FIRE MANAGEMENT AND WOODY INVASIVE PLANTS IN OAK ECOSYSTEMS

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Abstract.—The use of prescribed fire to sustain oak forests has increased rapidly in the last decade as the threat of poor regeneration and increased dominance of shade tolerant or fire sensitive tree species grows. While prescribed fire can favor oak regeneration, it may also increase the invasion and expansion of nonnative invasive plant species (NNIS). Little is known about the effects of fire on invasives in eastern U.S. oak forests. The majority of knowledge regarding the response of NNIS is anecdotal as managers have reported the expansion of invasives such as tree-of-heaven (*Ailanthus altissima*) and princess tree (*Paulownia tomentosa*) following prescribed fires. How can prescribed fire be used so that it does not facilitate the expansion of NNIS? Managers need to be proactive and integrate NNIS control strategies into prescribed fire and timber management programs at a landscape level. This paper presents a review of the current state of knowledge regarding woody NNIS and the use of prescribed fire in the Eastern United States. It includes a summary of the common traits of NNIS, potential responses of woody NNIS to fire, proactive approaches to managing for NNIS, and a list of recommended resources related to NNIS and forest management practices. In addition, an overview of the author's current work on the effects of prescribed fire on *Ailanthus* in southeastern Ohio is presented.

INTRODUCTION

Active fire suppression and the conversion of former agricultural lands over the last 80 plus years have produced dramatic changes in forest structure and composition within the eastern United States (Dibble and others 2008). Fire intolerant species such as red maple (*Acer rubrum* L.) often dominate the sapling and midstory layer creating dense shade conditions. In contrast, oaks (*Quercus* spp.) are disturbance-dependent species (Abrams 1996). Forest managers often utilize some combination of harvesting, fire, and herbicide treatments which alter light levels to favor oak establishment (Brose and others 2008). Unfortunately, many nonnative invasive plants also have the potential to thrive in these same disturbed habitats or open conditions. Oaks have many disturbance-type adaptations that confer protection from fire, such as root-centered growth, thick bark, vigorous sprouting ability, and well-protected buds (Dey and Fan 2009). However, they do not compete well with faster growing native and nonnative plant species, especially on higher quality sites (Johnson and others 2009). It is likely that competition between oaks and nonnative invaders can also occur on dry, low fertility sites since some woody nonnative plants (e.g., *Ailanthus*, *Paulownia*) can thrive on poor sites. Nonnative plant species have become established at varying densities and distributions within forest edges and interiors. There are some NNIS species, such as the shade tolerant oriental bittersweet (*Celastrus orbiculatus*), which becomes established in undisturbed forest canopies. Once established, it and many other NNIS can persist for extended periods in a suppressed condition until a disturbance occurs that increases light and other resources, allowing rapid growth and expansion.

Reintroducing fire to oak ecosystems may increase susceptibility to nonnative plant invasion which may impede the restorative effects of burning. Recent work suggests fire alone does not increase light levels enough to favor the growth of regenerating oak (Hutchinson and others 2005). However, prescribed fire following a shelterwood harvest has been a successful prescription to promote oak recruitment and retention (Brose and Van Lear 1998). This treatment creates a higher level of disturbance than fire alone, and thus increases concerns of NNIS expansion. When invasive plants are present or nearby, forest managers have reported increases in their abundance following prescribed burns plus timber harvesting.

Management recommendations to control NNIS within eastern forests have improved in the last decade (Evans and others 2006, Webster and others 2006). Until recently there has been limited research addressing how NNIS respond to fire in the Eastern United States. Huebner (2006) evaluated 17 common invaders for their response to fire and their potential to alter fire regimes. She reported that 12 species were potentially controllable with repeated growing season burns while 5, including *Ailanthus*, had the potential to increase in abundance in response to fire. Kuppinger and others (2010) found that *Paulownia* quickly established across varying habitats immediately after fire but over time failed to persist except in resource-limited habitats. The use of fire to control NNIS in the East has been tested with a few species such as Japanese stiltgrass (*Microstegium vimineum*) and Japanese barberry (*Berberis thunbergii*) with some success (Flory and Lewis 2009, Ward and others 2009). However, using prescribed fire to control NNIS should proceed with caution given the sparse information currently available. In this paper, I focus on how biological and ecological traits of woody invasive species are intertwined in predicting the impact of fire and other management activities on their abundance and expansion. The use of prescribed fire to control NNIS will not be addressed. I give an overview of an ongoing study of the effects of fire on *Ailanthus*, as well as an efficient and cost-effective invasive plant mapping tool. A proactive NNIS management action list is also provided.

