frequently than they may want to. Because there are multiple ecosystem states and no clear correct choice, it is extremely important to articulate clear and specific goals.

Particularly given uncertainty, this suggests a need for diversity in the

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Cole, David N., and Yung, Laurie, eds. Beyond Naturalness : Rethinking Park and Wilderness Stewardship in an Era of Rapid Change. Washington DC, USA: Island Press, 2010. ProQuest ebrary. Web. 11 January 2016.
Copyright © 2010. Island Press. All rights reserved.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

choices that are made, incorporating some built-in redundancy, planned at large spatial scales and implemented within an adaptive framework (see Chapters 12 and 13 for additional detail). Although there will probably be no one-size-fits-all approach that can be rolled out everywhere, it is possible to consider the suite of goals to be considered and the types of approaches needed (Lindenmayer et al. 2008). More attention must be paid to the process of prioritizing effort, using either analytical or triage-based approaches (Hobbs et al. 2003; Wilson et al. 2007). For example, Hobbs and colleagues (2003) outline an approach that prioritizes restoration actions based on the value of an ecological asset, the level of threat it faces, and the probability that the intervention will succeed. Rather than simple rule-based decision making inherited from past experience, new approaches will involve more decision tree analysis. When there is no one right answer, the range of possibilities and the likely consequences of action and inaction must be made as explicit as possible.

Applying the New Ecology

In this chapter we have suggested that ecosystems are dynamic and change in unpredictable ways, an insight that overturns traditional ways of thinking about ecosystems as stable, static, and balanced. These new ways of thinking about ecosystem flux and change reveal high levels of complexity and uncertainty, but the science of ecology can help managers deal with this complexity. This at first seems paradoxical. Indeed, it is true that dynamic ecosystems provide managers fewer certainties on which management prescriptions can be based. In the future, protected area managers will have to embrace the dynamism and uncertainty inherent in ecosystems, recognizing that many different future states are possible and potentially desirable. Given the unprecedented environmental changes of the twenty-first century, simply recognizing that the old rules do not necessarily apply is an important initial step toward a realistic view of how ecosystems work. It is critical to accept that ecosystems are not stable and predictable, tending toward historic conditions. Nor are they like machines that can be understood through isolated information about individual parts. Dynamic ecosystems are complex and uncertain, which necessitates trying different things in different places and responding to changing circumstances in an adaptive way. It involves keeping a close eye on how the system is behaving and making careful decisions about when and where to intervene. This is difficult but not impossible. Many of the "new" approaches demanded by

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Cole, David N., and Yung, Laurie, eds. Beyond Naturalness : Rethinking Park and Wilderness Stewardship in an Era of Rapid Change. Washington DC, USA: Island Press, 2010. ProQuest ebrary. Web. 11 January 2016.
Copyright © 2010. Island Press. All rights reserved.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

our changed understanding of ecosystems are simply extensions of what we know should be good practice anyway. For instance, managers in Kruger National Park in South Africa have initiated a system of identifying "thresholds of potential concern" (Biggs and Rogers 2003), which act as triggers for particular types of intervention. This type of thinking moves away from the institutional tendency prevalent in many situations, which is to ignore potential problems until they become critical, only then instigating crisis management. It also demands the input of timely local information and expertise to inform decisions rather than reliance on broad general rules. In other words, the protected area manager needs to know his or her own turf and make decisions contingent on the local conditions but cognizant of the broader landscape and regional perspective.

Learning how to intervene effectively and efficiently in the dynamics of ecosystems is the key task for the coming decades. Moving on from naturalness demands that managers and scientists alike come to grips with the full extent of this task and find effective ways of making it work.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

BOX 3.1. WHAT DYNAMIC ECOSYSTEMS MEAN FOR PROTECTED AREA MANAGEMENT

- Advances in ecological understanding over the past few decades challenge traditional notions of naturalness.
- It is now clear that ecosystems are not stable and predictable, tending toward historic conditions. This has profound implications for the stewardship of parks and wilderness.
- When managing ecosystems, it is important to embrace disturbance and different types of dynamism as key characteristics of ecosystems.
- When designing interventions, managers must understand that there is no single "correct" or "natural" ecosystem state to aim for. They should focus on outcomes and specific conservation goals rather than on whether change is caused by humans.

REFERENCES

Arno, S. F., and C. E. Fiedler. 2005. *Mimicking nature's fire*. Island Press, Washington, DC.

