Chapter 1

SETTING THE STAGE: THEORETICAL AND CONCEPTUAL BACKGROUND OF HISTORICAL RANGE OF VARIATION

William H. Romme,1 John A. Wiens,2,3 and Hugh D. Safford4,5

1Colorado State University, Fort Collins, CO, USA
2PRBO Conservation Science, Petaluma, CA, USA
3University of Western Australia, Crawley, WA, Australia
4USDA Forest Service, Pacific Southwest Region, Vallejo, CA, USA
5University of California, Davis, CA, USA
Background and history

History is nothing but assisted and recorded memory.

George Santayana

The times they are a-changin'.

Bob Dylan

1.1 INTRODUCTION

The above quotations, from two philosophers of different times and modes of expression, capture the essential tension that underlies this book. “History” is the template on which the present is founded, but what we know of history is determined by human knowledge and the interpretation (or filtering) of past events. As we probe more deeply into the past, our knowledge becomes more fragmentary, uncertainty increases. Yet history holds precious clues to why things are the way they are today, and therefore how we might act to keep them that way or alter them, and how we might avoid mistakes of the past. History provides essential lessons for the conservation and management of natural resources.

At the same time, times are changing, and changing rapidly. The climate is warming. The rapid expansion of human populations and economies has dramatically depleted the extent of the earth’s natural and seminatural habitats. Land-use change and habitat fragmentation have reduced the availability and connectivity of suitable habitat for native plants and wildlife. Although the future is by definition uncertain (Fig. 1.1), it seems increasingly likely that the future will be quite different from the present or the past. Even if history has been a useful (albeit less than certain) guide for conservation and management up to now, will it be hopelessly compromised, and thus irrelevant, in a radically different future?

This is the question that carries through this book. In this chapter, we set the stage for what follows by providing a perspective on historical ecology and environmental variation, briefly reviewing some of the issues in the application of history to resource management, and introducing some of the key themes developed more comprehensively in the following chapters. A general thesis of this book is that the future is built on foundations laid in the past, no matter the rapidity, profundity, or direction of potential change. The mechanisms by which organisms and ecosystems respond to global change in the future will be those by which they have responded in the past. Although the future is an unknown place, we do well to remember that the value of historical knowledge and past experience is highest where the lay of the land is least familiar.

1.2 HISTORICAL ECOLGY AND HISTORICAL RANGE OF VARIATION (HRV)

Resource management across the United States and other parts of the world is often predicated on restoring ecosystem patterns and processes understood from analyses of historical conditions. In practice, desired conditions for ecological restoration, conservation, and resource management are commonly derived from historical “reference states” (Meffe & Carroll 1994; Egan & Howell 2001). Because most current ecosystems have been highly altered by human use, ecological management tends to focus on the past. Managers and scientists use information about places and proc-
processes revealed through historical ecology to generate assessments of ecological trends, serve as the basis for benchmarks of ecological integrity, develop and parameterize models of ecological processes, and provide targets for preservation, restoration, resource management, and policy (Landres et al. 1999; Swetnam et al. 1999; Egan & Howell 2001). Historical ecology is particularly useful for documenting mechanisms of temporal change and providing context to interpret the meaning of this change for current and future management. For example, reconstructions of long-term vegetation change, based on pollen preserved in lake-bottom sediments or macrofossils within packrat middens, reveal that Pleistocene and early Holocene community assemblages were generally dissimilar to widespread plant communities today (Jackson 2006). This historical perspective tells us that current communities probably will not simply migrate intact to higher latitudes and elevations with global warming, but that future species assemblages will likely differ compositionally from contemporary assemblages, just as they did after the major climatic changes at the end of the Pleistocene. Similarly, knowledge that piñon pine (Pinus monophylla and Pinus edulis) migrated northward from Pleistocene refugia in southern Arizona and northern Mexico, and that this migration continues today (Miller & Wigand 1994; Swetnam et al. 1999), tells us that recent piñon expansion into grasslands and shrublands at the northern limit of its current range may represent a process of natural biogeographic spread rather than an unnatural response to land-use practices (Romme et al. 2009).

