Kudzu (Puerarial obata) continues to spread unabated in the South. To assist in kudzu control and containment efforts 15 herbicide treatments were tested in 1981 on a Piedmont site in Alabama using replicated plots, with retreatments applied a year later when needed. After 2 years, treatments that gave comparable control to the standard prescription of Tordon 10K at 50 lb/acre were Tordon 101 at 1 and 2 gal/acre, Banvel 720 at 3 and 4 gal/acre, Spike 80W at 6 and 10 lb/acre, and Spike 20P at 20 and 30 lb/acre. The Tordon and Banvel herbicides are currently registered for forest land site preparation and Spike 80W for fence rows and noncroplands. Spike 20P is an experimental compound. Tordon 101 at 1 gal/acre and Banvel 720 at 3 gal/acre were the most cost-effective compounds when two broadcast applications were made in successive years. Tordon 101 and the Spike herbicides also aided in controlling blackberry (Rubus spp.) and Japanese honeysuckle (Lonicera japonica). Round up and Brushkiller’s 4-41 and 10-51 were ineffective in controlling kudzu.

Multiflora rose was defoliated completely 320 days after spring foliar application of metsulfuron. Metsulfuron and 2,4-D plus dicamba spring foliar applied controlled multiflora rose equally. Metsulfuron applied to soil using a spotgun at 20 mg per m diam of multiflora rose in the spring resulted in 95% control 320 days later in one study but only 50% control in another. Control was less when lower rates of metsulfuron were soil-applied with a spotgun. Tebuthiuron spring soil-applied completely controlled multiflora rose. All spring-applied foliar and soil applications seemed to control multiflora rose better than fall treatments.

In the development of novel strategies for control of invasive plant species,

researchers might first consider plant performance throughout a range of habitats and then

concentrate management activities in habitats where plants are least resilient. We determined

the relative resilience of forest- and open-grown populations of the invasive shrub

*Lonicera maackii* (Caprifoliaceae) growing in northern Kentucky. Resilience was assessed

by imposing a clipping regime (once each year from 1986 to 1989) during which shrub

resprouting abilities were measured. Habitat-specific population regeneration from seeds

in the seed bank was also measured. Forest-grown *L. maackii* shrubs were less resilient

than open-grown shrubs when stressed by repeated clipping, due presumably to exhaustion

of stored reserves in shrub bases. This suggests that forests are secondary habitats for *L.*

*maackii.* However, resprouting potential and seed production in forests appear sufficient

to regenerate populations after most common disturbances. The ability to modify sprouting

patterns while maintaining resprouting ability and some seed production over a wide range

of habitats is an important adaptation of this invasive shrub. Management suggestions for

shrub eradication are provided.

Garlic mustard [Alliaria petiolata (Bieb.) Cavara & Grande] is a naturalized European obligate biennial herb that invades forest communities in the midwestern and northeastern United States and southeastern Canada. Three potential control methods (prescribed fire, 3% v:v glyphosate, cutting) were tested in a densely infested oak forest in northern Illinois. Spring treatment with either glyphosate or mid-intensity fire reduced garlic mustard adult (rosette) density and seedling frequency, while fall treatment creased rosette density only. Low-intensity fire did not affect garlic mustard presence. successful treatments produced cascading effects observable one to two years after treatment. Treating seedlings in spring reduced adult density the following year, and treating adults in either spring or fall resulted in lower seedling frequency two years later. Cutting flowering plants at ground level resulted in 99% mortality and reduced seed production to virtually zero; cutting at 10 cm above ground level produced 71% mortality and reduced total seed production by 98%. Recommended management is to prevent seed production until the seed bank is exhausted by repeated applications of fire, herbicide, cutting on an annual basis until garlic mustard is absent from the site for a minimum of three years.

Field studies were conducted to evaluate the efficacy of selected herbicides to control the noxious weed mile-a-minute (Polygonum perfoliatum L.). The effectiveness of pre- and postemergence applications of the herbicides Oust, Velpar L, Arsenal, AAtrex, Pursuit, and Pursuit Plus and postemergence application of Roundup were evaluated. Preemergence applications of most of the herbicides were more effective in controlling mile-a-minute than postemergence applications. Low preemergent rates of Oust, Velpar L, Arsenal, AAtrex, Pursuit, and Pursuit Plus were highly effective in controlling mile-a-minute; Roundup and Arsenal provided the best postemergence control.

Groundlayer response to prescribed fire was monitored in a central Illinois sand forest between 1990 and 1994. The first of three annual fires resulted in a significant increase in richness and cover of herbaceous species, and a minor decrease in woody cover. Successive fires maintained or slightly increased herb richness and cover, but did not change woody cover. Before burning, the forest understory was dominated by dense shrubs (74- 89% cover) over a sparse herb layer (4-18% cover). After the first fire, herb cover increased over fourfold to 48-57%, and to 65-66% after the second fire. Fire nonsignificantly reduced woody cover by some 20%, primarily due to a reduction in Parthenocissus quinquefolia (Virginia creeper), but did not affect frequency of woody vegetation. Species richness increased over 50% after the first fire, from 6.2-7.0/M2 to 9.8-10.8/M2, due to the increased frequency of herbaceous, and especially annual, species. Most of the postfire increase in herbaceous cover was due to Eupatorium rugosum (white snakeroot), which increased from <5% cover preburn to 23-36% cover after the first fire, and 50-55% cover after the second fire. Following a fire-free year, herbaceous cover decreased slightly but remained >3X higher than preburn levels. The alien biennial Alliaria petiolata was maintained in a reduced condition by repeated fires, but in the absence of fire doubled in cover every 2 yr, from 4.6% in 1990 to 8.6% in 1992 to 17.0% in 1994.

Experimental control of *Alliaria petiolata* was conducted in three sites over two years,

testing three herbicides at various concentrations, and monitoring response of both *A.*

*petiolata* and groundlayer flora. Glyphosate (trade name Roundup) significantly reduced

*A. petiolata* by >93% when applied at 1% and 2%, but not at 0.5%, concentrations.

Glyphosate at all concentrations had little effect on herbaceous species, which were

primarily dormant at the time of application, but at 0.5% concentration significantly

reduced cover of sedges (*Carex jamesii* and *C. laxiflora*) from a pretreatment mean of

13.1% to a post-treatment mean of 2.2%. Bentazon (trade name Basagran) nonsignificantly

reduced *A. petiolata* cover by >90% (compared to a 70% reduction in the

control plots) when applied at 0.56 kg and 1.12 kg AI/ha. Bentazon did not affect cover

of groundlayer species, nor species density. Acifluorfen (trade name Blazer) killed all *A.*

*petiolata*, inhibited *A. petiolata* seedling germination, and significantly reduced cover of

native herbs by >70%, and appeared to have a strong soil residual.