Biggs, H. C., and K. H. Rogers. 2003. An adaptive system to link science, monitoring and management in practice. Pp. 59–82 in J. du Toit, K. H. Rogers, and H. C. Biggs, eds. *The Kruger experience: Ecology and management of savanna heterogeneity*. Island Press, Washington, DC.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Cole, David N., and Yung, Laurie, eds. Beyond Naturalness : Rethinking Park and Wilderness Stewardship in an Era of Rapid Change. Washington DC, USA: Island Press, 2010. ProQuest ebrary. Web. 11 January 2016.
Copyright © 2010. Island Press. All rights reserved.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Bradshaw, W. E., and C. M. Holzapfel. 2006. Evolutionary response to rapid climate change. *Science* 312:1477–1478.

Christensen, N. L. 1988. Succession and natural disturbance: Paradigms, problems, and preservation of natural ecosystems. Pp. 62–86 in J. K. Agee and D. R. Johnson, eds. *Ecosystem management for parks and wilderness*. University of Washington Press, Seattle.

Clements, F. E. 1916. *Plant succession: An analysis of the development of vegetation*. Publication No. 242. Carnegie Institute, Washington, DC.

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

Cramer, V. A. 2006. Old fields as complex systems: New concepts for describing the dynamics of abandoned farmland. Pp. 31–46 in V. A. Cramer and R. J. Hobbs, eds. *Old fields: Dynamics and restoration of abandoned farmland*. Island Press, Washington, DC.

Cramer, V. A., R. J. Hobbs, and R. J. Standish. 2008. What's new about old fields? Land abandonment and ecosystem assembly. *Trends in Ecology and Evolution* 23:104–112.

Daily, G. C., ed. 1997. *Nature's services: Societal dependence on natural ecosystems*. Island Press, Washington, DC.

Estes, J. A., and D. O. Duggins. 1995. Sea otters and kelp forests in Alaska: Generality and variation in a community ecological paradigm. *Ecological Monographs* 65:75–100.

Graves, S. D., and A. M. Shapiro. 2003. Exotics as host plants of the California butterfly fauna. *Biological Conservation* 110:413–433.

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

Hobbs, R. J., V. A. Cramer, and L. J. Kristjanson. 2003. What happens if we can't fix it? Triage, palliative care and setting priorities in salinising landscapes. *Australian Journal of Botany* 51:647–653.

Hobbs, R. J., A. Jentsch, and V. M. Temperton. 2007. Restoration as a process of succession and assembly mediated by disturbance. Pp. 150–167 in L. R. Walker, J. Walker, and R. J. Hobbs, eds. *Linking restoration and ecological succession*. Springer, New York.

Hobbs, R. J., and K. N. Suding, eds. 2009. *New models for ecosystem dynamics and restoration*. Island Press, Washington, DC.

Hobbs, R. J., and L. Walker. 2006. Old field succession: Development of concepts. Pp. 17–30 in V. A. Cramer and R. J. Hobbs, eds. *Old fields: Dynamics and restoration of abandoned farmland*. Island Press, Washington, DC.

Hobbs, R. J., S. Yates, and H. A. Mooney. 2007. Long-term data reveal complex dynamics in grassland in relation to climate and disturbance. *Ecological Monographs* 77:545–568.

Keeley, J. E. 2006. South coast bioregion. Pp. 350–390 in N. G. Sugihara, J. W. van

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Cole, David N., and Yung, Laurie, eds. Beyond Naturalness : Rethinking Park and Wilderness Stewardship in an Era of Rapid Change. Washington DC, USA: Island Press, 2010. ProQuest ebrary. Web. 11 January 2016.
Copyright © 2010. Island Press. All rights reserved.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Wagtendonk, K. E. Shaffer, J. Fites-Kaufman, and A. E. Thode, eds. *Fire in California's ecosystems*. University of California Press, Berkeley.

Landres, P. B., P. Morgan, and F. J. Swanson. 1999. Overview of the use of natural variability concepts in managing ecological systems. *Ecological Applications* 9:1179–1188.

Lindenmayer, D., R. J. Hobbs, R. Montague-Drake, J. Alexandra, A. Bennett, M. Burgman, P. Cale, et al. 2008. A checklist for ecological management of landscapes for conservation. *Ecology Letters* 11:78–91.

Lodge, D. M., and C. Hamlin, eds. 2006. *Religion and the new ecology: Environmental responsibility in a world in flux*. University of Notre Dame, Notre Dame, IN.

