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# Chapter 1:

## Fire and Nonnative Invasive Plants—Introduction

Fire is a process integral to the functioning of most temperate wildland ecosystems. Lightning-caused and anthropogenic fires have influenced the vegetation of North America profoundly for millennia (Brown and Smith 2000; Pyne 1982b). In some cases, fire has been used to manipulate the species composition and structure of ecosystems to meet management objectives, including control of nonnative invasive plant species (DiTomaso and others 2006a; Grace and others 2001; Keeley 2001; Myers and others 2001; Pyke and others, in review). However, fire can also threaten human life, property, and natural and cultural resources. Under some conditions, fire can increase abundance of nonnative invasive plants (Goodwin and others 2002), which may subsequently alter fire behavior and fire regimes, sometimes creating new, self-sustaining, invasive plant/fire cycles (Brooks and others 2004; D’Antonio and Vitousek 1992). These altered fire regimes can reduce native species diversity, alter ecosystem functions, and increase the threat of fire to human communities and wildland ecosystems.

Wildland managers must decide when, where, and for what specific reasons they should use fire to meet management objectives. To develop effective plans and make well-informed decisions, managers need to understand the scientific principles that drive the relationships between fire and nonnative invasive

plants. They also need to understand how fire-invasives issues affect management in their geographic regions. Managers have indicated that better interpretation of science, including peer-reviewed synthesis, is essential for “bridging the worlds of fire managers and researchers” (White 2004). Several publications summarize regional and topical aspects of integrated fire and invasive plant management (Brooks and others 2004; Brooks and Esque 2002; Brooks and Pyke 2001; D’Antonio and Vitousek 1992; D’Antonio 2000; DiTomaso and others 2006a). However, a published synthesis of major fire-invasive plant issues on a national scale is lacking. To address this need, this volume reviews the scientific literature regarding relationships between fire and nonnative invasive plants in the United States and presents information useful for improving fire and nonnative species management in wildland ecosystems.

This volume complements Volume 2 of the Rainbow Series, *Wildland Fire and Ecosystems – Effects of Fire on Flora* (Brown and Smith 2000). Readers are referred to that volume for information on autecological relationships between plants and fire, past fire regimes, and successional patterns for forest and grassland ecosystems in the United States. However, *Effects of Fire on Flora* provides only a cursory treatment of nonnative species. In contrast, this volume focuses

on nonnative invasive plants and fire. It is intended as a review of knowledge for wildland managers who are interested in using prescribed fire to reduce nonnative invasive plants, and those who are concerned that fire and fire management activities may increase abundance of nonnative species to the detriment of native ecosystems. This volume can be used to inform management plans and actions, although it is not comprehensive or detailed enough to provide prescriptions for management on particular sites. Objectives of this volume are

1. To synthesize scientific information regarding relationships between wildland fire and nonnative invasive plant species; and
2. To identify the nonnative invasive species currently of greatest concern and the wildland communities where fire-invasive issues are of greatest concern in major bioregions of the United States, synthesize information unique to those areas, and describe emerging fire-invasive issues in each bioregion.

## Scope of This Volume

Other volumes in the Rainbow Series are framed only in terms of fire effects, but interactions between fire and nonnative invasive plants are more complicated. Nonnative invasive plant species may establish or increase in response to fire, but fire exclusion may also provide opportunities for invaders to establish in some plant communities (chapter 2). Fire can also be used to control invading plant species in some plant communities (chapter 4). Once invading species establish and begin to dominate a site, they may change many properties of fuel beds, which in turn may affect the fire regime (chapter 3). To capture the complex interrelationships between fire and nonnative invasive plant species, we follow three main themes throughout this volume: fire effects on nonnative plant invasions (including effects of fire exclusion policy and fire suppression tactics), changes in fuel characteristics and fire regimes caused by nonnative plant invasions, and the intentional use of fire to control nonnative invasives.

In this volume, “nonnative” refers to a species that has evolved outside the United States and has intentionally or unintentionally been transported and disseminated by humans into and within the United States (adapted from Li 1995). We include a few exceptions to this definition, however. For instance, in chapter 11 we address some species that are native to the mainland United States but not to the Hawaiian Islands; and in chapter 5 we include reed canarygrass (*Phalaris arundinacea*) and common reed (*Phragmites australis*), which have origins in both the United States and Eurasia, and have ecotypes or strains that are invasive in some situations. The patterns and processes described

in this volume may also apply to species native to the United States that are spreading outside their historical ranges (for example, black locust (*Robinia pseudoacacia*), mesquite (*Prosopis* spp.), and juniper (*Juniperus* spp.)), but these species are not addressed in detail in this volume.