The response of the understory herbaceous flora to fire management was studied in a degraded woodland in northern Illinois. The site contains a rapidly expanding population of Alliaria petiolata, a non-indigenous plant that is highly invasive in forests. Three treatment units (March fire, May fire, and unburned) were sampled in 1991, prior to fire treatments. Following prescribed fire, plots were sampled annually from 1992 to 1994, inclusive, to track the response of the vegetation to the fire treatment. The purpose of the experiment was to assess the impact of fire on (1) A. petiolata populations, (2) the native herbaceous flora, and (3) shrubs and saplings. The initial impact of fire on A. petiolata, understory forbs, shrubs, and saplings was strongly negative in the growing season burn unit and moderate in the dormant season burn unit. After three years, A. petiolata had not recovered to preburn densities in the growing season burn unit. Likewise, densities and richness of native herbaceous species remained below preburn values in the growing season burn unit after three years. Dormant season and growing season burns equally and strongly reduced shrub and sapling densities relative to the control unit.

Rose rosette disease, lethal to multiflora rose and indigenous to North America, has been proposed as a biocontrol agent for multiflora rose, a noxious weed in the central and eastern United States. Studies in experimental plots showed that the disease can be intensified by grafting infected shoots onto plants in established stands (i.e., augmentation). The rate of disease spread in augmented plots was significantly faster compared to epidemics in nonaugmented plots at 5 locations. Augmentation provided effective control 3 to 5 yr after implementation. Risk to ornamental rose seems to be low under conditions of this study. Plots to assess risk of the disease to ornamental roses, located at distances greater than 100 m from augmentation sites, showed no infection during the 3 yr of this study.

We studied the utility of gap formation and soil disturbance as methods to enhance establishment of plant species in the understory of a northern Kentucky forest where Lonicera maackii (Amur honeysuckle) produced dense thickets. In May 1994, gaps (5 m diameter) were cut in the shrub thicket. In adjacent areas, the shrub canopy remained intact. Subplots were established where soil was either turned with a spade to a depth of 15 cm or not disturbed. We monitored plant establishment for three growing seasons (1994, 1995, and 1996). Shrub removal increased light availability to about 10% of full sun. Gap formation had a significant (p < 0.05) and positive influence on total plant density (exclusive of

L. maackii), and soil disturbance did not (p > 0.05). After three growing seasons, the most important species were L. maackii, Alliaria petiolata, Parthenocissus quinquefolia, Vitis vulpina, and Acer negundo. Of these species, only V. vulpine showed significantly (p < 0.05) higher densities in gaps. Other less important species such as Phytolacca americana, Campsis radicans, and Eupatorium rugosum occurred almost exclusively in gaps. Of the 44 taxa observed in this study, most were generalist species that also occur in early successional habitats. Long-term dominance of the understory by L. maackii has likely modified system attributes with corresponding effects on community development. Shrub removal provides a window of establishment for various plant species, but successful restoration may require

further management to augment species availability and to control new invaders.

Rhamnus frangula L. (glossy buckthorn) is an aggressive introduced species that has become a serious problem in wetlands in the upper midwestern States. Three mechanical control methods were tested for effectiveness during the Both cutting and girdling were ineffective as control methods when applied December through March; neither method caused any mortality in these trials. followed by an application of glyphosate herbicide to the cut stump, resulted to 100% kill of buckthorn individuals in four trials during the same December March period.

An assumption of weed science and conservation biology is that small populations are more vulnerable to elimination and extinction than large populations. We tested this with the invasive biennial garlic mustard (*Alliaria petiolata*). We compared 61 experimental populations from which every flowering plant was removed for 4 years, with 56 control populations. Whereas the majority of the control populations continued to expand in size over the 4 years, experimental populations showed a strong experimental effect, remaining stable in size, declining in size, or going extinct. Small populations were far more vulnerable to extinction than large populations: 43% of small experimental populations (initially fewer than 10 individuals) went extinct, but only 7% of large populations (initially more than

50 individuals). However, some small experimental populations persisted, and in a few cases, larger experimental populations continued to expand even though every flowering individual had been removed. These results and a simple population model suggest the importance of buried seeds in allowing this species to persist despite attempts to eradicate it.

Negative effects on native plant populations are often attributed to invasions by exotic plants, but experimental evidence is lacking to support many of these claims. *Lonicera* *maackii,* an exotic shrub with long leaf phenology, has become naturalized throughout the eastern United States. This study investigated the effects of *L. maackii* on demography of *Galium aparine, Impatiens pallida* and *Pilea pumila,* native annual herbs in differing phenological categories. These interactions were examined in two Ohio forest stands. One stand has a history of logging, burning and grazing and a higher *L. maackii* density, whereas the other stand has little anthropogenic disturbance and a lower *L. maackii* density. Three types of experimental plots were established: *L. maackii* removal, *L. maackii* present and, at the

less disturbed stand, *L. maackii* absent. Seedlings of the annuals were transplanted and monitored for 1 y for survival to reproductive age and fecundity. In the more disturbed stand, survival of *Galium aparine* and *Impatiens pallida* and fecundity of all three species were significantly greater in the removal treatment than where *Lonicera* *maackii* was present. In the less disturbed stand there was no treatment effect on survival, but fecundity of all annuals was greater in the removal treatment than where *L. maackii* was present. Also, fecundity of *I. pallida* and *Pilea pumila* was greater where *L. maackii* was absent than where it was present. At both sites fitness (estimated as the product of survival and

fecundity) was highest for each species in the removal treatment and lowest where *L. maackii*

was present. These results demonstrate direct effects of the invasive shrub *Lonicera maackii* on populations of annuals. They suggest that other annuals, particularly those that are shade-intolerant

or photosynthesize only in the early spring, will decline in the presence of shrubs with

early leaf expansion.

We examined vegetation change over time at managed and unmanaged oak woodland sites located in Cook County, Illinois, forest preserves. The managed site (Cap Sauers Holding) was dominated by red and white oak *(Quercus rubra* and *Q. alba)* in 1995, and density was 313 trees ha-'. Historical records indicate that white oak dominated the site and tree density was between 5 and 50 trees ha-'. Management initiated in 1989 included prescribed burning and woody plant removal. Vegetation was surveyed in 1988 and 1995. No significant change in total ground cover or in cover of native or exotic species (plants <1 m tall) was detected in 1995. However, herbaceous species as a percent of the total ground cover increased from 58% in 1988 to 81% in 1995. Woody species decreased from 42% of the total cover in 1988 to only 19% in 1995. Selected taxa—white snakeroot *(Eupatorium rugosum),* enchanter's nightshade *(Circaea lutetiana),* woodland knotweed *(Polygonum virginianum),* and oak species *(Quercus* spp.)—significantly in-creased in cover between the 1988 and 1995 surveys. Exotic shrubs decreased by 3139 stems ha-1, natives decreased by 2635 stems ha-', and the canopy cover of exotic and native shrubs decreased significantly. Tree canopy cover at the managed site did not change significantly between years. In contrast, at the unmanaged site (McClaughry Springs Forest Preserve), total ground cover (plants <1.4 m tall) significantly increased over four years, mostly due to increases in woody vegetation. Density of woody species in all size classes increased, and there was a significant increase in Virginia creeper *(Parthenocissus quinquefolia).* Invasive shrubs substantially increased in the suppressed (stems <1.4 m tall) and intermediate (stems >1.4 m tall but <11 cm dbh) layers. Management at Cap Sauers Holding, while not having a conclusive positive effect on herbaceous species, has substantially reduced the density and cover of invasive and exotic shrubs and maintained tree canopy cover, all of which increased at the unmanaged site. The results of this study indicate that management, in the form of prescribed burns and removal of woody species, achieved some restoration goals at this site.