Mills, L. S., M. E. Soulé, and D. F. Doak. 1993. The keystone species concept in ecology and conservation. *BioScience* 43:219–224.

Noss, R. F. 1990. Indicators for monitoring biodiversity: A hierarchical approach. *Conservation Biology* 4:355–364.

Odum, E. P. 1969. The strategy of ecosystem development. *Science* 164:262–270.

Pickett, S. T. A., and R. S. Ostfield. 1995. The shifting paradigm in ecology. Pp. 261–278 in R. L. Knight and S. F. Bates, eds. *A new century for natural resources management*. Island Press, Washington, DC.

Restrepo, C., P. Vitousek, and P. Neville. 2003. Landslides significantly alter land cover and the distribution of biomass: An example from the Ninole ridges of Hawai'i. *Plant Ecology* 166:131–143.

Scheffer, M., S. Carpenter, J. A. Foley, C. Folke, and B. Walker. 2001. Catastrophic shifts in ecosystems. *Nature* 413:591–596.

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

Strayer, D. L., V. T. Eviner, J. M. Jeschke, and M. L. Pace. 2006. Understanding the long-term effects of species invasions. *Trends in Ecology and Evolution* 21:645–651.

Stromberg, J. C., and M. K. Chew. 2002. Flood pulses and restoration of riparian vegetation in the American Southwest. Pp. 11–49 in B. Middleton, ed. *Flood pulsing and wetlands: Restoring the natural hydrological balance*. Wiley, New York.

Suding, K. N., and K. L. Gross. 2006. The dynamic nature of ecological systems: Multiple states and restoration trajectories. Pp. 190–209 in D. A. Falk, M. A. Palmer, and J. B. Zedler, eds. *Foundations of restoration ecology*. Island Press, Washington, DC.

Suding, K. N., K. L. Gross, and G. R. Houseman. 2004. Alternative states and positive feedbacks in restoration ecology. *Trends in Ecology and Evolution* 19:46–53.

Temperton, V. M., and R. J. Hobbs. 2004. The search for ecological assembly rules and its relevance to restoration ecology. Pp. 34–54 in V. M. Temperton,

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Cole, David N., and Yung, Laurie, eds. Beyond Naturalness : Rethinking Park and Wilderness Stewardship in an Era of Rapid Change. Washington DC, USA: Island Press, 2010. ProQuest ebrary. Web. 11 January 2016.
Copyright © 2010. Island Press. All rights reserved.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

R. J. Hobbs, T. J. Nuttle, and S. Halle, eds. *Assembly rules and restoration ecology: Bridging the gap between theory and practice*. Island Press, Washington, DC.

Thompson, J. N. 1998. Rapid evolution as an ecological process. *Trends in Ecology and Evolution* 13:329–332.

Walker, B., C. S. Holling, S. R. Carpenter, and A. Kinzig. 2004. Resilience, adaptability and transformability in social-ecological systems. *Ecology and Society* 9:5.

Wanless, R. M., A. Angel, R. J. Cuthbert, G. M. Hilton, and P. G. Ryan. 2007. Can predation by invasive mice drive seabird extinctions? *Biology Letters* 3:241–244.

Wilson, K. A., E. C. Underwood, S. A. Morrison, K. R. Klausmeyer, W. W. Murdoch, B. Reyers, G. Wardell-Johnson, et al. 2007. Conserving biodiversity efficiently: What to do, where, and when. *PLoS Biology* 5(9):e223. doi:10.1371/journal.pbio.0050223:e223.

Wright, J. P., and C. G. Jones. 2006. The concept of organisms as ecosystem engineers ten years on: Progress, limitations, and challenges. *BioScience* 56:203–209.

Yachi, S., and M. Loreau. 1999. Biodiversity and ecosystem productivity in a fluctuating environment: The insurance hypothesis. *Proceedings of the National Academy of Science* 96:1463–1468.

Zavaleta, E. S., R. J. Hobbs, and H. A. Mooney. 2001. Viewing invasive species removal in a whole-ecosystem context. *Trends in Ecology and Evolution* 16:454–459.

680c26f6237b62b19484dcb8bf03c8f9
ebrary

680c26f6237b62b19484dcb8bf03c8f9
ebrary

Cole, David N., and Yung, Laurie, eds. Beyond Naturalness : Rethinking Park and Wilderness Stewardship in an Era of Rapid Change. Washington DC, USA: Island Press, 2010. ProQuest ebrary. Web. 11 January 2016.
Copyright © 2010. Island Press. All rights reserved.