Restoration ecology and resource management incorporate historical ecology based on the premise that the ecological conditions most likely to preserve native species or conserve natural resources are those that sustained them in the past, when ecosystems were presumed to be less affected by people. Environments varied then, but the variations were more “natural,” so species were likely to have adapted evolutionarily to those variations. The expectation, then, is that by managing an ecosystem within the bounds of historical (i.e. “natural”) variation for key ecosystem patterns and processes, sustainability and persistence should be fostered (Manley et al. 1995; Egan & Howell 2001; Wiens et al. 2002). Less explicitly, the use of historical ecology to inform contemporary practices assumes that current environmental envelopes are much as they were in the past, absent the rather massive effects of humans in transforming the landscape (Turner et al. 1990). This manifests the persistent belief, expressed in disciplines as varied as natural philosophy, systems dynamics, and organic gardening, in an overall balance of nature (Pimm 1991; Kricher 2009).

Historical ecology involves the general application of historical information to a wide array of questions and issues in both basic and applied ecology. The use of historical information in natural resource conservation, restoration, and management has become formalized in the concept of HRV. In its simplest form, HRV is characterized as the range of some condition or process (e.g. disturbance regime, stand structure, patch size, diversity) that has occurred over some specified period in the past (Box 1.1). In this book, we borrow from Landres et al. (1999), Keane et al. (2009), and others to define HRV as

The variation of ecological characteristics and processes over scales of time and space that are appropriate for a given management application.

In contrast to the generality of historical ecology, the HRV concept focuses on a distilled subset of historical ecological knowledge developed for use by resource managers; it represents an explicit effort to incorporate a historical perspective into management and conservation. Of necessity, the concept of HRV involves specification of the historical period over which to characterize natural variability. In the United States, the reference period for HRV assessments has often been restricted to the few centuries preceding European settlement (Aplet & Keeton 1999). Accordingly, many proposed land-management actions have treated the period immediately prior to settlement as an explicit target and have sought to re-create conditions thought to be characteristic of this period.

Multiple terms and subtly different concepts have evolved to describe and characterize HRV, but all get at a very similar basic idea. Box 1.1 summarizes many of the terms and definitions that have received widespread use and presents some new terms and concepts recently developed to help integrate historical ecology with social perspectives on ecosystem management; these ideas are developed later in this chapter.