COMMON TRAITS OF INVASIVE SPECIES

Whether the management goal is to promote or to control a given species, it is important to understand its biology. Knowledge of an invasive plant's life history is critical to predicting how it might respond to fire and other management treatments. Consideration must be given to its life form. Is it an annual, biennial, woody perennial tree, shrub, or vine? Is it dioecious, producing male and female plants such as *Ailanthus*, common buckthorn (*Rhamnus cathartica*), and autumn olive (*Elaeagnus umbellate*)? Monitoring the local seasonal patterns of a species' growth to include time of leaf break and leaf drop, flowering, and onset of dormancy is invaluable in developing the most effective fire, mechanical, or chemical control treatments. If treatments occur during periods when energy reserves are at their lowest levels, they will be most effective in reducing sprouting compared with periods of higher reserves.

Disturbance-dependent species are often shade intolerant and drought tolerant. They often have root-centered growth with large carbohydrate stores which can be readily utilized when growth-limiting shade is removed. Some NNIS such as *Ailanthus* produce extensive root systems that share carbohydrate reserves that support multiple shoots growing across large areas in varying light environments. Conversely, shade intolerant species display shoot-centered growth, quickly occupying space and gaining competitive height over slower-growing species.

Shade tolerant NNIS such as Amur honeysuckle (*Lonicera maackii*) typically are the first to leaf out in the spring and last to drop leaves in fall. The Oriental bittersweet vine can grow and persist in undisturbed forests until a canopy disturbance releases it to grow rapidly (Webster and others 2006). Linking the timing of fire and other methods of control to low energy reserves is essential to limit invasives. The challenge lies in trying to minimize harmful effects on native vegetation while at the same time controlling the NNIS.

There are a number of traits that are often associated with invasive nonnative plants. These may include but are not limited to: (1) ability to sprout, (2) prolific seed production, (3) seed dispersal by wind or birds, (4) rapid growth rate, (5) early age to seed production, (6) ability to form pure stands, and (7) presence in early successional plant communities.

Other important attributes of NNIS to consider include: (1) how long do seeds remain viable; (2) is the plant allelopathic (i.e., does it produce chemicals that inhibit native seed germination and seedling establishment); (3) is the species shade tolerant; and (4) can it persist suppressed in the understory for extended periods of time? These are all crucial in understanding how individual NNIS may respond to fire and other disturbances. Unfortunately, basic biological and ecological information is incomplete or lacking for a number of the common NNIS found in eastern U.S. oak forests, as demonstrated by the summary provided in Table 1.

POTENTIAL RESPONSES TO FIRE

It is expected that many woody NNIS will respond to prescribed fire in a similar manner to that of native vegetation. Common responses and postfire conditions that favor early successional invasives can include:

- **Stem topkilling with resprouting.** Depending on fire severity and timing of the fire, stems may be topkilled followed by the sprouting of dormant buds. *Ailanthus* is a prolific sprouter with an extensive shallow root system with many potential bud sources (Kowarik and Saumel 2007). Like oak, it appears to respond positively to fire with vigorous sprouting. But unlike oak, it can also expand by vigorous root suckering similar to aspen and sassafras (Burns and Honkala 1990).
- **Increased understory light and available soil nutrients.** Increases in resource availability often favor the growth and expansion of NNIS.
- **Consumption of litter layer and exposure of mineral soil.** As with oak, these conditions often favor seed germination and seedling establishment, especially those that require light for germination such as *Paulownia*.
- **Soil disturbance.** Site preparation such as fire breaks can create exposed bare soil.
- **Spread by equipment.** Movement of dozers, trucks, and other vehicles from one site to another can facilitate the spread of invasive plants across a landscape. Both seeds and small viable vegetative fragments can be transported.