Only a small subset of nonnative plants is considered “invasive” (Rejmánek and others 2005; Williamson 1996). In this volume, the term “invasive” refers to a species that can establish, persist, and spread in a new area (*sensu* Burke and Grime 1996; Mack and others 2000; Sakai and others 2001) and also cause—or have potential to cause—negative impacts or harm to native ecosystems, habitats, or species. The decision of whether ecological changes or other impacts constitute net “harm” is a function of human values and can be ambiguous (see, for example, reviews by Lodge and others 2006; Mooney 2005). In this volume, harm in natural areas occurs when a species is so abundant that it causes significant changes in ecosystem composition, structure, or function, which are often viewed as harmful (Westbrooks 1998). Randall (1997) states this idea pragmatically: A plant species is considered invasive in natural areas when its occurrence interferes with management goals such as maintenance of native biotic diversity, protection of habitat for rare species, or restoration of ecological processes.

The basic biology of a nonnative species provides some insights regarding its potential invasiveness, so autecology is a useful starting point for understanding the potential impacts of disturbances, including fire, on nonnative species. However, genetic and clinal variation can lead to variable responses (Rejmánek and Richardson 1996; Wade 1997). Therefore, the nonnative species of greatest concern vary from region to region. In this volume, the nonnatives of greatest concern are listed at the beginning of each bioregional chapter, then discussed within the chapter in terms of both autecology and site-specific responses. Throughout this volume, the first reference to a species in each chapter gives both the common name most often used in the literature and the scientific name (from the U.S. Department of Agriculture’s Integrated Taxonomic Information System (ITIS Database 2004)); subsequent references in the chapter use only the common name. Readers seeking information on a particular species should refer to the index.

Understanding the interactions among invasive species, native plant communities, and fire requires more than an understanding of autecology. As noted by Bazzaz (1986), “The colonizer and the colonized are partners in the process.” Invasibility—the susceptibility of a plant community to invasion (*sensu* Davis and others 2000; Howard and others 2004; Lonsdale 1999; Smith and others 2004; Williamson 1996)—varies among plant communities. Additionally, the responses

of plant communities to fire depend on a host of factors, including the frequency and severity of fire, season and spatial extent of burns, preburn vegetation occurrence (including nonnatives) and phenology, site conditions (particularly moisture, available nutrients, light, and disturbance history), and postfire conditions, including weather and availability of seed from invasive plants (Klinger and others 2006a; Pyke and others, in review; Stohlgren and others 2005). Such comprehensive knowledge is rarely available in the scientific literature in relation to invasive species (chapter 12), so managers must integrate incomplete knowledge, gathered at a variety of locations using different methods, for application to invasives in specific plant communities. McPherson (2001) comments that this “creative application of existing knowledge” is “as important, and as difficult, as the development of new knowledge.” To assist managers in this formidable task, this volume draws mainly on peer-reviewed reports of primary research, that is, articles published in scientific journals and reports in reviewed scientific publication series, such as USDA Forest Service research papers and general technical reports. We also include information from case studies, informal reports, unpublished research, and personal communications. While this kind of information is probably accurate, its scope of inference is often difficult to determine. Therefore, the reader should use caution in applying that information, especially in locations or under conditions that differ from those described.

Secondary sources, including literature reviews, receive less emphasis in this volume than primary research because (1) reviews do not consistently report the scope of a study or its limits of inference, and (2) reviews occasionally misquote an original source. However, this volume does rely on *Fire Effects on Flora* (Brown and Smith 2000) for background information on fire regimes in the bioregional chapters in Part II. Additionally, reviews from two Internet sources, the Fire Effects Information System (FEIS, at [www.fs.fed.us/database/feis](http://www.fs.fed.us/database/feis)) and The Nature Conservancy’s (TNC) Element Stewardship Abstracts (ESAs, provided by the Invasive Species Initiative at <http://tncweeds.ucdavis.edu/index.html>), receive frequent use in this volume. Both sources include extensive information and are written specifically for managers. FEIS species reviews include biological and ecological information as well as information relating specifically to fire. ESAs focus especially on management and control techniques for invasive species. Literature reviews are identified as such the first time they are used in each chapter, so the reader will be aware that these are not primary sources. In regard to FEIS and TNC reviews, this note can also alert the reader that the Internet site may provide further information on fire, impacts, and control methods.