---

1 The HRV acronym has been used to refer to “historical range of variability” and to “historical range of variation” (Box 1.1). We use the latter terminology throughout this book.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Historical range of variation (HRV)</td>
<td>The variation of ecological characteristics and processes over scales of space and time that are appropriate for a given management application</td>
<td>This book</td>
</tr>
<tr>
<td>Historical range of variability</td>
<td>“the estimated range of some ecological condition or process that occurred in the past . . . often expressed as a probability distribution of likely states . . . denotes a dynamic set of boundaries between which most native biodiversity variables have persisted – with fluctuations – through time and across space”</td>
<td>Binkley and Duncan (2010)</td>
</tr>
<tr>
<td>Historical range of variability</td>
<td>“HRV . . . represents how vegetation is structured (e.g. tree density), how it varies spatially and temporally, and how fire functions (e.g. fire size, intervals) with little effect of people, except where people have been a significant structuring force”</td>
<td>Baker (2009, p. 3)</td>
</tr>
<tr>
<td>Historical range of variability</td>
<td>“the variability of regional or landscape composition, structure, and disturbances, during a period of time of several cycles of the common disturbance intervals, and similar environmental gradients, referring, for the United States, to a period prior to extensive agricultural or industrial development”</td>
<td>Hann and Bunnell (2001, p. 394)</td>
</tr>
<tr>
<td>Historical range of variation</td>
<td>“the range of variation over a period of record, ideally encompassing multiple generations of dominant plants, a time span that would also encompass much of the relevant variation in animal populations and physical factors”</td>
<td>White and Walker (1997, p. 343)</td>
</tr>
<tr>
<td>Historical range of variability</td>
<td>“characterizes fluctuations in ecosystem conditions or processes over time . . . define[s] the bounds of system behavior that remain relatively consistent over time”</td>
<td>Morgan et al. (1994, p 88)</td>
</tr>
<tr>
<td>Historic range of variability</td>
<td>“the spatial and temporal variation in composition, structure and function experienced in an ecosystem from about 1600 to 1850, when the influences of European-Americans were minimal [within the land area being evaluated]”</td>
<td>Dillon et al. (2005, p. 1)</td>
</tr>
<tr>
<td>Historical range and variability</td>
<td>“the variation of historical ecosystem characteristics and processes over time and space scales that are appropriate for the management application”</td>
<td>Keane et al. (2009, p. 1026)</td>
</tr>
<tr>
<td>natural range of variability (NRV)</td>
<td>The ecological conditions and processes within a specified area, period of time, and climate, and the variation in these conditions, that would occur without substantial influence from human mechanisms”</td>
<td>Hann and Bunnell (2001, p. 394)</td>
</tr>
<tr>
<td>Reference conditions</td>
<td>“the spectrum of ecosystem conditions (i.e. structure, composition, and function) found within a defined area over a specified time period preceding Euro-American settlement”</td>
<td>Stephenson (1999, p. 1253)</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
<td>Reference</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>Reference conditions</td>
<td>“Reference conditions characterize the variability associated with biotic communities and native species diversity. They provide insights to important questions such as the natural frequency, intensity, and scale of forest disturbances; the age-class distribution of forest trees; and the abundance or rareness of plant or animal species within an ecosystem.”</td>
<td>Kaufmann et al. (1994, p. 7)</td>
</tr>
<tr>
<td>Natural range of variation</td>
<td>“the range of variation in the absence of human influence”</td>
<td>White and Walker (1997, p. 343)</td>
</tr>
<tr>
<td>Natural variability</td>
<td>“the ecological conditions, and the spatial and temporal variation in these conditions, that are relatively unaffected by people, within a period of time and geographical area appropriate to an expressed goal”</td>
<td>Landres et al. (1999, p. 1180)</td>
</tr>
<tr>
<td>Future range of variability (FRV)</td>
<td>“the estimated range of some ecological condition or process that may occur in the future – a dynamic set of boundaries on some condition or process that may occur in the future . . . [may be] expressed as a probability distribution of likely states”</td>
<td>Binkley and Duncan (2010)</td>
</tr>
<tr>
<td>Social range of variability (SRV)</td>
<td>“the range of an ecological condition that society finds acceptable at a given time . . . [reflecting] the suite of resource-management options that most people consider acceptable”</td>
<td>Duncan et al. (2010)</td>
</tr>
<tr>
<td>Social range of variability (SRV)</td>
<td>“the range of an ecological condition that society finds acceptable at a given time . . . [may be] expressed as a distribution of public acceptability”</td>
<td>Binkley and Duncan (2010)</td>
</tr>
<tr>
<td>Ecological range of variability (ERV)</td>
<td>“the estimated range of some ecological condition as a function of the biophysical forces, such as fires and hurricanes, and the social forces, e.g., burning, harvest, and development, that affect the area”</td>
<td>Duncan et al. (2010)</td>
</tr>
</tbody>
</table>

The concept of HRV and assessments of HRV for specific places have been developed and applied most often in forested ecosystems of the western United States, where the impacts of Euro-American settlement occurred relatively recently (generally mid-to late 1800s) and where long-lived trees are available for relatively precise reconstructions of past forest structure and disturbance regimes. Insights from historical ecology also have figured prominently in land-management and policy decisions in places where a formal HRV assessment has not been developed, such as in the forested landscapes of New England where European settlement occurred very early (beginning in the 1600s) and almost all of the original forest has been cut at least once or even removed for agriculture (Foster et al. 1996). Thus, a formal HRV assessment is
only one of many ways in which ecological history can inform present-day resource management. Where a local HRV assessment has been developed, with comparisons of historical versus current conditions, it is tempting to assume that the HRV condition therefore must be the desired management target. This follows immediately from the assumption that the ecological systems are in a dynamic equilibrium, varying about an unchanging long-term mean (Fig. 1.1). Conditions that existed during the HRV reference period may indeed be appropriate targets for some ecosystems or for some elements of an ecosystem (e.g., as a coarse-filter strategy for maintaining overall ecological integrity and resilience; Hunter 1990; Haufler et al. 1996; Holling & Meffe 1996). It is increasingly recognized, however, that returning some or even many characteristics of specific landscapes to the HRV condition may be neither ecologically feasible nor socially desirable, especially in the face of climate change, escalating land-use impacts, and spread of invasive species. Millar and Woolfenden (1999) and Millar et al. (2007) discuss issues of technical feasibility, pointing out that restoration and maintenance of some of the ecological conditions that prevailed during the “Little Ice Age” (which is the reference period for many HRV studies) would become increasingly difficult, expensive, and uncertain of success as we move into a progressively warmer world. A case in point would be restoration of salmon (Oncorhynchus spp.) populations in southern California streams where the species was present historically but where future water temperatures are expected to be too warm for salmon (Millar, pers. comm. 2008). Duncan et al. (2010) illustrate the social fallacy of uncritically assuming HRV to be the management target by pointing out that a high-severity fire regime might be the “natural” or historical norm in a wildland–urban interface area, but that society would never accept large destructive fires as a management objective. Although such issues have led some to dismiss the HRV concept as irrelevant, most would argue that HRV is irrelevant only if used naively. We briefly mention several well-conceived and useful applications of HRV later in this chapter, and others are discussed elsewhere in this book.