In hardwood subtropical forests of southern Florida, nonnative vines have been hypothesized ro be

detrimental, as many species form dense "vine blankets" that shroud the forest. To investigate the

effects of nonnative vines in post­ hurricane regeneration, we set up four large (two pairs of 30 X

60 m) study areas in each of three study sites. One of each pair was unmanaged and the other was

managed by removal of nonnative plants, predominantly vines. Within these areas, we sampled

vegetation in 5 X 5 m plots for stems 2 cm DBH (diameter at breast height) or greater and in 2 X

0.5 m plots for stems of all sizes. For five years, at annual censuses, we tagged and measured

stems of vines, trees, shrubs and herbs in these plots. For each 5 X 5 m plot, we estimated percent

coverage by individual vine species, using native and nonnative vines as classes. We investigated

the hypotheses that: (1) plot coverage, occurrence and recruitment of nonnative vines were greater

than that of native vines in unmanaged plots; (2) the management program was effective at reducing

cover by nonnative vines; and (3) reduction of cover by nonnative vines improved recruitment of

seedlings and saplings of native trees, shrubs, and herbs. In unmanaged plots, nonnative vines

recruited more seedlings and had a significantly higher plot-cover index, but not a higher

frequency of occurrence. Management significantly reduced cover by nonnative vines and had a

significant overall positive effect on recruitment of seedlings and saplings of native trees,

shrubs and herbs. Management also affected the seedling community (which included vines, trees,

shrubs, and herbs) in some unanticipated ways, favoring early successional species for a longer

period of time. The vine species with the greatest potential to "strangle" gaps were those that

rapidly formed dense cover, had shade tolerant seedling recruitment, and were animal-dispersed.

This suite of traits was more common in the nonnative vines than in the native vines. Our results

suggest that some vines may alter the spatiotemporal pattern of recruitment sites in a forest ecosystem following a natural disturbance by creating many very shady spots very quickly.

Acer platanoides is an exotic, invasive tree in eastern deciduous forests of North America where past research shows it to thrive in the forest interior and to suppress understory diversity. To test the efficacy of restoration strategies and to probe dynamics of this tree's seedling bank, trees and seedlings of Acer platanoides were removed in 1997 from a mixed maple forest carpeted by an even mix of exotic Acer platanoides and native Acer saccharum seedlings. The treatments were removal of trees (height > 1.5 m) and removal of small seedlings (height < 1.5 m), using a crossed design with a total of 80 permanent plots, all sampled before removals and two years later. After two years, removal of Acer platanoides trees had caused an increase in native Acer saccharum seedling densities over those in control areas and had caused a decrease of new Acer platanoides recruitment. Conversely, removal of Acer platanoides seedlings initiated far more new Acer platanoides than Acer saccharum seedlings. The Acer platanoides seedling bank was partially, but not fully, replenished two years after its removal. Although removal of canopy trees appears effective as a restoration tool, other exotic species (especially Lonicera japonica, Alliaria petiolata, and Robinia pseudoacacia) proliferated where tree removals opened the canopy. Restoring the pre-invasion com- munity will thus require future intervention.

Eight herbicide treatments were applied by low volume basal applications and compared to hand cutting for the removal of *Ailanthus altissima.* Manual cutting of *Ailanthus* stimulated resprouting and increased overall stand density. Chemical control not only removed existing trees but also prevented resprouting. When evaluated 2 years after treatment, optimal control of *Ailanthus* was achieved with a combination of Garlon 4 and Tordon K herbicides. Garlon 4 at 20% v/v alone Garlon 4 combined with Stalker, or

Stalker herbicide alone controlled *Ailanthus* better than hand cutting but were not as effective as treatments containing picloram. Removal of *Ailanthus* resulted in a shift in herbaceous species to native species of the region without reseeding with naturally occurring herbs. Manual control of *Ailanthus* should be avoided in order to prevent proliferation. Herbicide control of *Ailanthus* is the preferred

method of control because it successfully kills the trees and prevents resprouting. Because major *Ailanthus* infestations occur near roadways, access with a backpack sprayer should be achievable.

Restoration often includes control of invasive plants, but little is known about how native plant communities respond to this control. The biennial Alliaria petiolata (M. Bieb.) Cavara and Grande (garlic mustard) is one of the most prevalent invasive plants in forests of eastern North America. We investigated the effects of the herbicide Round-up (glyphosate) on Alliaria and the response of the forest floor plant community to the herbicide and the subsequent decline of Alliaria. In an old-growth Acer–Fagus stand and a second-growth Liriodendron-dominated stand in Hueston Woods State

Nature Preserve, Ohio, United States, we spot applied Round-up in November 2000 and 2001 in 25 1 · 1–m plots and maintained 25 control plots. Herbicide decreased Alliaria density in both stands and reduced the density of other species in leaf during treatment (mostly exotic winter annuals) in the old-growth stand. Treatment did not affect the initial density of the Alliaria cohort that germinated in

the spring of 2001, but decreased the 2002 cohort. Community differences were found in the old-growth stand after Alliaria reduction, specifically greater cover of spring ephemerals in the herbicide treatment. In the second-growth stand, herbicide treatment increased reproduction of the late-summer perennial, Phryma leptostachya. These results indicate that glyphosate reduces Alliaria without negatively impacting native species and that some native species respond positively to a single-year

reduction in this invasive biennial.

Effects of the non-indigenous shrub *Rhamnus frangula* L*.* (glossy buckthorn) on tree recruitment, herb cover, forest floor plant species richness, and *R. frangula* recruitment were tested in two southeastern New Hampshire *Pinus* forests using a randomized complete-block field experiment. The treatment,

applied in January of 2000, was the presence of well-established *R. frangula* populations with three levels: *R. frangula* absent prior to experiment(“uninvaded”), > 90% *R. frangula* cover (“*Rhamnus* present”), and removal of >90% *R. frangula* cover (“*Rhamnus* removed”). After 2 years of measurements, *Rhamnus* present had significantly lower first-year native tree seedling densitythan *Rhamnus* removed and uninvaded plots (0.11, 0.40, and 0.40 seedlings/m2respectively). First-year native tree seedling density in the *Rhamnus* removedand uninvaded treatments were similar. Neither percent herb cover nor plantspecies richness were significantly affected by the removal of *R. frangula* in thetwo years following treatment. We believe these results indicate that the presenceof dense *R. frangula* inhibits the establishment of tree seedlings. *Rhamnus* removed plots sampled one year after removal had five-fold greater first-year *R. frangula* seedling density than the other treatments. However, after two yearsfirst-year *R. frangula* seedling density was similarly low in all treatments (< 0.5

*R. frangula* seedlings/m2). Control efforts for *R. frangula* may need to focus on conspecific seedling emergence for at least two years following initial control.

