TESTING FIVE TREATMENTS TO CONTROL *LONICERA* AND PROMOTE NATURAL HARDWOOD REPRODUCTION IN NORTH ALABAMA

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Abstract—We partnered with the Land Trust of North Alabama to implement an invasive species treatment demonstration project on property with high recreational use. The stand had low-quality upland hardwoods with eight dominant or codominant tree species averaging 5.5 inches in diameter at breast height (d.b.h.) and 456 stems per acre (SPA). We treated honeysuckles (*Lonicera* spp.) using mechanical removal, mechanical removal with cut stump herbicide application, foliar herbicide treatment, and a single dormant season prescribed fire, in addition to an untreated control area. The pretreatment density of *Lonicera* in all five treatment areas ranged from 11,000 to 15,300 SPA, which was 84 to 96 percent of all woody stems in the understory. Posttreatment SPA of *Lonicera* was 500 to 39,400, ranging from 16 to 98 percent of all understory stems. Foliar herbicide treatment was most effective in reducing *Lonicera* stems. Hardwood tree reproduction was depauperate.

INTRODUCTION

The issue of invasive flora and fauna in eastern hardwood forests continues to receive heightened attention (Riitters and others 2017). Forest landowners, managers, policymakers, and educators require an understanding of the impact of invasive plants and animals and how forest management decisions and disturbance will affect their distribution and resilience (Martin and others 2009). After all, the services gained from our forested systems depend directly upon the condition of the ecosystem and cannot be taken for granted (Collier and Vankat 2002, Martin and others 2009). Sustaining forested systems will require intensive, active conservation practices to address the extent of invasive plant species coverage, the consequences of different actions, and the effort needed to situationally address problems.

Demonstration areas and case studies can transfer available technology and science to stakeholders to help them gain understanding and assistance in making conservation activity decisions. One such demonstration area with the Land Trust of North Alabama (LTNA) on the Monte Sano Nature Preserve (hereafter, “Preserve”) property in Huntsville, AL, has been developed to show how various tending treatments will impact the highly invasive plant species group, *Lonicera* (honeysuckles, family Caprifoliaceae). The Preserve (1,100 acres) is managed by the LTNA, which pursues multiple organizational goals: conservation of sensitive species, conservation of historical sites, encouragement of outdoor recreation, and facilitation of environmental education (https://www.landtrustnal.org). These project goals included targeting a specific plant community in a comprehensive restoration ecology approach, galvanizing the mission of the LTNA to strengthen connections to communities, and sustaining LTNA land holdings by delivering stewardship benefits to the public.

To support this project, over the past 10 years scientists and foresters with the U.S. Department of Agriculture, Forest Service, Southern Research Station, in conjunction with University of Alabama-Huntsville faculty and students, have conducted a survey of the woody vegetation on several properties, including the Preserve. Our vegetation survey of grid points systematically distributed across the landscape allowed us to have data associated with changes in slope, elevation, soils, and land uses. From these data, preliminary modeling of *Lonicera* spp. highlighted a need to target its invasion and spread (Laliberte 2013, Werkheiser 2009).

The primary objectives of this study were (1) to evaluate the most efficient and acceptable method to reduce the density of *Lonicera* in LTNA forested stands and (2) to establish a demonstration project to transfer knowledge related to the detrimental impact of nonnative invasive species and show potential treatment outcomes.

METHODS

Cumberland Plateau forests, which includes those found in northeastern Alabama and the Preserve, are dominated by either oak-hickory (*Quercus*-*Carya*) upland types on the broad tabletops or intermediate mixed

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mesophytic and oak-hickory types on the side slopes or escarpment (Braun 1950). These classifications result from local topographic and edaphic conditions, a consequence of geological uplifting and subsequent erosion. Over 30 canopy species can be found in the highly diverse forests of the Cumberland Plateau (Hinkle and others 1993). A myriad of disturbances has influenced these forests, and most stands are considered second- or third-growth (Hart and Grissino-Mayer 2008). Over the past 50 to 100 years, they have become dominated by oaks, yellow-poplar (*Liriodendron tulipifera* L.), ash (*Fraxinus* spp.), and other important species. More recent disturbance is attributed to the proximity of the Preserve to the metropolitan area of Huntsville, AL. The Preserve has high levels of recreational use and increased potential for the introduction of nonnative invasive species from seed sources on adjacent landowner properties, distribution via birds, and spread along roads and trails (Riitters and others 2017).