This volume is a survey as well as a synthesis, so it does not include every citation on every nonnative invasive plant species in the United States. Even unlimited resources would make a comprehensive treatment of fire and invasive species infeasible since new nonnative plants continue to invade the United States (Westbrooks 1998) and changing climatic conditions may alter competitive relationships between native and nonnative species (D’Antonio 2000). However, since the patterns described here are based on biological and ecological concepts, this volume may help managers evaluate the potential invasiveness of nonnative species about which little is known, the potential vulnerability of a particular ecosystem to establishment of new invasives, and how fire management activities may affect an ecosystem’s susceptibility to invasion.

A literature review can provide perspective on a problem and suggest possible approaches for addressing it, but reviews and research from other areas cannot substitute for careful, long-term monitoring of what is taking place on the particular landscape of concern to a manager. Clear objectives, literature-based knowledge, and field-based knowledge are all essential for effective management. McPherson (2001) describes the complex challenges inherent in managing nonnative invasive species. He urges policy makers to resist applying oversimplified answers to complex issues such as those associated with biological invasions, and encourages managers to “synthesize disparate information for practical use and rely on all relevant knowledge at their disposal.” As a synthesis of current knowledge on fire and nonnative invasives, this volume provides a tool that policy makers, managers, and members of the public can use in meeting management challenges.

## Fire Behavior and Fire Regimes

We discuss here the key concepts of fire behavior and ecology that are used in this volume. A glossary of technical terms is in the appendix.

**Fire behavior**—The pattern of fire spread and heat release in an individual fire is referred to as fire behavior. It is affected by the fuel, weather, and topographic conditions at the time of burning. Fires are often described on the basis of the vertical stratum of fuels in which fire spread occurs. *Ground fires* spread in duff or peat (partly decayed organic matter in contact with the mineral soil surface). *Surface fires* spread in litter, woody material on or near the soil surface, herbs, shrubs, and small trees. *Crown fires* spread in the crowns of trees or tall shrubs (National Wildfire Coordinating Group 1996).

Individual fires are described quantitatively by *rate of spread*, *residence time*, *flame length*, and *flame depth* in the flaming front. They can also be described in terms of energy release. *Fire intensity* is the amount

of heat released per unit time; this rate is described quantitatively by *fireline intensity*, the rate of heat release in the flaming front, regardless of its depth, and *reaction intensity*, the rate of heat release per unit area of the flaming front. *Total heat release* includes the heat produced in the flaming front and also behind the flaming front, by glowing and smoldering combustion (McPherson and others 1990).

**Fire severity**—The degree to which a site has been altered by fire is referred to as fire severity (National Wildfire Coordinating Group 1996). Descriptions of fire severity depend on the specific fire effects under study and the measurement methods used. Ecological studies typically examine relationships between fire severity and effects on individuals, populations, communities, and ecosystems. Management documents such as Burned Area Emergency Response plans relate fire severity to the effects of fire on soil stability. If fire severity is measured using aerial or satellite measurements, changes in the vegetation canopy (consumed, scorched, or intact) are the main descriptors. If fire severity is measured in sampling plots on the ground, descriptions of effects on individual organisms, litter and duff cover, and physical change in the soil can be used.

In this volume, we use “low severity” to refer to fires that cause little alteration to the soil and little mortality to underground plant parts or seed banks. “High severity” refers to fires that alter soil properties and/or kill substantial amounts of underground plant tissue. Ideally, primary research and postfire monitoring programs could describe fire severity either in terms of vegetation change, with detail as to the vegetation type and stratum discussed, or to changes in soil properties (DeBano and others 1998) (table 1-1). Relationships between fire severity and plant survival and persistence are discussed more thoroughly in chapter 2 (see “Influence of Fire Severity on Postfire Invasions” on page 12).

**Fire regimes**—The cumulative effects of fires over time have profound influence on ecosystem components, structure, and processes. The characteristic pattern of repeated burning over large expanses of space and long periods of time is referred to as the fire regime

(Lyon and others 2000a; Sugihara and others 2006a). Fire regimes are described for a specific geographic area or vegetation type by the characteristic fire type (ground, surface, or crown fire), frequency, intensity, severity, size, spatial complexity, and seasonality. Fire frequency is described in this volume by the fire-return interval, the average time before fire reburns a given area.