The recruitment of native seedlings is often reduced in areas where the invasive Amur honeysuckle (Lonicera maackii) is abundant. To address this recruitment problem, we evaluated the effectiveness of L. maackii eradication methods and restoration efforts using seedlings of six native tree species planted within eradication and unmanipulated (control) plots. Two eradication methods using glyphosate herbicide were evaluated: cut and paint and stem injection with an EZ-Ject lance. Lonicera maackii

density and biomass as well as microenvironmental characteristics were measured to study their effects on seedling growth and survivorship. Mean biomass of Amur honeysuckle was 361 ± 69 kg/ha, and density was 21,380 ± 3,171 plants/ha. Both eradication treatments were effective in killing L. maackii (‡ 94%). The injection treatment was most effective on large L. maackii individuals (>1.5 cm diameter), was 43% faster to apply than cutting and painting and less fatiguing for the operator, decreased operator exposure to herbicide, and minimized impact to nontarget vegetation. Deer browse tree protectors were used on half of the seedlings, but did not affect survivorship or growth. After 3 years, survival of native seedlings was significantly less where L. maackii was left intact (32± 3%) compared with the eradication plots (p < 0.002). Seedling survival was significantly different between cut (51± 3%) and injected (45 ± 3%) plots. Species had different final percent survival and rates of mortality. Species survival differed greatly by species (in descending order): Fraxinus pennsylvanica >Quercus muehlenbergii ‡ Prunus serotina ‡ Juglans nigra > Cercis canadensis > Cornus florida. Survivorship and growth of native seedlings was affected by a severe first-year drought and by site location. One site

exhibited greater spring soil moisture, pH, percent open canopy, and had greater survivorship relative to the other site (55 ± 2 vs. 30 ± 2%). Overall, both L. maackii eradication methods were successful, but restorationists should be aware of the potential for differential survivorship of native seedlings depending on species identity and microenvironmental conditions.

In May 2005, 12 plots approximately 21 by 27 m each were established on the exterior bank of a dredge spoil area in Georgetown, SC. The tree cover was primarily Chinese tallowtree, but there were also live oak trees in each plot. Also in May 2005, Chinese tallowtrees (d.b.h. > 2.4 cm) in three randomly selected plots received a ‘hack and squirt’ application of imazapyr (50 percent v/v Habitat), tallowtrees in three plots received triclopyr (50 percent v/v Garlon 4) by ‘hack and squirt’ injection, and the tallowtrees in three plots received glyphosate (undiluted AquaNeet) by ‘hack and squirt’ injection.

Three plots were an untreated control. The d.b.h. and percent defoliation of all trees (d.b.h. > 2.4 cm) were tallied in July 2005 and May 2006. The imazapyr treatment had the highest percent (96 percent in May 2006) of tallowtrees in the highest defoliation class (75 to 100 percent defoliated). Triclopyr plots had 41.3 percent in the highest class in 2006. Glyphosate plots had 62 percent in the highest class in 2006. The live oak trees (4 to 84 cm d.b.h.) did not show any herbicide damage in any treatment. These results indicate that imazapyr can be used to eradicate Chinese tallowtree by ‘hack and squirt’ injection

without short-term (12 months) damage to dominant live oak trees.

Chinese privet is a nonnative shrub that has invaded mesic forests throughout the south- eastern United States during the past century. Foliar sprays of glyphosate and triclopyr were tested in three factorial experiments that included wide ranges of application rate, timing, and formulation to refine methods for controlling Chinese privet. For spring (April) and fall (October and December) applications, percentage control of privet cover averaged 93 to 100% and 49 to 70% for glyphosate and triclopyr treatments, respectively, whereas for summer (June and August) applications, control averaged 67 to 69% and 14 to 26%, respectively (study 1). However, privet control was not influenced by variation in herbicide rates of 1.7, 3.4, 5.0, or 6.7 kg aelha compared with each of the five application timings. No differences were found in August comparisons of liquid vs. dry glyphosate products or water-soluble vs. oil-soluble triclopyr products for each of the four rates (study 2). In a comparison of low rates of glyphosate applied in August with or without trenching of plot perimeters to isolate privet clumps (study 3), control increased from 12 to 65% as rate increased from 0 to 0.8 kg ae/ha, suggesting that rate responses may occur at lower values than those tested in studies 1 and 2. Isolation of privet clumps by trenching did not have a statistically detectable effect on privet susceptibility to glyphosate. Low rates of glyphosate (1.7 kg ae/ha or possibly lower) will provide effective control of privet when applied in the spring or fall.

Japanese stiltgrass is a nonnative invasive grass that occurs in a variety of habitats and is

widely distributed throughout the eastern United States. In natural areas such as forests, herbicide

options that selectively control Japanese stiltgrass while preserving native herbaceous and woody

vegetation may be desired. The efficacy of three selective postemergence herbicides (fenoxaprop-P,

imazapic, and sethoxydim) applied early season, midseason, or late season on monoculture understory

stands of Japanese stiltgrass in forests was examined in an experiment conducted at a site in North

Carolina and a site in Virginia from 2002 to 2004. The herbicides, averaged across application

timings, controlled Japanese stiltgrass at the end of the growing season 83 to 89% and seedhead

production 79 to 94% compared with nontreated plants. Seedling emergence was reduced in the

spring of 2004 by 89, 70, and 78% by fenoxaprop-P, imazapic, and sethoxydim, respectively, applied

in 2003. In another experiment at the North Carolina site in 2002 and 2003, fenoxaprop-P or sethoxydim

applied twice (4 wk apart) at half-registered rates controlled Japanese stiltgrass. This study

demonstrates that land managers have multiple POST herbicide and application timing, rate, and

frequency options for Japanese stiltgrass control.

*Lonicera maackii* (Rupr.) Herder (Caprifoliaceae), Amur honeysuckle, is an exotic and

invasive species in the United States that has quickly overtaken disturbed habitats in the

eastern and midwestern United States, as well as in Ontario, Canada. A reduction of light

due to its dense canopy, extended growing season compared to native species, and production

of numerous basal sprouts allow *L. maackii* to outcompete its native counterparts.

Eradication of this species can be difficult and time-consuming. This research was

undertaken to identify how *L. maackii* influences species diversity and species re-establishment

and to determine an efficient and effective eradication method. A study was

designed to determine if *L. maackii* inhibited species diversity, if the removal of *L.*

*maackii* would increase species diversity by reopening the canopy, and if mechanical

removal or mechanical removal coupled with glyphosate treatment could be used effectively

for its long-term eradication. It was found that *L. maackii* removal increased species

diversity, and mechanical removal coupled with the application of glyphosate is an

effective and relatively simple method for eradicating *L. maackii,* while mechanical stem

removal alone simply delayed its growth.