Trail access from an LTNA parking lot adjacent to the Preserve provided an opportunity for treatment of *Lonicera* in a highly viewed and foot-trafficked area. The treatment area was located along the Railroad Bed Trail, just south of a parking area. We flagged five treatment units measuring approximately 100- by 100-feet to delineate boundaries. One survey measurement plot was centrally located in each treatment unit. Plot centers were permanently marked with a 24-inch piece of reinforcing steel, and GPS coordinates for plot centers were recorded. At each plot center, a 0.025-acre plot was established. All trees ≥1.5 inches diameter at breast height (d.b.h., 4.5 feet above groundline) were monumented (distance and azimuth measured and recorded from plot center), and species and d.b.h. were recorded. Tree crown position was recorded (dominant, codominant, intermediate, suppressed), and an assessment of tree health following Gottschalk and MacFarlane (1993) was made. Canopy cover was measured using a handheld spherical densitometer in five locations within each plot. Within each plot, we also surveyed a 0.01-acre plot by enumerating the reproduction cohort (trees <1.5 inches d.b.h.) by species and height class. Stems of *Lonicera* were recorded in the 0.01-acre plot, and all stems were counted as they originated at ground level. Several species of honeysuckles occur on the study site; we did not identify *Lonicera* to the species level. Data were collected prior to treatment implementation and at 1 year and 3 years posttreatment.

The five treatments implemented to test *Lonicera* control included: (1) control, no treatment; (2) mechanically remove all *Lonicera* stems; (3) treat all *Lonicera* with a foliar herbicide; (4) mechanically remove all *Lonicera* stems and treat cut surfaces, as well as small stems, with herbicide; and (5) prescribed fire. Mechanical removal (treatment 2) consisted of severing all stems at groundline with pruners and a brush saw, with cut stems removed from the unit boundaries. This treatment targeted larger stems, although all *Lonicera* stems were severed as was feasible. The herbicide treatment (treatment 3) targeted all stem sizes using a direct foliar spray of a commercially available herbicide concentrate that was a mixture of 18-percent glyphosate and 2-percent triclopyr, which we diluted as a 5-percent solution in water. We used a backpack sprayer and spray wand, and all exposed leaf surfaces were wetted. For the mechanical/herbicide treatment (treatment 4), all stems that could be severed were cut and removed from the unit boundaries, and the cut stump surface was immediately treated with imazapyr herbicide (mixed at 20-percent volume/volume with water) using a small utility spray bottle; smaller *Lonicera* stems were treated with the glyphosate/triclopyr solution via the backpack sprayer as in treatment 3. The mechanical and herbicide treatments were done on October 19, 2015. Removal of all vegetation in a 4-foot buffer outside of treatment 5 provided a firebreak for the prescribed fire. We worked with the City of Huntsville, Bureau of Fire Prevention and the Alabama Forestry Commission to implement the prescribed fire on March 17, 2016. We documented the fire using a HOBO® data recorder and a temperature-sensitive probe; we also measured the forest floor litter consumption. Maximum fire temperature reached 170 °F, and approximately 0.5 inches of forest litter were consumed. This was a cool fire that crept slowly over the treatment area, which is typical for areas that have not been recently subjected to fire.

For transferring these activities and their consequences to the public, we installed informative signs at each unit, immediately adjacent to the trail. The demonstration site is frequently used for field tours and related science-delivery activities. Partners involved included the LTNA, Forest Service, University of Alabama-Huntsville, City of Huntsville, and Alabama Forestry Commission.

