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Chapter 16:

Fire and Nonnative Plants— Summary and Conclusions

This volume synthesizes scientific information about interactions between fire and nonnative invasive plants in wildlands of the United States. If the subject were clear and simple, this volume would be short; obviously, it is not. Relationships between fire and nonnative species are variable and difficult to interpret for many reasons:

- Fire and invasions are both inherently complex, responding to site and climate factors and the condition of the plant community. In addition, the nationwide scope of this volume incorporates great variation across ecosystems, climates, and regions.
- Fire effects and invasions interact with other ecosystem processes and land use history and patterns, and these interactions and effects can vary over time.
- Research tends to focus on highly successful invasions even though comparisons to failed or marginally successful invasions could be instructive (Beyers and others 2002).
- To date, research on fire and nonnative invasives has been limited, with few studies covering more than 1 year after fire (chapter 12).

The complexity of this subject makes it difficult to identify trends and implications for management. In this chapter we summarize the patterns (and lack of patterns) currently demonstrated by research regarding fire effects on nonnatives and the use of prescribed fire to reduce invasions, and we suggest some management implications. We also present some of today's burning questions about relationships between plant invasions and fire. Background for the assertions in this chapter can be found in Parts I and III of this volume. Readers interested in specific regional problems and issues should refer to Part II.

Nonnative Invasive Species and Wildland Fire

The literature shows that fire in many cases favors nonnative species over natives and thereby may lead to postfire invasions—that is, cases where ecosystems, habitats, or species are threatened because fire has promoted the establishment and spread of invasive plants (chapter 1). In some cases, nonnative species alter the native plant community and fuel characteristics to the extent that the fire regime is altered, and

the altered fire regime favors further dominance of the plant community by the nonnative invader. This positive feedback loop is sometimes referred to as a grass/fire cycle or invasive plant/fire regime cycle (chapter 3).

The potential for nonnatives to negatively impact wildland ecosystems after fire suggests that managers should give priority to (1) controlling nonnative species known to be invasive after fire in the area burned or similar areas, especially if they are likely to alter the fire regime; (2) preventing new invasions through early detection and eradication of likely invaders; and (3) long-term monitoring and adaptive management after fire to control or reduce invasions. Tables provided at the beginning of each bioregional chapter in Part II may be helpful for identifying potential invaders. However, postfire invasion cannot be assumed for every ecosystem or for every nonnative species—even those mentioned in the bioregional tables. Invasion potential varies with prefire plant community condition, fire characteristics, and climate, and it depends on which plants and propagules (native and nonnative) are present within and near the burn. Invasions can be exacerbated by other disturbances and management activities, and they can be transient or persistent (chapter 2). While postfire invasion cannot be assumed, neither can a burn that is not invaded immediately after fire be assumed “safe” from invasion. Nonnative species may persist at low density for years before becoming invasive. Postfire disturbances, such as grazing or logging, may “tip the scales” toward invasion by altering resource availability, increasing nonnative propagules, and stressing native plants. In addition, wildlands are constantly exposed to new nonnative species with unknown invasive potential.

Generalizations commonly made about fire and nonnative species are supported by the literature under some circumstances but not others (chapter 2). For example, nonnative species establishment may increase with increasing fire severity, but this pattern can also be influenced by condition of the prefire plant community, postfire response of onsite species (both native and nonnative), propagule pressure, and the uniformity and size of high-severity burn patches. Plant communities dominated by native species that sprout after fire may be more resistant to invasion than communities where desired natives must regenerate from seed. Invasions are more likely in some plant communities when the baseline fire regime is disrupted, including locations where a nonnative grass/fire cycle has developed and native grasslands from which fire has been excluded for periods exceeding the baseline fire-return interval. Unfortunately, current conditions can diverge from presettlement conditions in so many ways that this generalization may not be helpful for predicting post-fire responses. Postfire invasions tend to become less

severe with increasing time since fire in closed-canopy forests and chaparral, but there are exceptions, and few long-term studies have investigated this pattern. Postfire invasions tend to be more severe with time since fire in shrub/grass ecosystems invaded by trees where native understory species (often sprouters) have been reduced. Postfire invasions are less likely in high-elevation than low-elevation ecosystems. Where human-caused disturbance occurs in high-elevation ecosystems, however, postfire invasions are more likely than in similar undisturbed systems.