In addition, topographic effects on fire severity and intensity can create a variety of microsites within a burned landscape. If thinning treatments are combined with a prescribed fire or if a fire is severe enough to cause overstory mortality, patches of invasive plants can occur in the openings). This can promote NNIS movement towards forest interiors. Depending on site features and fire severity, postfire competition among new propagules (e.g., wind-blown or bird-dispersed seeds) or sprouts can be very high. Consideration must be given to the ability of a NNIS to successfully occupy a site after a burn as well as its ability to reproduce in that post-disturbance community.

CURRENT STATE OF KNOWLEDGE

A comprehensive synthesis of available scientific and technical information regarding the interactions between fire and nonnative invasive plants is available through the U.S. Department of Agriculture Forest Service's Fire Effects Information System (FEIS) (USDA FS 2012). Detailed information for each of 69 invasive species includes: distribution and occurrence,

Table 1.—Ecological and biological traits of common problem nonnative woody invasives in eastern U.S. oak forests*

Common and Latin Name	Shade Tolerance	Breeding System	Annual Rate of Seed Production	Seed Dispersal	Age to Produce Seed	Seed Bank	Growth Rate	Sprouting Ability	Competitive Ability	Successional Status
Trees										
Ailanthus (tree-of-heaven),† *A. altimissa*	moderate	dioecious	very high (>200,000 /female)	wind	~5 yrs	1-2 yrs?	rapid (3-6 ft/yr)	vigorous	high; forms dense thickets	early, but can persist
Norway maple, *Acer platanoides*	very tolerant	dioecious	high	wind	?	1 yr?	moderate?	limited	suppression via dense shade	early, but persists
Paulownia (princess/ empress tree), *Paulownia tomentosa*	intolerant	perfect flowers	very high (>20 million/ tree)	wind	3-5 yrs	2-3 yrs	rapid seedling & sprout growth	very high	transient, high as seedling; less with age	early, can persist
Shrubs										
Autumn olive, *Elaeagnus umbellata*	moderate	primarily dioecious	very high (66,000 /mature shrub)	birds	3-5 yrs	?	?	vigorous	displaces natives, can form dense thickets	early
Bush honeysuckles, (Amur) *Lonicera* spp.	moderate to tolerant	perfect flowers, not-well studied	variable, up to 1 million/ plant	birds	5-8 yrs	~2-3 yrs	Rapid in high light	yes	leaves first to expand & last to drop; rapid seedling height growth	early, but can persist as large dense mature shrubs
Common buckthorn, *Rhamnus cathartica*	tolerant	typically dioecious	heavy	gravity and birds	5-6 yrs	several yrs	medium to fast	yes	forms dense thickets	varies: early and mid-late
Japanese barberry, *Berberis thunbergii*	tolerant	perfect flowers	varies with genotype	birds	?	~1 yr	varies with light	yes	form dense thickets	early, but persists
Multiflora rose, *Rosa multiflora*	tolerant	?	500,000/yr	gravity & birds	?	10-20 yrs	?	yes	form dense impenetrable clumps	early
Privet (Chinese, European, & Japanese), *Ligustrum* spp.	moderate to tolerant	perfect flowers	hundreds/ mature shrub	birds	?	none	not reported	yes	form dense thickets	early, but can persist

(Table 1 continued on next page)

Table 1 (continued).—Ecological and biological traits of common problem nonnative woody invasives in eastern U.S. oak forests*

Common and Latin Name	Shade Tolerance	Breeding System	Annual Rate of Seed Production	Seed Dispersal	Age to Produce Seed	Seed Bank	Growth Rate	Sprouting Ability	Competitive Ability	Successional Status
Vines										
Japanese honeysuckle, *Lonicera japonica*	moderate to tolerant	requires cross-fertilization	prolific	birds	3-5 yrs	?	rapid once established	yes	aggressive colonizer, creates dense mats & thickets	early, but persists
Kudzu, *Pueraria montana* var. *lobata*	shade intolerant	?	infrequent	infrequent seeder	3 yrs	?	rapid (65-98 ft/yr)	high	aggressive asexual colonizer	early, but persists
Oriental bittersweet, *Celastrus orbiculatus*	tolerant & intolerant	both dioecious & perfect	abundant	birds	?	1 yr	rapid post-disturbance	high	overtops and girdles, can form thickets	early, but persists