RESULTS

Overstory and Midstory Trees

Posttreatment canopy cover was 92 percent and did not change with treatment. Trees were primarily in dominant and codominant positions and were assessed as fair-to-poor health based on canopy dieback and low crown density, along with poor bole form. Overstory and midstory tree composition consisted of 12 species. Canopy-level species included white ash (*F. americana* L.), chinquapin oak (*Q. muehlenbergii* Englem.), scarlet oak (*Q. coccinea* Muench.), persimmon (*Diospyros virginiana* L.), slippery elm (*Ulmus rubra* Muhl.), shagbark hickory (*C. ovata* K. Koch), sugar maple (*Acer saccharum* Marsh.), and yellow buckeye (*Aesculus flava* Sol.). Midstory species included eastern hophornbeam (*Ostrya virginiana* K. Koch), eastern redcedar (*Juniperus virginiana* L.), eastern redbud (*Cercis canadensis* L.), and winged elm (*U. alata* Michx.). Species richness did not change by any treatment. Average basal areas and stem densities for overstory trees are given in table 1. No large overstory trees suffered mortality due to the treatments, but one eastern redbud that was 4.4 inches d.b.h. died immediately after the fire, and one 1.7-inch-d.b.h. yellow buckeye died by year 3. At year 3, we found that a single 2.3-inch-d.b.h. stem of eastern hophornbean died in the control, and a 2.3-inch-d.b.h. hophornbean stem died in the herbicide treatment. There were a few changes in stem densities due to ingrowth (table 2). In the prescribed fire treatment, one sugar maple sapling grew from 3.5 inches d.b.h. to 3.6 inches d.b.h., which moved it into another diameter class (class 2, see table 2) and one slippery elm sapling moved from class 2 to class 3. A chinquapin oak in the control unit grew from 9.4 inches d.b.h. to 9.8 inches d.b.h., moving it into the next largest size class (class 5). In year 3, there were no changes in stem densities or diameter class distributions for the mechanical/herbicide and mechanical-only treatments.

Understory Vegetation

Changes were most notable in the understory layer of vegetation. We tallied 12 different species of woody species in the understory in all units prior to treatment and 10 species in posttreatment year 1. Blue ash (*F. quadrangulata* Michx.), blackhaw (*Viburnum prunifolium* L.), and deciduous holly (*Ilex decidua* Walter) were no longer present in the units posttreatment year 1, and eastern redcedar was found in the mechanical/herbicide treatment. The holly was only tallied in the mechanical treatment unit prior to treatment; there were four stems per acre (SPA), all in size class >4 feet tall and <1.5 inches d.b.h., and all were removed in the

Table 1—Overstory tree basal area and stem density by treatment for all trees ≥1.5 inches d.b.h. for the Land Trust of North Alabama Monte Sano Nature Preserve *Lonicera* treatment demonstration project

	Basal area			Stem density		
Lonicera treatment	Pre	Yr1	Yr3	Pre	Yr1	Yr3
	square feet per acre			*stems per acre*		
Control	45.3	45.6	48.2	280	280	240
Mechanical	186.5	189.7	198.9	480	480	480
Foliar herbicide	135.7	134.8	141.7	560	560	520
Mechanical and herbicide	78.4	80.7	85.1	440	440	440
Prescribed fire	106.2	103.1	111.3	520	480	440

d.b.h. = diameter at breast height.

Pre = pretreatment, Yr1 = one growing season posttreatment, Yr3 = three growing seasons posttreatment.

Table 2—Stem densities in stems per acre by diameter class (for all trees ≥1.5 inches d.b.h.) for the Land Trust of North Alabama Monte Sano Nature Preserve *Lonicera* control demonstration project

d.b.h.	Control			Mechanical			Foliar herbicide			Mechanical and herbicide			Prescribed fire		
class	Pre	Yr1	Yr3	Pre	Yr1	Yr3	Pre	Yr1	Yr3	Pre	Yr1	Yr3	Pre	Yr1	Yr3
							stems per acre								
1	160	160	120	160	160	160	280	280	240	160	160	160	200	160	120
2	0	0	0	80	80	80	0	0	0	120	120	120	200	200	160
3	40	40	40	0	0	0	160	160	160	80	80	80	40	40	80
4	80	80	40	80	80	80	0	0	0	0	0	0	40	40	40
5	0	0	40	80	80	80	80	80	80	80	80	80	0	0	0
6	0	0	0	40	40	40	40	40	40	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	40	40	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40
9	0	0	0	40	40	40	0	0	0	0	0	0	0	0	0

d.b.h. = diameter at breast height, Pre = pretreatment, Yr1 = one growing season posttreatment, Yr3 = three growing seasons posttreatment.

d.b.h. classes: 1 = 1.5-3.5 inches, 2 = 3.6-5.5 inches, 3 = 5.6-7.5 inches, 4 = 7.6-9.5 inches, 5 = 9.6-11.5 inches, 6 = 11.6-13.5 inches, 7 = 13.6-15.5 inches, 8 = 15.6-17.5 inches, 9 = 17.6-19.5 inches.