One of the proximate results of forest fragmentation, anda cause of continued microenvironmental change and exacerbation of ecological problems, is increased invasions by weedy plant species. One such example is Alliaria petiolata (Brassicaceae), a serious pest threatening much of eastern North America. Alliaria petiolata impedes mitigation of fragmentation and restoration efforts because it tends to outcompete and possibly extirpate much of the native understory species on localized scales. As part of a strategy to address the problems of fragmented habitats, an experiment was conducted to determine whether Sanguinaria canadensis (Papaveraceae) could outcompete A. petiolata. Using an additive design, I transplanted S. canadensis at densities of 0, 1, 2, 3, 5, 7, 9, 11, 15, and 20 ramets/m2 in 1997 and allowed them to interact with initial A. petiolata densities of 128 seedlings and 31 rosettes/m2. As of 2000, multivariate analyses of variance with repeated measures and simple analyses

of variance indicated that initial S. canadensis densities of as little as 5 ramets/m2 suppressed A. petiolata. Initial S. canadensis densities of 9 and 11 ramets/m2 resulted in the lowest numbers of late-spring seedlings, numbers and sizes of year 1 and 2 rosettes, numbers and gross areas of stem leaves, numbers of flowering individuals, number of flowers, number of fruits (siliques), and height at flowering.

While it remains to be tested whether this will continue and if the reestablishment of S. canadensis will help reassemble forest ecosystems, the experiments indicated that transplanting S. canadensis was effective at mitigating the spread of A. petiolata.

In the Northeast, land managers are combating the deleterious effects that

invasive plants have on other species and natural communities with attempts to remove

them or substantially reduce their density. Control methods vary depending on the target

species’ growth form, the extent of the invasion, and other species and resources at the

site. Mechanical treatment, prescribed fire, hand-pulling, and application of herbicides,

alone or in combination, have all been used to attempt control.

Woody invasive plants are often difficult to eliminate due to their ability to sprout

from stems, stumps, and roots. Successful control of these species requires

understanding temporal variations in their below-ground resources. Total non-structural

carbohydrate (TNC) reserves in the roots of woody species support growth following

disturbance and generally follow an annual cycle of depletion and replenishment. This

study evaluates the effectiveness of treatments when applied during periods of decreased

TNC reserves.

Treatments were applied to seven invasive shrubs (*Cornus racemosa*, *Rhamnus*

*cathartica*, *Rosa multiflora*, *Berberis thunbergii*, *Lonicera morrowii*, *Smilax rotundifolia*,

and *Cytisus scoparius*) at three different sites in Massachusetts and New York.

Treatments included cutting and/or burning, applied singly or in combination, in either

the dormant or growing seasons.

TNC were depleted following all treatments. Dormant-season-treated plants,

whether cut or burned, sprouted and replenished their reserves within the following

growing season. For growing-season-treated plants TNC remained depleted longer, with

a greater effect on plants that received more treatments. For most species studied, TNC

recovered to pre-treatment levels by the end of one growing season without treatment.

Sprout growth was influenced by the extent of carbohydrate reserves present

before treatment. Biomass and heights of sprouts were significantly lower in growingseason-

treated plants than those treated in the dormant season, even when data were

adjusted for different lengths of recovery time.

All treatments reduced the cover of the target invasive shrub. As the plants

sprouted, they regained some of their initial cover and are expected to dominate without

further treatment. Timing treatments to the cycle of TNC can increase the effectiveness

of control methods, although repeated treatments may be necessary for several years.

The introduced *Sapium sebiferum* (Chinese tallow tree) has spread across the southeastern

United States and is rapidly replacing native prairies with monospecific *Sapium* forests. Most attempts

to control *Sapium* are only temporarily effective because of its large seed bank and ability to resprout

from cut stumps. We performed a two-year field experiment to evaluate the effectiveness of using large

shredding mowers to mulch live *Sapium* trees and restore *Sapium*-invaded prairies. We predicted that

*Sapium* mulch would damp diurnal soil temperature fluctuations and suppress *Sapium* seed germination

because *Sapium* seed germination is highly dependent upon those fluctuations. We manipulated mulch

depths and types (0, 10, and 15 cm deep *Sapium* mulch and hardwood and straw mulch) in the field and

measured soil temperatures beneath them. Diurnal soil temperature fluctuations were damped at depths as little as 5 cm, and *Sapium* mulch significantly reduced *Sapium* seedling emergence. Deep layers of *Sapium* mulch (15 cm) reduced seedling survival and native vegetation cover as well. Comparisons among *Sapium* mulch and alternative mulch materials revealed no allelopathic effects of *Sapium* mulch on *Sapium* seedling emergence, survival, or growth. Vigorous regrowth of native vegetation through 5 cm of *Sapium* mulch was evident by the end of the first growing season. With no trees or stumps remaining on the site, a mowing regime can be implemented immediately regardless of the pre-mulching density of the trees. A heavy closed-canopy *Sapium* forest might result in mulch depths that slow the return of native vegetation and delay accumulation of adequate fuel loads to support prescribed burning.

The Carolinian Life Zone in southwestern Ontario, Canada is valued because it represents an almost

disjunct ecosystem (i.e., one that is typical of the mid-Atlantic United States, rather than the rest of Canada or the nearby states in the United States). The landscape of the Carolinian Life Zone has undergone dramatic transformation, especially in recent decades as agriculture, urbanization, and recreation have intensified. One of the most apparent changes is the invasion of exotic plant species

that exacerbates the need for mass restoration efforts. Within the Carolinian Life Zone, Rondeau Provincial Park has experienced an influx of nonindigenous, invasive species in recent years. Tree-of-heaven (Ailanthus altissima) is one example. The infestation is still relatively localized to (mainly) the park, slowly spreading, and manageable as long as something is done immediately. We examined the

effects of hand-pulling and mulching, cut stump and glyphosate application, cut stump alone, and the EZJect Capsule Injection System (using glyphosate) on the management of A. altissima within the park. Cut stump and glyphosate treatment was most effective and efficient in its control of young A. altissima shoots because it limits disturbance and has acceptable capital and operating costs.

Hand-pulling and mulching was the second choice, mainly because of the risk of additional disturbance that increased shoot densities 1 year after treatment. Cut stump alone was not effective, worsened the infestation, and is not recommended for this species. The EZJect system was effective at managing mature, seed-producing shoots, although the somewhat higher capital costs mean that the system

probably should be purchased for management of several invasive tree species to make it more cost-effective.