The concept of HRV has been described and illustrated in several excellent review articles, including a special section in Ecological Applications in 1999 (Parsons et al. 1999) and a recent summary by Keane et al. (2009). The relevance of historical ecology and HRV to the broader framework of ecosystem management was also reviewed in earlier articles that are still very pertinent, notably Kaufmann et al. (1994), Morgan et al. (1994), and Christensen et al. (1996). Rather than duplicate those detailed reviews, we instead highlight a few key concepts and issues that remain at the forefront of thinking about HRV, especially in the context of coping with future environmental change.

### 1.3 SOME CRITICAL ISSUES AND LIMITATIONS OF THE HRV CONCEPT

In the last decade or two, several serious conceptual and data-related issues regarding the use of HRV in resource management have emerged. It is these concerns that have led some to believe that HRV is not a useful tool in real-life management. Three issues are particularly important: the role of humans in reference ecosystems, the amount and quality of data available, and the dramatic and often irreversible alterations of ecosystems being wrought by climate change, invasive species, and intensifying human land use. These concerns are addressed briefly below, and a variety of examples of dealing with them effectively are presented in greater detail in the other chapters in this book.

#### The role of humans in reference ecosystems

An early criticism of the HRV concept was that it seemed to overlook the significant environmental impacts of indigenous people during the historical reference period. Developed as it was by people mainly of European background and affluent socioeconomic status, the idea of HRV was suggested to have misanthropic or even racist overtones, especially when it was expressed as the “range of natural conditions” (Box 1.1). This is a major reason why the term “historical range of variation” is used most often today: it avoids the knotty question of what is “natural” and allows for a potentially important history of human influence within reference ecosystems. The issue now is one of determining just what that influence was. On one side of the question are scholars and popular writers who argue that pre-Columbian Native American people

---

2 Throughout this book, we use “Native American” to refer to North American indigenous peoples.
substantially altered North American ecosystems almost everywhere. On the other side are authors describing America as a pristine wilderness essentially untouched by humans (see Vale 2002). Neither extreme position is likely to be correct. Just as climate and topography vary across the continent, so too the activities and impacts of Native Americans varied across space and through time (Vale 2002). There were places and times where the ecological impacts of indigenous people were likely quite intense, as near a Flathead village along the Yellowstone River, and other places where impacts probably were negligible, as in the unproductive and game-poor lodgepole pine (Pinus contorta) forests on the Yellowstone Plateau (Vale 2002). The challenge for ecologists and managers doing HRV work today is to determine objectively the kinds and magnitudes of human influences on ecological structure and function in a specific place during a specific time in the past.

Although the specific ecological impacts of indigenous people in North America prior to the arrival of Europeans will always be somewhat uncertain (Duncan et al. 2010), there is no question that the trappers, loggers, miners, grazers, farmers, industrialists, and settlers who swept across the continent beginning in the sixteenth century ushered in a new era of enormous ecological change. It is these changes against which HRV provides an especially meaningful benchmark. This is why the reference period in HRV assessments is often the several centuries just prior to Euro-American settlement; this usually is the time for which we have the most complete information about ecological conditions as they existed before the storm. Impacts of indigenous people during that reference period may or may not need to be included as important components of HRV, depending on the particular locale and specific ecological questions being addressed (see Nowacki et al., Chapter 6, this book).

The amount and quality of data available for HRV summaries and assessments

The availability of accurate and relevant information is a limiting factor in many facets of resource management, and historical assessments are no exception. This topic has been discussed both in the reviews cited above and in articles and reports dealing with historical assessments conducted in specific places. Box 1.2 summarizes some of the major issues related to sources, strengths, and limitations of historical ecological data and HRV information in particular.