Management Implications

Scientific study of the relationship between fire and nonnative invasive species is a relatively young field of investigation (Klinger and others 2006a) with many uncertainties. Many studies *describe* postfire invasions, but our scientific knowledge base is not yet extensive enough in space and time to *explain* or *predict* patterns of invasion across a range of ecosystems (Rejmánek and others 2005a), with or without fire. Information about fire effects on specific plant communities with specific invasive species provides the best knowledge base for management decisions regarding those communities and species. Knowledge of nonnative species biology, ecology, and responses in similar environments may also be useful for directing management decisions, although the effect of the particular environment must be considered (Rejmánek and others 2005a). One of the few consistent predictors of a nonnative species' potential to invade is its success in previous invasions (Daehler and Carino 2000; Kolar and Lodge 2001; Reichard and Hamilton 1997; Williamson 1999). Yet, as Williamson (1999) comments, “...we know that that can fail badly.” This approach may be useful for predicting which species are “risky” but not for predicting which species are “safe”. The most useful predictions likely require the integration of several approaches (Rejmánek and others 2005a).

While more knowledge is needed on fire and invasive species, research will never eliminate uncertainty, so scientists and managers must integrate many kinds of knowledge while remaining aware of their applications and limitations. The more the prefire plant community and conditions in a burned area diverge from conditions described in published research, the less reliable predictions based on that research will be. This is why the location and scope of research projects should be presented clearly in publications and read with care by managers. Management actions in general, including those based on extrapolation of research results, should be implemented with caution, monitored, and adapted as new knowledge develops. Partnerships between scientists and managers are likely to increase the pace and

effectiveness of adaptive management (Beyers and others 2002). Hobbs and Mooney's (2005) comment on nonnative species invasions in light of global change applies well to fire/invasive interactions: "Scientists need to become smarter at considering potential scenarios based on multiple levels of uncertainty. Even qualitative analyses of likely outcomes can provide useful input to decision-making processes."

Many strategies for evaluating and addressing potential postfire invasions by nonnative species are described in this volume and the supporting literature. A brief summary is provided here.

During Fire Suppression—Wildfire managers should include training for crews on identifying nonnative invasive plants and preventing their spread. Firelines and fire suppression facilities should be located away from known invasions whenever possible. Equipment should be washed before being used on a fire so it will not introduce propagules of invasive species. Camps, staging areas, and helibases should be monitored during and after the fire to prevent establishment and spread of nonnative species. Additional guidelines and specific recommendations and requirements are available in chapter 14 and guides and manuals cited therein.

During Postfire Mitigation—Preventing invasive plants from establishing in burned areas is the most effective and least costly management approach. This can be accomplished through early detection and eradication, careful monitoring, and limiting invasive plant seed dispersal into burned areas. Opportunities for postfire establishment can be minimized by following the guidelines presented in chapter 14 and in the agency and extension publications referenced there; see also Goodwin and others (2002).

Successful postfire mitigation is likely to require that managers prioritize species and sites for exclusion, containment, control, or eradication based on their current distribution and potential to cause ecological harm. This process requires information on the distribution, dominance, and ecological effects of invasive and potentially invasive plants on and near the burn, especially species likely to alter fuel characteristics and fire regimes.

Use of Fire in Suppression Activities and for Other Management Goals—The potential for introducing or increasing the abundance of nonnative invasive species must be addressed in *all* land management planning and activities, including choice of appropriate management response to wildfire and use of prescribed fire for goals such as wildlife habitat improvement and site preparation. Minimize or avoid use of fire in areas at high risk for establishment or spread of invasives due to high propagule pressure or fire tolerance (for example, persistent seed bank

and vegetative sprouting) (chapters 2 and 14). Where fire is used, incorporate precautions mentioned above ("During Fire Suppression").

Addressing Invasive-Caused Changes in Fire Regimes—If a species has already changed one or more fire regime characteristics, evaluate the altered regime and prioritize species control based on potential for negative effects on native species diversity, ecosystem processes, natural resources, public safety, property, and local economies. In some cases, it may not be possible to restore communities to their pre-invasion state, and managers may need to establish communities of native species that can coexist with the nonnatives (chapters 3 and 11).

Sharing Information—More high-quality research on relationships between fire and nonnative species is sorely needed (chapter 12). Managers will benefit from such studies only if they are published in a timely fashion. Managers could also benefit by sharing information from postfire monitoring of invasive species patterns after wildland and prescribed burns.