The exotic, invasive shrub European buckthorn (*Rhamnus cathartica*) is a major threat to

natural areas in North America. While many publications describe buckthorn eradication methods, few

compare the efficacy of different methods, and none are comprehensive. In this study, we tested the efficacy of 15 combinations of five commonly used herbicides and two physical interventions (cutting and girdling) on the regrowth of 317 buckthorn shrubs in northeastern Illinois. Treatments were performed randomly on plants with primary stems ≥3 cm, and effects on treated stems, untreated stems of multistemmed shrubs, and all stems were evaluated six months later. We found neither physical nor chemical methods alone to be optimal, but rather a combination of cutting or girdling with certain herbicides was best. We found Roundup Pro (Roundup), Stalker, and Tordon RTU (Tordon) to be more effective than either Garlon 4 or Brushmaster. Importantly, our data suggests that girdling or cutting of a single stem of multiple-stemmed buckthorn before using Roundup, Stalker, or Tordon usually results in the death of the entire shrub, thereby potentially saving a great deal of time and money. All herbicides were rated equally safe for human applicators by manufacturers, and required approximately equal time and effort to apply. Though Roundup was the most expensive of the three most effective herbicides, manufacturers’ labels indicated that it is potentially safest for use in dry natural areas. However, none of the herbicides evaluated are appropriate for use in water, wetland areas, or in areas below mean high water marks.

Invasive plants can have substantial negative impacts on native flora and fauna.

As a result, ecological restoration often involves removal of invasive species. We examined the

effects of the removal of Hedera helix (English ivy) on regeneration of native vegetation in the

Piedmont of Georgia. Ivy was removed by hand or by herbicide from five 5 m 3 5 m plots for

each treatment and half of each plot was seeded with native seeds. We then counted the

number of seedlings present in each plot bimonthly over a 5-mo period. Ivy removal by

pulling resulted in the greatest density and diversity of seedlings. Furthermore, these plots

exhibited increased seedling density and diversity due to seed addition. Spraying was effective

in removal of the ivy but significantly lowered seedling density and diversity and hindered any

seed addition efforts. Control plots in which ivy was not removed had no seedlings germinate.

Our results suggest that the method of exotic plant removal and the addition of native seed

can have profound effects on the regeneration of native vegetation and should be a major

consideration for future exotic plant removal projects.

Three herbicides were tested using four stem application techniques for control of both single trunks and clumps of tree-of-heaven [*Ailanthus altissima* (Miller) Swingle]. Imazapyr, triclopyr, and glyphosate were applied using cut stump, stump injection, and stem injection techniques. Imazapyr and triclopyr were also applied as a basal bark treatment. Treatments were compared against manual cutting and untreated controls. Untreated cut stems did not provide control of tree-of-heaven. Cut stump treatment with imazapyr and triclopyr (20% v/v in oil) resulted in more than 90% reduction in both vigor ratings and resprouting of single stems and clumps. In contrast, stump injection applications were ineffective

with all herbicides. For stem injection treatments, undiluted imazapyr gave the best results (>95% canopy reduction), but glyphosate also provided excellent control (92% canopy reduction). Removing stems 4, 8, or 12 months after treatment did not impact the level of control with imazapic. Imazapic at half the standard rate also gave good control of multistemmed clumps. Basal bark treatments with imazapyr or triclopyr (20% v/v in oil) gave equally good results, providing nearly complete control. Triclopyr is less selective than imazapyr and thus offers a better option when desirable vegetation

surrounds the stems. These results provide several effective options for the control of tree-of-heaven in both urban and riparian sites.

Tree-of-heaven (*Ailanthus altissima* [Mill.] Swingle) is a non-native invasive plant

that is spreading throughout much of the U.S. In this study, efficacy of the herbicides triclopyr

and imazapyr was tested using injection and basal bark treatment methods. No treatment was

100 percent effective. Only triclopyr injection was significantly different from other treatments,

providing the least control. Both injection and basal spray treatments with imazapyr affected

untreated neighbor stems, probably through root connections and/or root leaking.

Field studies were conducted from 2000 to 2002 to determine whether glyphosate applied during periods of low temperature (, 10 C) provides effective control of garlic mustard without injury to nontarget native herbs. A 1% glyphosate solution was applied on three dates between November and March in 2000 to 2001 and 2001 to 2002, when average daily temperatures ranged from 24.2 to 7 C. Glyphosate reduced the population density of prereproductive springtime garlic mustard infestations, regardless of application timing. During the primary bolting period (April to June), mortality of garlic mustard rosettes in sprayed plots was 87 to 94%, whereas mortality in nontreated plots was 12% in the

first year and 41% in the second. Nontarget native herbaceous species were not injured by the cold-weather herbicide applications and exhibited higher springtime densities than in the nontreated plots. By targeting garlic mustard rosettes during the part of the year when most other plant species are dormant, managers can selectively control garlic mustard without damage to native herbs and, thereby, increase forest restoration success.

Fire has often been shown to promote invasion by non-native plant species, but few studies have examined the process in temperate-zone deciduous forests. To examine the potential of prescribed fire to facilitate invasions in the Central Hardwoods ecosystem, we experimentally burned small plots and simulated aspects of fire at a forested site in southeastern Ohio, USA. Treatments included high and low burn intensity, lime addition, and litter removal to test hypotheses of population limitation by fire intensity, fire-caused nutrient release, and removal of leaf litter, respectively. Treatments were arranged in a randomized block design in two landscape positions (dry upland, moist lowland) and two canopy

conditions (gap, no gap). The experimental sites were not significantly different from randomly chosen forest sites in any of 12 environmental variables. Seeds of two problematic non-native species (Microstegium vimineum and Rosa multiflora) were sown into plots following treatment to

test the possibility of seed limitation. We recorded germination and height growth at three dates 1, 4, and 14 months following burning. Germination was promoted by litter removal and high- and low-intensity fire treatments in M. vimineum, and by high-intensity fire in R. multiflora. Seedling growth of both species was greatest following high-intensity fire under canopy gaps. Germination in the second year showed treatment effects similar to the first year indicating persistence of fire effects. Both species showed stronger recruitment in valleys and in canopy gaps, reflecting an interaction of fire and landscape position. We infer that prescribed burning and canopy-opening management practices have the potential to facilitate invasion of the study area by creating conditions promoting establishment and growth of at least two non-native species. The absence of these species in previous studies appears to be due to a lack of propagules rather than the unsuitability of forest sites for germination or growth.