There are perhaps three key issues to consider when evaluating historical conditions that existed in any particular place. First is the “fading record,” the idea that we generally have more information and can more readily reconstruct missing information for more recent time periods than for long-distant times (Swetnam et al. 1999). The record fades with time because the necessary materials for historical reconstruction gradually decay over time: things like old fire-scarred trees, ancient dead wood, and packrat middens are continually lost to wood harvest, wildfires, natural biological and physical decomposition, and weather. A major reason why HRV assessments are particularly useful in forests of the western United States is because the generally dry climate and relatively recent Euro-American settlement mean that these paleo-materials have been lost at a slower rate than in other places having a moister climate and/or a longer period of Euro-American land use.

The second key issue is what we might call the “selective record” of what is available – and unavailable – for any time in the past (Santayana’s “assisted and recorded memory”). We have good information in many western forests about pre-1850 stand structure, composition, and fire frequency because trees that were alive at that time are still extant, either as very old living individuals or as well-preserved dead wood. But even where we have the best record of canopy structure and dynamics, we usually have little or no direct information about the herbaceous understory, invertebrate communities, soil microbial communities, or biogeochemical processes. These latter elements of an ecosystem, arguably as important as the trees, simply do not leave any tangible evidence for us to interpret today. Instead, we must make logical inferences about these components, which is not necessarily a bad thing in itself. It is important to remember, however, that this information is inferential rather than direct.

Finally, we cannot escape the fact that our historical information usually comes from localized places (e.g. a particular forest stand containing old trees and fire scars, or a particular lake with datable sediments), but the landscape of management interest typically is much larger. Therefore, we face issues of extrapolation and interpolation as we scale up from the sources of data to the area of application (White & Walker 1997; see Wiens et al., Chapter 5, this book). Moreover, the
available reference sites may not be representative of the landscape as a whole: fire-scarred trees may be concentrated on drier sites where fires historically burned at lower intensity rather than on more productive sites that supported higher-intensity fires, or packrat middens may represent the localized flora of the rocky area itself instead of the open expanses that surround the rocks (Swetnam et al. 1999). To a greater or lesser degree, every individual place in the world is different from every other place because of differences in local environment and history, many of which are subtle. The challenge to ecologists is to combine insights from data sets that are incomplete to synthesize a broader picture of ecosystem structure and dynamics (White & Walker 1997). This is no small task, although several chapters in this book illustrate innovative approaches that have been applied successfully to the problem of characterizing the whole from the available parts.

**Facing a future of climate change, invasive species, and accelerating human land-use impacts**

Given the scope and magnitude of current and impending ecological changes taking place throughout the planet, it is no surprise that critics question whether historical ecology, and HRV in particular, still has any relevance to resource management. Indeed, if the only
Box 1.3 Examples of how the HRV concept can be utilized effectively in resource management, planning, and policymaking, despite anticipated changes in climate, land use, and invasive species (see text for explanations). The list is meant to be illustrative rather than comprehensive.

<table>
<thead>
<tr>
<th>Application</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifying ecological conditions that will enhance ecological resilience</td>
<td>Restoring pre-1900 structure to southwestern ponderosa pine forests</td>
</tr>
<tr>
<td>in the face of changing climate and fire regimes</td>
<td>(e.g. Allen et al. 2002; Fulé 2008)</td>
</tr>
<tr>
<td>Evaluating the ecological feasibility of management goals that society</td>
<td>Using prescribed burning to reduce fuels and prevent severe fires in</td>
</tr>
<tr>
<td>may find desirable</td>
<td>wildland-interface zones (e.g. Romme et al. 2004)</td>
</tr>
<tr>
<td>Designing management plans that maintain ecological integrity while</td>
<td>Mimicking historical spatial and temporal patterns of forest disturbance,</td>
</tr>
<tr>
<td>producing economic commodities</td>
<td>in programs designed to simultaneously harvest timber and maintain</td>
</tr>
<tr>
<td></td>
<td>old-growth forest habitats (e.g. Cissel et al. 1999)</td>
</tr>
<tr>
<td>Educating the public and facilitating collaborative discourse and decision</td>
<td>Integrating historical ecological insights with social perceptions and</td>
</tr>
<tr>
<td>making about resource-management goals and methods</td>
<td>desires to explore a “future range of variability” (e.g. Duncan et al.</td>
</tr>
<tr>
<td></td>
<td>2010)</td>
</tr>
<tr>
<td>Others . . . see chapters in this book</td>
<td></td>
</tr>
</tbody>
</table>