*Primary reference source is the Fire Effects Information System Database (USDA FS 2012)
†Demonstrated to be allelopathic
? Represents lacking or unknown information

botanical and ecological characteristics, fire effects, and management considerations. In 2011, the FEIS staff summarized the knowledge gaps of eastern U.S. invasive plants (Gucker and others 2011). They concluded that current information in the eastern United States is very limited and largely anecdotal. In addition, the transfer of research findings to managers needs improvement so they can make better informed decisions. They also recommend more experiments and observations of how NNIS respond to fire, including: (1) several years of data in a particular ecosystem, (2) various burning conditions, (3) season of burn, (4) varying fire severities, and (5) varying intervals between burns. It is noteworthy that these same research questions are also critical in developing better fire prescription guidelines for promoting oak restoration.

In 2008, the federal interagency Joint Fire Science Program (JFSP) made a request for research proposals that specifically addressed the interaction of invasive plants and fire in the eastern United States. Two main questions were addressed. First, what are the effects of nonnative invasive plant species on fire behavior and fire regimes? Secondly, what are the effects of fire and fire management on the distribution of NNIS? The three funded studies are:

1. Fire and the invasive Japanese stiltgrass (*Microstegium vimineum*) in eastern deciduous forests. Principal investigators: S. Luke Flory and Keith Clay, Indiana University.
2. To burn or not to burn Oriental bittersweet (*Celastrus orbiculatus*): a fire manager's conundrum. Principal investigators: Noel B. Pavlovic and Stacey Leicht-Young, U.S. Geological Survey.
3. Prescribing fire in managed oak forest landscapes: interactions with the invasive tree *Ailanthus altissima*. Principal investigators: Joanne Rebbeck and Todd Hutchinson, U.S. Forest Service.

Research questions for each project are provided in Table 2. Since all are active at this writing, annual project reports and updated deliverables are available at the JFSP website http://www.firescience.gov/JFSP_Search_Advanced.cfm. Future technical publications are planned with management recommendations. An overview of the *Ailanthus* project in Ohio follows.

Table 2.—Summary of research questions of Joint Fire Science Program funded projects investigating the interaction of fire and nonnative invasive plants in the eastern United States

Plant species	Life form	Study location	Research questions
Japanese stiltgrass	Annual grass	Big Oaks National Wildlife Preserve, SE Indiana	How do stiltgrass invasions affect fire behavior? How do prescribed fires and timing of fires affect invasions? Do invasions alter the effects of fire on native species and habitats? Can fire be used as a tool to manage invasions?
Oriental bittersweet	Perennial vine	Indiana Dunes National Lakeshore, Lake Michigan	How does fire impact seed viability? How does fire influence the susceptibility of different habitats to invasion? What are the effects of fire on established plants? Can bittersweet presence and abundance be predicted in a fire landscape?
Ailanthus	Tree	Tar Hollow State Forest, SE Ohio	What is the influence of past harvesting and fire history on the distribution and abundance of *Ailanthus* in a forested landscape? What are the direct effects of fire on the demography of Ailanthus populations?

FIRE AND *AILANTHUS* IN SOUTHEASTERN OHIO: A CASE STUDY

Background

Ailanthus is a common NNIS in the eastern United States and can invade and expand dramatically when forests are disturbed. It is extremely fast-growing, reaching heights of 80-100 feet. It is dioecious and is a prolific seeder with up to 350,000 seeds produced per tree in a single growing season (Kowarik and Saumel 2007). Seeds develop in the summer mature in early fall and can persist until March. Wind-dispersed seeds can travel in excess of 330 feet (Landenberger and others 2007). The longevity of seeds in soil is not fully known. It appears that seeds are short-lived, typically 1-2 years, but germination rates are very high (80-100 percent) in disturbed stands. In addition, *Ailanthus* is capable of aggressive clonal spread, often creating dense thickets that can outcompete native trees. While considered shade intolerant, clonal sprouts attached to a parent tree can persist in a shaded forest understory for up to 20 years (Kowarik 1995). Vigorous sprouts can develop 50-90 feet from a parent tree (Illick and Brouse 1926). Although the long-term effects of *Ailanthus* on native tree regeneration are not known, it likely has a negative impact because of its highly competitive traits and production of the allelopathic compound ailanthone (Hiesey 1996).