The impact of invasive plant species on native plants is largely assumed to be negative, but supporting evidence is sparse. A common control method of non-native plants is herbicide application, but little is known about the effects of these chemicals on non-target plant populations, or differences in these

populations before and after control measures are taken. We examined the response of the forest floor plant community to herbicide-mediated reduction of Alliaria petiolata in an old-growth and a second-growth forest stand in Hueston Woods State Park, Preble and Butler Counties, OH. Fifty 1 3 1 m plots were established in each stand, and 25 plots per stand were treated with Round-up each November 2000–2004, which reduced cover of adult Alliaria petiolata but did not suppress recruitment. Percent cover of herbs and woody plants 0.85 m tall was assessed in May and June, 2000–2005. To determine compositional differences between sprayed and unsprayed plots in each stand we ordinated plots based on peak cover of each species using nonmetric multidimensional scaling, tested for differences in community composition with a multiple response permutation procedure, and compared total cover of growth forms with Kruskal-Wallis tests. Five years of Alliaria petiolata control only modestly affected the forest floor vegetation. Neither species richness nor diversity differed significantly between sprayed and unsprayed treatments in any year of the study. Community composition differed each year between stands, but treatments differed significantly only in 2002 (in the second-growth stand), and marginally in 2004 and 2005 (in the old-growth stand). Treatment affected cover of some growth forms during the study, but only in some years: in the second-growth stand sprayed plots had significantly greater cover of spring perennials and graminoids in 2003 and marginally lower cover of annuals in 2005; in the old-growth stand sprayed plots had marginally more spring perennials in 2005. Wintergreen species, particularly the exotic annual Stellaria media, had lower cover in sprayed plots in the old-growth stand in 2005. We attribute the compositional differences we observed in the forest floor community to competitive impacts of Alliaria petiolata, but suggest that effects were modest due to the

persistence of rosettes in the sprayed plots.

Funding for ecological restoration efforts sometimes ends prematurely and exacerbates problems that originally were the rationale for the project. In our test of methods to manage exotic species, we mimicked this real world situation and compared management after one year with no ecological restoration with exotic species management continued yearly for five years and followed by ecological restoration (transplanting adult plants of four native species) in year five. Our study site in Ontario, Canada consisted of eight fragmented woodlots dominated by sugar maple (*Acer saccharum*) and

American beech (*Fagus grandifolia*) that supported dense populations of the exotic species garlic mustard (*Alliaria petiolata*), dame’s rocket (*Hesperis matronalis*), and celandine (*Chelidonium majus*). In 1998, we quantified the impact and duration of one-time use of glyphosate, hand-pulling, inflorescence clipping, and mulch on the seedbank and shoots of three exotic species, native herbaceous species, and (for shoots, non-adult) native species of shrubs and trees. By 2006, above- and belowground densities of exotic species significantly increased and native species significantly decreased with one-time treatments of glyphosate and hand-pulling (ANOVA). The exotic species recovered quickly from one-time application of glyphosate, and hand-pulling disturbed the soil and increased relative emergence of exotic species from seed. As expected, inflorescence clipping and mulching were ineffective as one-time treatments but did not worsen the exotic species problem or decrease native species’ densities. The repeated management plus ecological restoration was more successful in all cases, with similar results by 2006, while one-time application of glyphosate and hand-pulling worsened problems. We caution that initiating exotic species management can be risky if funding is not secure enough to support longer term efforts.

Asian bush honeysuckles (*Lonicera maackii* [Rupr.] Maxim*, L. morrowii* Gray,

and *L. tartarica* L.) have proved extremely invasive in eastern hardwood forests. In addition to

displacing native forest ground flora and associated fauna, these understory shrubs pose a threat

to forest regeneration. Effective control strategies need to be developed to incorporate into routine

silvicultural prescriptions for affected stands. This study tested ten control treatments in a fully

stocked, mature central hardwood forest in central Indiana for efficacy and cost. Treatments

included: low volume foliar applications of 4 percent triclopyr (Garlon 3A), 3 percent triclopyr

(Garlon 3A) + 1/8 percent imazapyr (Arsenal), and 5 percent glyphosate (Glypro Plus), each

applied in both early spring and late fall; full basal bark application of 20 percent triclopyr (Garlon

4) in AX-IT basal oil; streamline basal bark application of 20 percent triclopyr (Garlon 4) in

AX-IT basal oil; and cut stump treatments with either picloram + 2,4-D (Pathway) or 20 percent

triclopyr (Garlon 4) in AX-IT. Treatment timings were chosen to test effectiveness of herbicide

control at a time of year when native vegetation would be least vulnerable to off target damage.

Efficacy was tested across four shrub size classes. All but one of the low volume foliar applications

were equally effective, controlling 70 to 94 percent of bush honeysuckle shrubs between 2 and

8 feet tall. Triclopyr applied in the fall (Nov. 2) provided only 2 percent control. Both basal bark

applications provided inconsistent and poor control. Both cut stump treatments were equally

effective on the larger two size classes of shrubs, but efficacy declined on smaller shrubs due to

operational difficulties of locating all shrubs in a treatment unit. Depending on bush honeysuckle

stand stocking and size distribution, treatment costs ranged from $83 per acre to $383 per acre.

Melaleuca quinquenervia (melaleuca) is a native of Australia but has become an invasive plant in Florida, USA. We conducted a long-term demographic study of melaleuca in three sections (central, transitional, and peripheral) of monoculture stands located in Florida, and quantified absolute density, diameter at breast height and basal area of trees by section at three sites. Additionally, we monitored the impacts of natural enemy (insects and fungi) on melaleuca populations which became apparent after 2001. Both

absolute density and basal area, from before (1997–2001) and after noticeable natural-enemy

impact (2002–2005), were compared. Prior to the natural-enemy impact, absolute density of melaleuca

trees declined primarily due to self-thinning and associated losses of small trees, but diameter

at breast height increased, as did the basal area. Later during the period when natural enemies

prevailed, absolute density declined at a significantly greater rate across all sections but was

highest at the periphery. The decrease in mean absolute density and basal area/ha of melaleuca

during the natural-enemy impacted period coincided with the increased incidence of the populations

of plant-feeding insects and fungi. The mean diameter at breast height continued to increase in

all sections of the stands throughout the study period. An increasing trend in basal area prior to

natural-enemy impact was reversed after increase in natural-enemy abundance and noticeable impact

in all three sections of the stands. These findings lend support to a growing body of

literature that implicates natural enemies as increasingly important density-independent regulators

of M. quinquenervia populations.

*Lonicera maackii* is thought to inhibit growth of herbaceous vegetation and woody seedlings. To determine the extent of this inhibition, in April 1996, *Lonicera* was removed from ten 30 x 30 m areas within Sugarcreek Reserve. Paired 20 x 20 m plots were established, one of each pair in the removal area and one adjacent to that area. These plots varied in history and topographic position. Twenty 1-m2 small plots were established in each large plot and sampled for herbaceous vegetation (by species and cover class) and woody seedlings (species and number). Sampling was done summer 1996 and spring 1997. Nine of the paired plots were resampled summer 2003 and spring 2004. Few differences were found between control and treated plots the first year after *Lonicera* removal. Significant differences between control and treated plots were found seven to eight years after treatment in both spring

and summer: treated plots had higher species richness, higher cover, and higher tree seedling densities. These results indicate that *Lonicera* removal can enhance ground layer species diversity and cover after a lag period of at least one year.