The following categories are used to describe fire regimes in this volume, following Brown (2000):

- *Stand-replacement fire regime* refers to a pattern in which fire kills or top-kills the above-ground parts of the dominant vegetation. Using this definition, forests that routinely experience crown fire or severe surface fire have a stand-replacement fire regime; grasslands and many shrublands also have stand-replacement fire regimes because fire usually kills or top-kills the dominant vegetation layer.
- *Understory fire regime* “understory fire regime” applies only to forests, woodlands, and shrublands. In a plant community with this kind of fire regime, most fires do not kill or top-kill the overstory vegetation and thus do not substantially change the plant community structure.
- *Mixed-severity fire regime* also applies only to forests, woodlands, and shrublands. In plant communities with this kind of fire regime, most fires either cause selective mortality of the overstory vegetation, depending on different species’ susceptibility to fire, or sequential fires vary in severity.

In this volume, we use the term “presettlement” to describe fire regimes before extensive settlement by European Americans, extensive conversion of wildlands for agriculture, and effective fire exclusion. This term is common in the literature on fire regimes (for example, Bonnicksen and Stone 1982; Brown 2000; Brown and others 1994; Feeney and others 1998; Frost 1998) because settlement by Europeans is generally considered the time at which ecological communities began to deviate dramatically from conditions under

**Table 1-1**—Examples of fire severity descriptors.

What is being described?	Fire severity	Description
Forest, woodland, shrub canopy	high	Overstory foliage consumed by fire
	moderate	Overstory foliage killed by fire but not consumed
	low	Overstory foliage not altered by fire
Ground and soil surface <sup>a</sup>	high	Consumes or chars organic material below soil surface
	moderate	Consumes all organic material on soil surface
	low	Leaves soil covered with partially charred organic material

<sup>a</sup> Adapted from DeBano and others (1998).

which they evolved or at least persisted for centuries or millennia. As a set of conditions theoretically based in evolutionary time, presettlement conditions are considered more ecologically robust than current conditions and therefore may be used to determine desired conditions for wildlands. While the term “presettlement” is convenient for discussion, it remains imprecise and value-laden: (1) it is difficult to decide just when the “presettlement” era ends for any given location; (2) in many ecosystems, it is difficult to describe the presettlement fire regime precisely; and (3) presettlement conditions may not provide appropriate or achievable management goals. This becomes especially clear when one considers the impossibility of recreating the Native American influences from past eras and eliminating European American influences, including the introduction of thousands of nonnative species. For on-the-ground management of specific plant and animal communities, it may be more useful to refer to the desired fire regime as a “reference” or “baseline” for management, without insisting that past conditions be reconstituted on the landscape (chapter 3).