Very little is known about the direct and immediate effects of fire on *Ailanthus*. Saplings are easily topkilled by fire, but resprouting is prolific (Lewis 2007). Managers have reported observing increases in *Ailanthus* via seed germination immediately following fires. However, in landscapes with very small populations of *Ailanthus*, it does not invade burned sites (e.g., Hutchinson and others 2005). It remains unknown whether a postburn *Ailanthus* expansion will inevitably occur if the propagule pressure is high. It may be that fire, by reducing litter and increasing light, creates improved conditions for *Ailanthus* establishment as other disturbances have been shown to do (Kota and others 2007).

At Tar Hollow State Forest in southeastern Ohio, thinning and burning treatments were conducted as part of the national Fire and Fire Surrogate Study. The explosive expansion of *Ailanthus* from seed followed the combined thin plus burn treatment (Hutchinson and others 2004, Rebbeck and others 2005). *Ailanthus* trees (≥4 in d.b.h.) were present but not abundant in this unit prior to treatment, and no seedlings were observed. Both treatments occurred in the same dormant season, and 2 years later, *Ailanthus* seedlings were present in 96 percent of plots at a mean density of >5000 per acre. However, it appears that the combination of propagule pressure and disturbance may have been critical, because in the adjacent thin only and burn only units, there were few if any adult *Ailanthus* prior to treatment (low propagule pressure) and there was not a large increase in *Ailanthus* after those treatments.

The Ohio Department of Natural Resources, Division of Forestry has an active prescribed fire program to sustain oak forests (Bowden 2009). Between 2001 and 2008, a total of 14 prescribed fires have been applied to 2,100 acres within a 9,600 acre portion of the Tar Hollow State Forest. The goal of our research project is to gain a better understanding of how the distribution and abundance of *Ailanthus* is related to recent fires, past timber harvesting, seed sources, and other landscape and stand characteristics. The study area is located within the Southern Unglaciated Allegheny Plateau. The topography is highly dissected, consisting of sharp ridges, steep slopes, and narrow valleys.

Research Approach

Geo-referenced digital aerial sketch mapping technology (DASM) (Schrader-Patton 2003) in a low-flying helicopter was employed to identify seed-producing female trees and patches of *Ailanthus* in winter 2008 when persistent seeds were highly visible (Fig. 1). During a 2 hour flight, 98 seed-bearing females and 42 patches, ranging in size from 0.44 to 33 acres, were identified within a 9600 acre area (Rebbeck and others 2010). Aerially-identified females

Figure 1.—Aerial view of female *Ailanthus* trees with seeds during a 2011 winter helicopter survey on the Marietta District of the Wayne National Forest. Photo is courtesy of Tom Shuman, ODNR Division of Forestry.

were ground-truthed with 95.7 percent accuracy using hand-held Global Positioning System (GPS) units. The method appears to be an effective and efficient tool to map the distribution of *Ailanthus* seed sources in a landscape. Additional aerial mapping of more than 164,000 acres is underway in cooperation with the Wayne National Forest and Ohio Division of Forestry. In the course of 6 days, 78,000 acres were surveyed on the Wayne National Forest at an estimated cost of $0.40 per acre.

A systematic grid of research plots was installed to quantify the abundance, size, and age distribution of *Ailanthus*, as well as other stand attributes (e.g., fire, harvesting, and stand structure). Past timber harvest records were digitized and incorporated into a Geographic Information System (GIS) database. Current data analysis includes GIS and statistical techniques such as classification and regression trees (CART) and Random Forests (Prasad and others 2006) to determine the relationships of *Ailanthus* presence and abundance to distance and direction from seed-producing trees, fire, timber harvest, and other landscape attributes. Relationships are being tested to determine the extent to which burning and/or harvesting favors the spread of the *Ailanthus* and to determine possible mechanisms of its expansion in this landscape.