application of HRV were to try to return ecosystems to replicas of pre-European conditions, then this criticism would be unassailable. The fallacy is in thinking of HRV as a specific target for a desired state of ecological systems, rather than using the historical record to assess how (and why or whether) such systems responded to environmental variations in the past as a way of informing current and future conservation management. Chapter 4 addresses this issue more fully. In the following section, however, we briefly develop some examples to illustrate that applications of the HRV concept are far broader and richer than a simplistic effort to reconstruct some idealized past state.

1.4 SOME EXAMPLES OF THE APPLICATION OF HRV IN A CHANGING WORLD

To set the stage for what will follow in subsequent chapters, we briefly examine four examples of useful and well-conceived applications of the HRV concept (summarized in Box 1.3). These examples and this discussion are meant to be illustrative rather than comprehensive.

HRV helps in identifying ecological conditions that will restore ecological resilience in the face of changing climate and fire regimes

The frequency and extent of severe, stand-replacing fires in Arizona ponderosa pine (Pinus ponderosa) forests have increased dramatically in the past two decades, and many of the burned forests appear to have been converted, perhaps permanently, to shrublands and grasslands (Savage & Mast 2005; Strom & Fulé 2007). The failure of the forests to regenerate after fire is ironic, because HRV data reveal that ponderosa pine was one of the most frequently burned vegetation types prior to the twentieth century, with typical fire-return intervals of a decade or less (Moore
et al. 1999). The key distinction is that historical fires usually were low-intensity surface burns. Ponderosa pine is well adapted to a fire regime of this kind: thick bark and a high crown prevent serious injury in mature trees, while frequent burning reduces fuel loads and maintains a low-density stand structure by selectively killing small trees and shrubs. Ponderosa pine should be able to survive – even thrive – in a future world of even more frequent fire if only the forests can be restored to the low-density, low-fuel condition that prevailed before heavy grazing and fire-suppression programs removed fire from the ecosystem after ca. 1880 and allowed unusually dense and vulnerable fuel structures to develop (Ecological Restoration Institute – http://www.eri.nau.edu/). Importantly, we need not necessarily return this ecosystem to an exact replica of its 1880 condition: it may be sufficient only to set the forests on a trajectory toward restoration of the key structural and functional elements that created historical resilience (Allen et al. 2002; Fulé 2008; Diggins et al. 2010).

HRV helps in evaluating the ecological feasibility of management goals that society may find desirable

Residents of rural or suburban communities surrounded by coniferous forests are increasingly cognizant of their vulnerability to destructive wildfires (Theobald & Romme 2007). Successful programs of fire mitigation via thinning and prescribed low-intensity burning have been developed and implemented for ponderosa pine forests (as just described), and it would seem logical that similar techniques could be applied to other coniferous forest types, such as lodgepole pine forests. An examination of historical conditions and disturbance regimes, however, raises questions about the likely effectiveness of a ponderosa pine-type fuel reduction program in lodgepole pine forests. Lodgepole pine forests were typically dense and fires were usually high intensity during the pre-1900 reference period (Sibold et al. 2006); fire size and severity were controlled far more by weather and climate than by fuel characteristics (Schoennagel et al. 2004). Drawing on this information about the historical fire regime as well as recent fire experience, Romme et al. (2004) identified both operational and ecological problems that would be faced in attempting to mitigate fire hazards in lodgepole pine forests using mechanical thinning and prescribed low-intensity burning. Operational problems include a surface-fuel structure that is not conducive to spreading surface fires, plus a narrow window of weather conditions within which sustained surface fire is even possible – between being too wet to burn at all and so dry that the fire spreads into the canopy. Ecological problems include the tendency of residual lodgepole pine trees to fall down after thinning of dense stands, plus the fact that the native flora is well adapted to high-severity burns recurring at long intervals (e.g. serotinous cones in lodgepole pine and dormant seeds of shrubs and herbs that are stimulated by fire to germinate), but may not be able to tolerate frequent re-burning given the kind of fire environment in which the flora developed. Romme et al. (2004) recommend instead a fire-mitigation program that partly emulates the historical fire regime, creating fuel breaks with small but high-severity burns (ignited either by managers or by lightning) in strategically located areas at times when weather conditions allow fire spread to be controlled, and regulating spatial patterns of exurban development to keep vulnerable structures out of areas at highest fire risk. Similar understanding of the ecology of fire in chaparral stands in southern California, which also burn naturally at high severity but have been heavily invaded by suburban homes, has led to similar recommendations regarding development zoning and strategic placement of fuel treatments (Safford 2007).