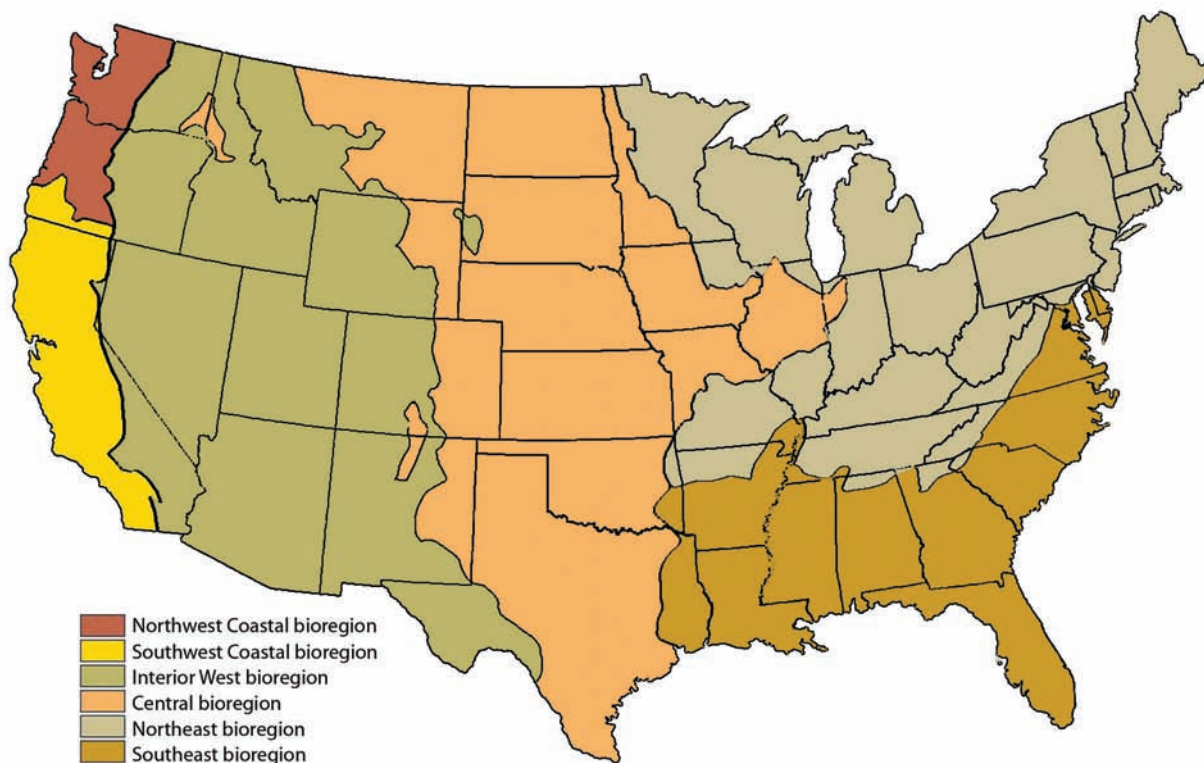
## Organization and Use of This Volume

This volume synthesizes current scientific understanding of relationships between fire and nonnative invasive plant species at a conceptual level in part I

and at a bioregional level in part II. In part III this information is synthesized further and related to specific management issues.

Chapters in part I describe botanical and ecological principles that govern relationships between fire and nonnative invasive plants. Chapter 2 describes the role of fire in promoting plant invasions, including traits that enable invasives to establish, persist, and spread after fire, and also the role of changes to plant communities brought about by fire (for example, altered nutrient availability and exposed mineral soil). It also discusses ways in which different plant communities may be more or less susceptible to establishment and spread of nonnative invasives in a postfire environment. Chapter 3 discusses the effects of nonnative invasive plants on fire regimes and includes information on fuel properties of plant communities influenced by invasive species. Chapter 4 addresses the use of prescribed fire to manage invasive plant species and interactions of fire with other control methods.

We have limited ability to predict the species likely to have negative impacts in a particular community (Woods 1997), so it is important for managers to have information about specific invasives and the relative invasibility of particular plant communities. Part II synthesizes this information at a bioregional level. We defined the bioregions according to broad plant community formations (fig. 1-1), based on Bailey’s (1995) classification. Each chapter in part II lists the nonnative species of greatest



**Figure 1-1**—Approximate boundaries of bioregions defined for this volume. Bioregions are based on Bailey’s (1995) classification. Alaska (included in chapter 10, Northwest Coastal bioregion) and Hawai`i (chapter 11) are not pictured.

concern in that bioregion and the plant communities considered most vulnerable to invasives. Thus, not all plant communities that occur in a bioregion are included in this volume.

The bioregional boundaries shown in figure 1-1 are, in reality, ecotones that may be hundreds of miles wide, and many invasive species occur in several bioregions. Most species are discussed in depth in only one bioregional chapter; in other chapters, discussion of the species focuses only on variations specific to the given bioregion. Each bioregional chapter synthesizes research and management information concerning fire effects on nonnative invasions, invasives' effects on fire regimes, and use of fire to control invasives. Finally, each chapter in part II identifies emerging issues in the bioregion regarding fire and invasives.

In addition to summarizing fire-invasive information for each bioregion, part II of this volume can be used as a reference on specific invasives and plant communities. To assess whether a particular community is likely to be susceptible to invasion by a particular nonnative species, first find the bioregional chapter that discusses that plant community. Look up the plant community in the table at the beginning of the bioregional chapter. Examine the list of invasive species of "high concern." Is the species you are seeking

included? Does it have the same life form and regeneration strategies as species that are of high concern? Is it listed as a "potentially" invasive species for that community? The answers to these questions provide some indication of the potential threat.

Part III evaluates the knowledge available to managers on fire and nonnative invasive plants (chapter 12), summarizes effects of nonfire fuel management on nonnative species (chapter 13), describes the effects of fire suppression and postfire emergency stabilization, restoration, and rehabilitation treatments on nonnative invasive plants (chapter 14), and suggests monitoring strategies to evaluate the effects of fire management actions on nonnatives (chapter 15). The final chapter summarizes major issues reviewed in this volume, describes barriers to effective management and possible ways to address these, and lists current burning questions in relation to fire and nonnative invasive species.

This volume is intended as a review useful for managers, policy makers, and the general public. It provides a place to start when designing management plans that involve both fire and invasive plants. Final plans will typically require additional, more detailed, local information than is provided in this volume.