To gain a better understanding of how *Ailanthus* responds to fire, replicated research plots were installed in 2009 to study the direct effects of prescribed fire and herbicide treatments on *Ailanthus* demography and spread. Herbicide stem injections of *Ailanthus* (hack-n-squirt with imazapyr) were completed in autumn 2009, and prescribed burns were completed in April 2010. Treatment effectiveness and postburn survival, topkill, sprouting, and establishment of *Ailanthus* are being monitored for three postburn growing seasons (Figs. 2 and 3). If *Ailanthus* successfully establishes and remains competitive, a second fire may be needed. A field tour and workshop as well as accompanying technical publications are planned to provide guidance on conducting prescribed fires in the presence of *Ailanthus* within managed oak forest landscapes.

Figure 2.—Basal sprouting of topkilled *Ailanthus* tree 10 weeks after early spring prescribed fire.

Figure 3.—Abundant *Ailanthus* regeneration on forest floor within gap created from an herbicide plus prescribed burn treatment.

RECOMMENDATIONS: PROACTIVE MEASURES FOR MANAGING INVASIVES

Benjamin Franklin's famous quote, "an ounce of prevention is worth a pound of cure" could be the centerpiece for adopting a proactive management approach of NNIS. It is much more efficient to eradicate a newly-introduced small NNIS population than control one that is large and well-established (Fig. 4). The U.S. Department of Agriculture (USDA) recommends utilizing early detection and rapid response management of invasive species and has a manager's tool kit at the National Invasive Species Information Center (http://www.invasivespeciesinfo.gov/toolkit/detection.shtml).

These are my recommended guidelines in the development of a successful management plan. However, keep in mind that some of these suggested guidelines may be extremely challenging to implement.

- Actively monitor for invasives.
- Develop "invasive plant" awareness in field staff.
- Know what invasives are present and learn their life histories.
- Stay current on new emerging invasive plants.
- It is easier to control a small population than large one.
- Eliminate invasives before they start reproducing.
- Focus treatment efforts on seed-bearing trees to minimize dispersal.
- Eliminate populations well in advance of a silviculture treatment such as fire or harvest (time required will depend on longevity of seed).
- Careful monitoring and follow-up is essential. Don't assume that the treatment was effective.
- Take a landscape approach to management. Observe adjoining stands and properties. Engage surrounding property owners to control invasives. Partner with other groups and work within a local cooperative weed management area.
- Use the appropriate herbicide with the appropriate method at the appropriate time of the year for more effective chemical control. Only stem inject woody perennials in fall when resources are being translocated to roots.
- Adopt clean sanitation practices. Keep logging or other cutting equipment clean to minimize spread. Use clean gravel and native seed mixes.
- Follow a triage treatment approach to focus on the least infested areas first. If may be more practical and efficient to only remove seed sources from extremely infested areas and ban any other silvicultural treatments.
- Utilize or develop a decision support system to prioritize treatment areas.