HRV helps in designing management plans that maintain ecological integrity while producing economic commodities

Management of Douglas-fir (Pseudotsuga menziesii) forests in the Pacific Northwest during the latter half of the twentieth century emphasized timber production but included old-growth forest reserves intended to maintain overall biological diversity and to preserve habitat for the spotted owl (Strix occidentalis). In response to concerns about the effectiveness of the existing reserve system, Cissel et al. (1999) used spatial modeling techniques to simulate the future landscape structure that would result from continuation of the
current system of static reserves (the “interim plan”) and compared this outcome with the results of a more dynamic management plan in which spatial and temporal harvest patterns would more closely resemble the patterns produced by the historical fire regime (the “landscape plan”). Notably, the landscape plan did not attempt to recreate the precise landscape structure that existed at any specific time in the past; instead, it generally mimicked the historical disturbance frequency, patch size, and spatial distribution of disturbance patches. The simulations revealed several ecological advantages of the historically informed landscape plan: average size of old-growth reserves was greater, and reserves were more equably distributed across different topographic settings when compared with projected results for the static interim plan. A disadvantage of the landscape plan was higher costs for planning and implementing timber harvests. However, this disadvantage might be partially offset by the value of timber that would be harvested with the landscape plan.

**HRV helps in educating the public and facilitating collaborative discourse and decision making about resource-management goals and methods**

In the not-too-distant past, public resource management was very much a top-down affair: the experts in government agencies identified goals and options, and the public had a very limited role in responding to what was presented to them. One of the major trends of the past few decades is the development of more effective public engagement in resource-management decisions. Three tasks are central to success in this process: (1) providing an ecological context that informs people of what would be ecologically possible or impossible, (2) informing land managers of people’s desires and expectations for public lands, and (3) creatively integrating these two kinds of information into an ecologically realistic and socially acceptable plan of action. HRV assessments are ideally suited for the first task if the assessment is presented in understandable terms and not as an uncritically assumed target for the future. For the second task, the idea of a “social range of variability (SRV)” or “the suite of resource-management options that most people consider acceptable” has been recently introduced (Box 1.1). For the third task, Duncan et al. (2010) propose collaborative exploration of a “future range of variability (FRV)” (Box 1.1). By depicting both HRV and SRV as probability distributions, a region of overlap is identified, representing a combination of conditions that are potentially both ecologically feasible and socially acceptable (Fig. 1.2). This range of ecologically and socially compatible conditions can be further refined by considering likely future developments, such as climate change or economic incentives or disincentives for timber harvest, to produce an “ecological range of variability (ERV)” (Box 1.1). A key aspect of the exploration of an FRV is that ERV is never static; consequently, FRV will also be dynamic as social and ecological conditions change over time. This is illustrated for the case of old-growth forest cover in Fig. 1.3. Nevertheless, neither ERV nor FRV can change without limits. This is where HRV is especially useful: it helps identify key constraints on what is ecologically possible and informs and thereby broadens the perspective through which people decide what is ecologically desirable.