mechanical treatment. One SPA of blue ash and one of blackhaw were found only in the mechanical with herbicide treatment unit; both were in size class >4 feet tall and <1.5 inches d.b.h., and both were removed via treatment. Within these small plots, the changes in understory species diversity was minimal. At year 3, we tallied 11 species; no blackhaw, sugar maple, redcedar, or winged elm was tallied, but blue ash was found in the mechanical treatment and the mechanical/herbicide treatment, and holly was tallied in the mechanical treatment. Two new species were recorded: aromatic sumac (*Rhus aromatica* L.) in the mechanical/herbicide treatment and Osage orange (*Maclura pomifera* [Raf.] Schneid.) in the mechanical treatment. The reproduction cohort was depauperate of desired species such as oaks and hickories.

The pretreatment SPA of *Lonicera* in all five treatment plots ranged from 11,000 to 15,300, which was 84 to 96 percent of all stems in the understory. Posttreatment *Lonicera* density was 500 to 39,400 SPA, with a range of 16 to 98 percent of all understory stems. At year 3, the densities of all understory stems ranged from 7,400 SPA to 16,900 SPA. *Lonicera* densities were lowest in the herbicide treatment at 2,700 SPA and second lowest in the mechanical/herbicide treatment (9,500 SPA), followed by the mechanical treatment (16,700 stem per acre). *Lonicera* densities were greatest in the prescribed fire treatment (16,900 SPA). The control treatment had 12,600 *Lonicera* SPA. Interestingly, we have rarely observed *Lonicera* on the Monte Sano State Park, immediately adjacent to the Preserve.

Changes in *Lonicera* stem densities varied by treatment and size classes. The mechanical and the prescribed fire treatments resulted in increases in the density of *Lonicera* after 3 years, with increases of 1,000 SPA and 5,700 SPA, respectively. For the prescribed fire treatment, although stem density declined for stems that were >4 feet tall up to 1.5 inches d.b.h. (fig. 1), stems ≤4 feet tall increased in density, most likely from sprouting. Total understory stem densities and those of *Lonicera* showed a decline in the other three treatments. The greatest decline was quantified in the herbicide treatment, which had lost 9,200 *Lonicera* SPA, with the majority of these stems >1 foot tall (fig. 2). There was an increase of 400 SPA of ≤1-foot-tall *Lonicera* in the herbicide treatment; these stems may have not been treated due to their location underneath a thick canopy of other *Lonicera* stems. Across all size classes, there was a decrease of 4,900 SPA of *Lonicera* in the mechanical/herbicide treatment, with 10,800 SPA removed that were >1 foot tall, and a concurrent increase of 5,900 SPA in stems ≤1 foot tall, most likely due to omission error during treatment and new germinants.

At study initiation, *Lonicera* averaged 90 percent of stems in the reproduction cohort. At year 3, *Lonicera* was 99 percent of the reproduction stems for each of the control, mechanical, and prescribed fire treatments. For the mechanical/herbicide treatment, 85 percent of the reproduction was *Lonicera*, with 1,400 SPA of white ash, blue ash, shagbark hickory, and aromatic sumac. In the herbicide treatment, the reproduction was only