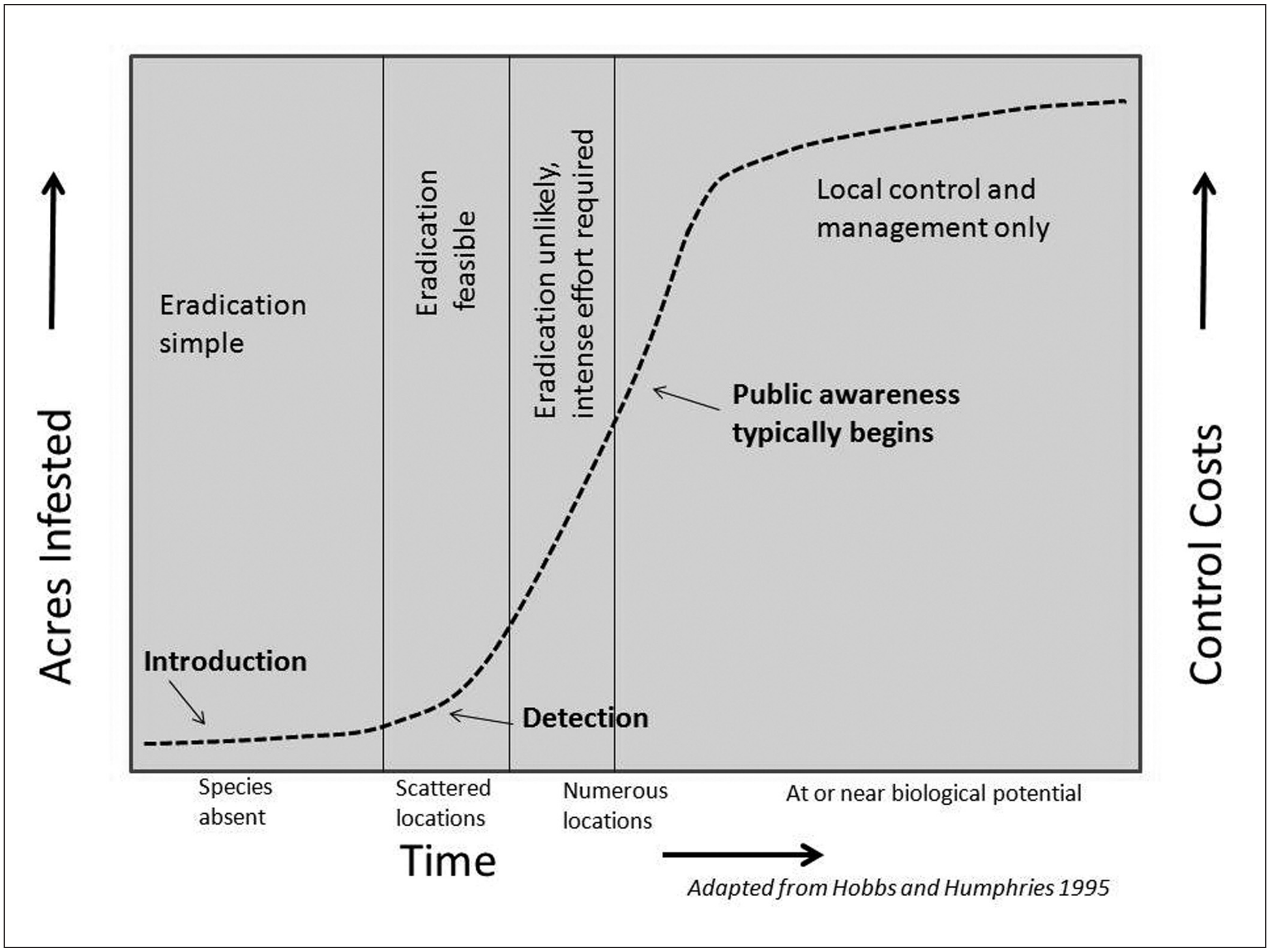

Figure 4.—Public awareness of invasive plants typically occurs after complete eradication is unlikely, increasing efforts and costs of control.

RECOMMENDED RESOURCES

1. **Mistaken Identity? Invasive Plants and their Native Look-alikes: an Identification Guide for the Mid-Atlantic.** A wonderful color photo guide with side by side comparisons of native and invasive plants that are difficult to distinguish.

Sarver, M.; Treher, A.; Wilson, L. [and others]. 2008. Dover, DE: Delaware Department of Agriculture. Mistaken identity? Invasive plants and their native look-alikes: an identification guide for the Mid-Atlantic. Available at http://weblogs.nal.usda.gov/invasivespecies/archives/2009/02/mistaken_identi.shtml.

2. **Fire Effects Information System (FEIS) Invasive Plants List.** This is a great resource, a one stop information portal for distribution and occurrence, biological and ecological characteristics, and management. It synthesizes available fire effects research on given species (includes peer reviewed and nonpeer reviewed literature). It was updated in 2011 to include 80 nonnative invasive plant species. Use caution when applying fire and management responses to other ecosystems and geographic regions.

U.S. Department of Agriculture, Forest Service. 2012. Fire Effects Information System, [Online]. Invasive plants list. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Visit the following to access FEIS: www.fs.fed.us/database/feis/plants/weed/index.html.