**1.5 PRÉCIS**

These four examples illustrate some ways in which the HRV concept can be a valuable tool in resource management, even in the face of a dramatically changing future. Although we have emphasized examples from terrestrial ecosystems, historical ecology and the HRV concept apply equally in aquatic ecosystems, as developed in Chapters 15 and 16 (Box 1.4). Despite the inherent limitations of all historical data and perspectives, HRV and, more broadly, an understanding of history nevertheless provide an ecological context for resource-management and conservation decisions that cannot be obtained from any other source. Rather than being a naïve concept focused only on an unattainable past, history, properly used, can enable resource management and conservation to move into an uncertain future. In the following 22 chapters, 54 authors from a wide variety of resource-management agencies, nongovernmental organizations, universities, and research institutes provide testament to the multifaceted and highly relevant stanchion that historical ecology and HRV provide to current and future conservation and resource management.
Fig. 1.2 Conceptual diagram illustrating the interaction of the range of variation for an ecological condition that reflects the disturbance of ecosystems by biophysical and human forces and their rate of recovery with the range of conditions that are considered socially acceptable. Figure 1.2A shows a hypothetical set of these relationships for some condition. Zone i represents ecological conditions that would occur without investment/intervention to prevent them but that do not have social acceptance; in Zone ii, the likelihood of occurrence is greater than the likelihood of acceptance; in Zone iii, the likelihood of occurrence is less than the likelihood of acceptance; and Zone iv represents conditions that would not occur without investment/intervention to enable them even though a segment of society wants them. To the degree that the two ranges do not overlap, social pressure/negotiation may be expected to change the shape of the ecological probabilities curve. This negotiation leads to the range of variation actually experienced (Fig. 1.2B). The exact probability distribution can only be estimated, but there is always uncertainty; hence, this distribution is represented by a fuzzy area between the two curves. Looking back in time, Fig. 1.2B would be called the historical range of variation. Looking forward in time, Fig. 1.2B would be called the future range of variation. The curve produced in Fig. 1.2B is potentially highly dynamic. Reprinted, with permission, from Duncan et al. (2010).
Fig. 1.3 (A) Probability distribution associated with percentage of old-growth forests in the Oregon Coast Range and the expression of the social range of acceptability of old-growth representation during the 1960s prior to passage of the National Environmental Policy Act (NEPA), which ensured public participation in planning processes. (B) Changes in local/regional social values during the mid-1990s (solid arrow and curves) led to a shift in the ecological range of variation (ERV) over the region (dashed arrow and curves) as federal land managers developed new forest plans for the Pacific Northwest region following NEPA policies and other environmental laws and political processes. (C) Because the social range of variation (SRV) continues to diverge from the ecological range of variation as the Northwest Forest Plan is implemented, policies can be expected to continue to shift the range of variation of old-growth forests farther to the right. Reprinted, with permission, from Duncan et al. (2010).
Box 1.4 Application of historical ecology in aquatic and terrestrial systems.

The science and application of historical ecology share many common elements across wet and dry environments. Resource managers concerned with conservation of both aquatic and terrestrial resources independently began using historical ecology to influence management decisions during the 1960s (Landres et al. 1999). In both systems, some practitioners employed “reference areas” to establish targets for ecological restoration (Karr 1981; Holling & Meffe 1996; Shields et al. 2003; Humphries & Winemiller 2009), while others focused on the ecological understanding provided by HRV assessments to provide context for management decisions. Clearly, issues of scale, system dynamics, and the importance of understanding processes that occur over extended periods motivated interest in historical ecology. Similarities in application of historical ecology within aquatic and terrestrial systems extend from motivations to methods, issues, and benefits realized. Aquatic ecologists use sediment cores in lakes, soil cores in valley bottoms, and backhoe trenches in areas of deposition to trace the history of biotic and geomorphological processes (e.g. Walters & Merritts 2008). In terrestrial systems, dendrochronology provides analogous time series (Grissino-Mayer et al. 2004). Historical survey records, aerial photographs, chronosequence approaches, and historical narratives are used by both aquatic and terrestrial managers to examine landscape patterns (e.g. Harding et al. 1998; Egan & Howell 2001). The challenge of locating historical legacies that reliably indicate the history of disturbance events or changes in species composition plagues scientists working in both aquatic and terrestrial systems. Likewise, separating patterns resulting from aboriginal or recent human activity from other ecological processes clouds understanding; examples include milldams in the eastern United States or European piedmont (Walters & Merritts 2008) and aboriginal fire in Northeastern forests (Lorimer 2001). Locating evidence for the spatial extent of disturbance events and making inferences from incomplete historical data also limit scientists in both types of environments. The use of historical ecology has revised several long-standing paradigms and changed management practices in both aquatic (Poff et al. 1997) and terrestrial (Foster et al. 1998) resource management. The apparent lack of dialogue among terrestrial and aquatic practitioners on this topic is therefore puzzling. We anticipate that the benefits gained through expanding this dialogue will lead to advances in management of aquatic and terrestrial resources.

REFERENCES