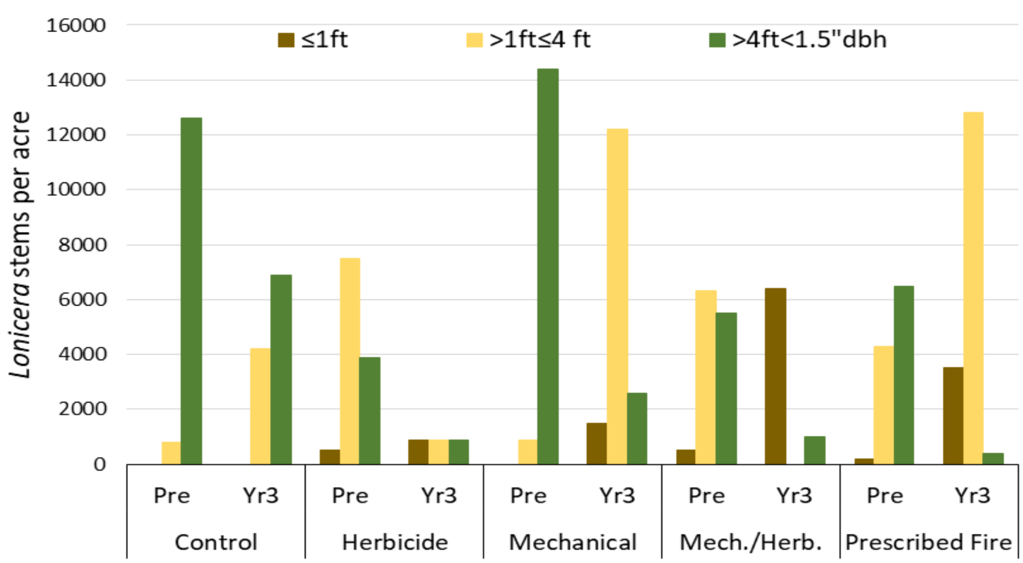

Figure 1—Stems per acre of *Lonicera* by height classes for each treatment at times Pre (pretreatment) and Yr3 (three growing seasons posttreatment) for the Land Trust of North Alabama Monte Sano Nature Preserve *Lonicera* control demonstration project.

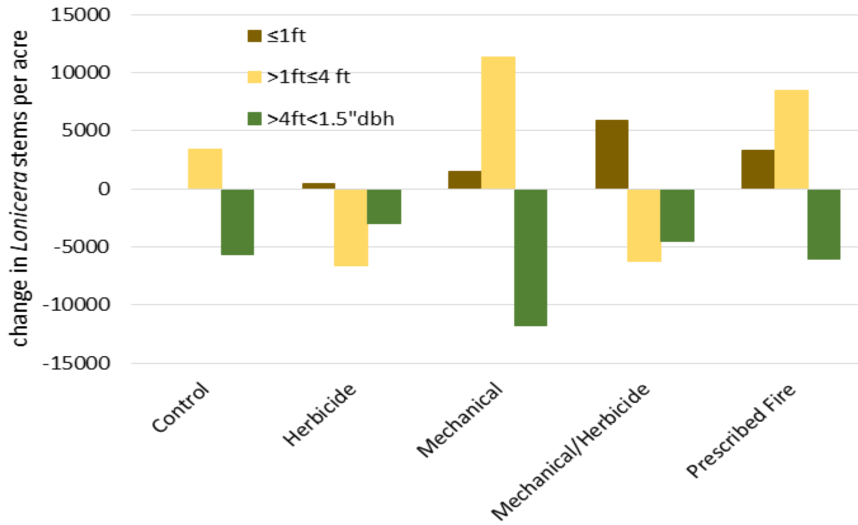

Figure 2—Change after three growing seasons in stems per acre of *Lonicera* by height classes for the Land Trust of North Alabama Monte Sano Nature Preserve *Lonicera* control demonstration project.

36 percent *Lonicera*, with 2,540 SPA of woody species including slippery elm, eastern hophornbeam, white and blue ash, and aromatic sumac.

DISCUSSION

Introduction of invasive plant species may change ecosystem structure and function (Bazzaz 1986, Vitousek 1990). While disturbance is known to open communities to invasion (Honu and Gibson 2006, Medley 1997), proximity to roads and urban areas also contributes (Flory and Clay 2006). Regardless of origin, *Lonicera* in the understory of Preserve property dominates that vegetation layer. We were able to most efficiently reduce the density of *Lonicera* using a foliar herbicide treatment. *Lonicera* stems of all sizes except those in the smallest size class (<1 foot tall) were reduced in the herbicide treatment; these small stems in the herbicide treatment were new seedlings which germinated posttreatment. Across a selection of herbicides, Rathfon and Ruble (2007) also found foliar spray to provide better control than cut stump or basal bark methods for control of bush honeysuckles.