3. **Wildland Fire in Ecosystems: Fire and Nonnative Invasive Plants.** An extensive review of information on NNIS and wildland fire. It covers a wide range of topics including management planning with an emphasis on the western United States.

Zouhar, K.; Smith, J.K.; Sutherland, S.; Brooks, M. L. 2008. Wildland fire in ecosystems: fire and nonnative invasive plants. Gen. Tech. Rep. RMRS-GTR-42-vol. 6. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 355 p. Available at http://www.treesearch.fs.fed.us/pubs/30622.

4. **Invasive Plant Responses to Silvicultural Practices in the South.** A guide to assist foresters and managers in the southern United States in developing management plans to reduce invasive plants. It is a good overview of integrating vegetation management guidelines and control techniques with silvicultural practices for other eastern U.S. regions.

Evans, C.W.; Moorhead, D.J.; Bargeron, C.T.; Douce, G.K. 2006. Invasive plant responses to silvicultural practices in the south. BW-2006-03. Tifton GA: The University of Georgia Bugwood Network. 52 p. View or download publication at http://www.invasive.org/silvicsforinvasives.pdf.

5. **A Field Guide for the Identification of Invasive Plants in Southern Forests.** An update of the 2003 edition. The guide displays distinguishing plant features throughout the year for accurate identification of 56 problematic invasive plants. Many species are found throughout the eastern region.

Miller, J.H.; Chambliss, E.B.; Loewenstein, N.J. 2010. A field guide for the identification of invasive plants in southern forests. Gen. Tech. Rep. SRS-119. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 126 p. View or download publication at http://www.treesearch.fs.fed.us/pubs/35292.

6. **A Management Guide for Invasive Plants in Southern Forests.** A companion to the Southern Forests Field ID guide described above. It provides great information on current management strategies and procedures for 56 invasive plants in a variety of habitats. Good overview on organizing, planning, and enacting invasive plant management and prevention programs.

Miller, J.H.; Manning, S.T.; Enloe, S.F. 2010. A management guide for invasive plants in southern forests. Gen. Tech. Rep. SRS-131. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 120 p. View or download publication at http://www.treesearch.fs.fed.us/pubs/36915.

7. **Invasive Plants Field and Reference Guide: An Ecological Perspective of Plant Invaders of Forests and Woodlands.** A handy ringed laminated guide suitable for field work. Provides key information for the accurate identification of invasive species, and gives a scientific synthesis of what is known about the behavior of these species in managed, disturbed, and pristine forested systems.

Huebner, C.; Olson, C.; Smith, H. 2005. Invasive plants field and reference guide: an ecological perspective of plant invaders of forests and woodlands. NA-TP-05-04. U.S. Forest Service, State and Private Forestry, Northeastern Area. View or download publication at http://www.treesearch.fs.fed.us/pubs/19822.

8. **A Guide to Nonnative Invasive Plants Inventoried in the North by Forest Inventory and Analysis.** The intent of this guide is to aid FIA field staff in identifying 44 invasive plant species in the 24-state Northern Research Station region (Maine south to Delaware west to Kansas and north to North Dakota). However, this guide can be used by anyone interested in learning about these invasive plants. It contains distribution maps, short descriptions, space for notes, and numerous pictures of each plant.

Olson, C. 2009. A guide to nonnative invasive plants inventoried in the North by Forest Inventory and Analysis. Gen. Tech. Rep. NRS-52. Newtown Square, PA; U.S. Department of Agriculture, Forest Service, Northern Research Station. 194 p. View or download publication at http://nrs.fs.fed.us/pubs/34183.

9. **Join a Regional Invasive Plants Listserve.** Subscribe to a regional invasive plants listserv to receive emails and updates to stay informed of emerging problem species and current control methods. Two such groups include the Midwest Invasive Plant Network at www.MIPN.org or the Mid-Atlantic Exotic Pest Plant Council website at www.ma-eppc.org.

SYNOPSIS

Land managers and researchers have much to learn about the interaction between fire and invasive plants in eastern oak forests woodlands and savannas. The use of fire alone should not be considered as a viable control option for invasives. Instead, an integrated management approach with early detection, removal, and monitoring should be utilized to minimize their deleterious impacts on oak ecosystems.

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