Use of Fire to Control Nonnative Invasive Species

Reduction of nonnative species abundance is usually just one facet of management to improve the condition of a native plant community. The use of prescribed fire to reduce nonnatives and contribute to overall management objectives is generally complex, and little research is available on the successes and failures of such efforts beyond the first few years after treatment (chapter 4). Therefore, integration of prescribed fire with other management techniques and long term monitoring of results are crucial to ensure that management objectives are being met.

Management Implications

To achieve long-term control of a nonnative invasive population and/or to favor native species with fire, managers must consider the regeneration strategies, phenology, and site requirements of all species in the management area. If invasive species are generally promoted by fire, fire alone is not likely to reduce them, although it may be effective during certain seasons or in combination with other treatments. Mechanical and chemical treatments may be useful to prepare for prescribed burning, especially on sites with sparse fuels. In addition, fire may be useful to prepare a site for introduction of desired native species, increase herbicide efficacy, or even promote population expansion of some biocontrol organisms.

In planning prescribed fire to control invasive species, managers can consider manipulating any or all

aspects of the fire regime. Where the phenology of native plants differs from that of nonnatives, it is sometimes possible to schedule prescribed fires and manage their behavior to reduce nonnatives without damaging the native species. In addition, managers can manipulate the type, intensity, and severity of fire, fire size and uniformity, and fire frequency to damage nonnatives, consume nonnative seed, or favor native species. In the mixtures of species that characterize many wildland ecosystems, however, it is difficult to develop a strategy that reduces all nonnatives and favors all native species. Combinations or sequences of treatments may be needed. As mentioned often in this volume, monitoring is essential so managers can adjust their techniques to meet objectives (chapter 15).

Questions

Considerable information is needed to better understand and manage the relationships between nonnative invasive species and fire in wildlands of the United States. Long-term experimental studies and monitoring are essential for their descriptive value and also for their potential contribution to the development of tools for predicting postfire invasions. The following issues require consideration by scientists and managers in the near future:

- Nonnative species can negatively impact wildland ecosystems, but in field situations it is often difficult to distinguish the impacts of nonnatives from the impacts of other factors. How can scientists isolate and measure the impacts of invaders? How can managers distinguish minor, possibly transitory, effects of invaders from major impacts that are likely to persist? Do the effects of invaders change over time, and if so, how?
- Wildland conditions will continue to change in the face of continuing urbanization and accompanying ecosystem fragmentation, including increasing global trade and introduction of new nonnative species, changing atmospheric composition and climate, and interactions of these factors (Hobbs and Mooney 2005; Mooney and Hobbs 2000). Some of these changes are likely to facilitate invasions that alter fuels and fire regimes. In light of these problems, what are

the most useful indicators that a nonnative species is likely to become invasive and alter ecosystem processes? Do these indicators vary by ecosystem?

- What tools are available, and at what scales, to help managers assess the invasibility or resistance of a particular plant community? What tools help assess the potential for establishment and spread of nonnatives after wildfire? How can managers prevent unintended consequences from prescribed fire? How can spatial information technology be used to obtain information on the presence and abundance of invasive species?
- Nonnative species exert selective pressures in wildland plant communities (Parker and others 1999), and the genetic structure of nonnative species may influence their potential to become invasive (Lee 2002). How does fire affect the gene pools of nonnative and native species interacting within a plant community?
- How do nonfire management activities affect undesirable nonnative species and desirable native species and communities? What combinations of management approaches will yield the most desirable results?

In discussing genetic influences of invasions, Barrett (2000) comments, "One of the most remarkable aspects of biological invasions is how unpredictable they are. Because of this, we should not be surprised if totally unexpected plant invaders appear, aided by new environmental conditions arising from global change." This idea can also be applied to the interactions of fire with nonnative invasive species. Scientists continue to seek explanations for invasions, develop predictive models, and seek ways to assess and address uncertainty in predictions (see, for example, Caley and others 2006; Colautti and others 2006; Cuddington and Hastings 2004; Daehler and Carino 2000; Drake and Lodge 2006; Lee 2002; Lockwood and others 2005; Sutherland 2004). However, the potential for surprise is practically limitless. It is crucial that we consider relationships between fire and nonnative invasive species with inquiring, open minds, paying careful attention to how fire and invasives interact in different situations and continually asking how they might be influenced by management practices.