The mechanical/herbicide treatment also reduced *Lonicera* stems, but these stems were concentrated in the >1 foot and larger size classes; stems in the smallest size class increased following treatment, a result of missed application (stems may have been hidden by taller *Lonicera* stems or were cut en masse with an incomplete subsequent herbicide treatment), coupled with release from the removal of larger stems. Similar results related to high densities of targeted species and incomplete treatment application were noted by Love and Anderson (2009), where they demonstrated that cutting invasive shrubs and applying herbicide to stumps was least effective. After one growing season posttreatment, stem numbers in the mechanical-only treatment had the greatest increase, and this increase was noted for *Lonicera* in all but the largest size class. Mechanical removal of the largest *Lonicera* stems resulted in an 11,800-SPA decrease of *Lonicera* in this size class; however, because the stumps were not treated, these stumps will be prolific sprouters (Smith and Smith 2010). In the mechanical treatment, the largest increase in stem density was size class >1 foot but ≤4 feet tall, a result of smaller stems responding to the increased growing space and rapid growth of stump sprouts, which have a well-established root allowing for allocation of resources to the aboveground plant. After one fire, the number of *Lonicera* stems increased, with increases in stems sizes for stems ≤4 feet tall; larger stems sizes were reduced following the fire. Repeated fires should reduce smaller stems and exhaust root reserves of sprouters (Nyboer 1992).

The percentage of the understory dominated by *Lonicera* was reduced to 16 percent in the herbicide treatment, providing growing space for other species. This study did not collect herbaceous plant data, but we observed several patches of wildflowers in this treatment unit in the spring following the treatment. Although there were no oak seedlings tallied posttreatment, parent trees of scarlet oak and chinquapin oak were present and could provide a seed source (acorns). Creating growing space by eliminating *Lonicera* should facilitate acorn germination, although additional treatment to keep the *Lonicera* in check will be needed for oak seedlings to recruit into the midstory (Dey and others 2019, Schweitzer 2019). Small ash seedlings increased from 5 SPA pretreatment to 21 SPA after treatment.

The pending spread of the emerald ash borer (*Agrilus planipennis* Fairmaire) to southern forests will kill overstory ashes (Knight and others 2013); developing a robust cohort prior to that epidemic may be paramount to sustaining ash in these systems, and these preliminary results support the use of herbicide in that process.

The expectation was that the most intense treatment (mechanical/herbicide) would result in the greatest *Lonicera* control. Early results did not support this theory, as the foliar herbicide treatment had the greatest impact in reducing *Lonicera*. In the mechanical/herbicide treatment, stems in the smallest size classes were not reduced. We surmised that small, cut stems were missed during the post-cut herbicide application. The inability of cut and treated stumps to sprout may be manifested in subsequent years. The most efficient treatment, in terms of labor and control, was the foliar herbicide treatment. Because of prolific stump sprouting, the mechanical-only treatment was the least effective, although many believe this to be the most aesthetically pleasing immediately posttreatment. Three years following mechanical treatment, *Lonicera* was the only species tallied in the >1-foot-tall to ≤4-foot-tall height class of understory stems in the mechanical removal treatment. A single fire did impact the larger *Lonicera* stems, but repeated fires will be necessary to diminish reserve resources in the root system and reduce sprouting. Using prescribed fire in this wildland-urban interface is most likely unviable, due to high-risk issues such as smoke management.

CONCLUSIONS

Invasive plants are increasingly impacting forests, and forests in the wildland-urban interface may be particularly prone to alteration and damage. Treating invasive plant species is one step toward conservation in action. Land stewards need to know the extent of invasive species densities and locations, have clear ideas as to the desired future conditions, and plan the most efficient treatment to move toward those goals. After all, hallmarks of good forest stewardship include the consideration of multiple resources, are based on landowner objectives, and use the best available practices. Forest stewardship by nongovernment entities such as the LTNA includes collaborative work to conserve and to advocate for ecological restoration. Oftentimes, these actions must be in concert with public opinions and desires. By involving various stakeholders and including a technology transfer component, this demonstration area on the Preserve will provide a framework for addressing a common issue in wildland-urban interface areas and will commence the process of active conservation and restoration. For example, we designed and posted signs at each treatment unit describing the treatments and the anticipated outcomes, and we have hosted invasive plant workshops and field tours. Although some managers are still reluctant to engage in control practices, especially if that involves the use of herbicides, we are demonstrating that with the correct activities, which includes the use of herbicides, degraded systems can be converted to more healthy and resilient upland hardwood forests. Desired species such as oaks, ashes, and hickories can be 'life-boated' as seed sources to assist in the recovery and restoration. The management implications of this project support active conservation methods to ensure desired future forest composition.

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