Alliaria petiolata is an invasive herb impacting forests throughout the eastern United States. We studied the impacts of glyphosate, bare ground, and summer precipitation on A. petiolata cover and density in two forest stands of different ages at Hueston Woods State Park, Preble and Butler Cos., OH. Fifty 1 x 1 m plots were established in each stand and 25 plots per stand were treated with glyphosate each November 2000–2004. Cover and density of A. petiolata rosettes and adults were measured multiple times each year from 2000 through 2005. Percent bare ground was estimated using a point frame in May 2003. Adult cover in May was significantly lower in sprayed vs. unsprayed plots in three of five years; in the other two years adult cover was very low in both sprayed and unsprayed plots. However, spray treatment did not significantly affect May rosette cover across years. ANCOVA revealed that May 2003 bare ground positively associated with density of A. petiolata rosettes in May 2003, but bare ground was not significantly associated with October 2003 rosette density. Variation across years in both October rosette density and May adult density of A. petiolata was significantly associated with precipitation the previous June; wetter Junes were followed by higher densities. Despite sustained suppression of adult A. petiolata in plots sprayed with glyphosate, new rosettes appeared each spring at densities comparable to unsprayed plots, which we attribute to seed dispersal from outside of the plots. Bare ground had minimal effect on A. petiolata populations. Evidence that A. petiolata density was

positively affected by June precipitation suggests that management efforts should be focused in years of wet summers.

Urban forests represent patches of biodiversity within otherwise degraded landscapes, yet these forests are threatened by invasion by exotic plant species. We investigated the response of a forest understory to removal of four common exotic species: Elaeagnus umbellata Thunb., Lonicera japonica Thunb., Ligustrum sinense, Laur., and Microstegium vimineum (Trin.) A. Camus in a forest within the city of Raleigh, NC, USA. In the summer of 2001, we initiated a removal experiment with three treatments. In the ‘‘repeated removal’’ treatment, all understory vegetation was initially removed by clipping and new exotic seedlings were repeatedly removed every 2 weeks throughout the study period. The ‘‘initial removal’’ treatment involved a one-time understory vegetation removal with no further weeding. Control plots had no intervention throughout the study period. We conducted vegetation surveys of the plots prior to treatment initiation and in April and August of 2002 and 2003. With a non-metric multidimensional scaling (NMS) ordination, we were able to discern differences in species composition between the repeated removal treatment and the other two treatments. However, using repeated measures ANOVA, we found no significant differences in native species richness, cover, and abundance among treatments during most sampling periods. We also used a seedbank study to determine that while some early successional species were present, no native shrubs and few native trees emerged from the seedbank. These results suggest that (1) repeated removal is required to decrease the importance of exotic species, especially if the site is in close proximity to a source of exotic propagules; and (2) subsequent to exotic removal, native species may not recover sufficiently without supplemental plantings. Therefore, restoration plans for urban forests should incorporate both long-term monitoring and native plant re-introduction to achieve a diverse native community.

Invasive plants can exert their effects on native plants through both above- and

belowground mechanisms. In a fully factorial field study, we examined the effects of activated

carbon addition and removal of aboveground biomass (i.e., cutting) on the survival, growth

and reproduction of transplanted Impatiens capensis seedlings in habitats dominated by either

Lonicera maackii (honeysuckle) or Alliaria petiolata (garlic mustard). Activated carbon can

adsorb organic molecules, including potential allelochemicals. Cutting of A. petiolata

increased survival and fruit production of I. capensis, while cutting of L. maackii increased

survival and tended to increase fruit production. Carbon application tended to increase

survival of I. capensis in A. petiolata-dominated plots, but had no effect in L. maackii-dominated

plots. The effects of carbon application on growth and fruit production of I. capensis

depended upon the cutting treatment in A. petiolata – dominated plots. In plots where A.

petiolata was not cut, carbon application increased height and fruit production. In plots where

A. petiolata was cut, carbon application decreased height and tended to decrease fruit

production. Impatiens capensis tended to survive longer when in competition with A. petiolata

than with L. maackii. While carbon application may benefit native plant growth in the

presence of A. petiolata, the addition of activated carbon after removal of aboveground

biomass, a source of both allelochemicals and light competition, may have little benefit as an

understory plant restoration tool.

A host-specific Asian weevil, Rhinoncomimus latipes Korotyaev, was approved in 2004 for release in North America for control of mile-a-minute weed, Persicaria perfoliata (L.) H. Gross (formerly Polygonum perfoliatum L.), an invasive annual vine from Asia. The impact of R. latipes feeding on P. perfoliata was studied in field cages over a 2-year period. In 2006, 20 weevils introduced into cages

with single plants in May (when weevils first emerge from overwintering) suppressed seed production for about 9 weeks, while weevils introduced in June (when the first summer generation of adults emerge) did not affect seed phenology. Plants in all cages produced substantial numbers of seeds late in the year, but the average seed (achene) weight was reduced for plants with 20 weevils per plant introduced in May. In 2007, plants grown with some competition from other plants within field cages showed substantial mortality, with 63% of plants with 10 or 20 weevils and 75% of plants with 40 weevils per plant dead by mid-August, compared with 12.5% of control plants. Reproduction was delayed by more than a month in surviving plants with 10 or 20 weevils, and by more than 2 months in the few survivors with 40 weevils. Surviving plants with 40 weevils per plant showed loss of apical dominance, which can allow plants to compensate for herbivore damage, but in the case of a light-adapted vine like P. perfoliata may prevent the plants from achieving needed sun exposure. These results suggest that R. latipes feeding on P. perfoliata has the potential to impact plant growth and reproduction, and can put affected plants at a substantial competitive disadvantage.

Japanese stiltgrass is a nonnative invasive grass occupying a range of habitats in the eastern United States. Conventional management recommendations include hand-removal, mowing, or a nonselective herbicide application in autumn prior to flowering. However, no study has directly compared the ecological impacts of long-term management strategies on Japanese stiltgrass populations or recruitment and establishment of native flora. An experiment was initiated in 2002 and continued for three growing seasons in mixed pine-hardwood forests in central North Carolina. Conventional treatments included hand-removal, mowing, or an application of glyphosate (1.1 kg ai/ha) once in autumn, and selective removal by hand or fenoxaprop-P (0.19 kg ai/ha) season-long as needed. All treatments were compared to nontreated plots. Percent vegetation cover by species was recorded twice

annually. Data were aggregated into five classes; Japanese stiltgrass, other exotic plants, native forbs, native monocots, and native woody plants. The soil seed bank of all species was estimated annually by extracting soil cores and documenting seedling emergence. All Japanese stiltgrass management treatments significantly reduced Japanese stiltgrass cover and seed bank over time compared to no management. However, recruitment and reestablishment of native plants and overall species richness were greater with selective Japanese stiltgrass management treatments including both hand-removal and fenoxaprop-P. Relative cover of other exotic plants decreased 2% to 49% after 3 yr with all Japanese stiltgrass management treatments except season-long hand-removal, which increased relative cover of other exotic plants 51%.

The numbers of invasive plants are increasing in forests of the Midwestern United States. These invasions are causing economic and ecological problems. Buckthorn is a nonnative invasive shrub, which grows rapidly and shades out surrounding native plants. It is important to better understand why buckthorn is invasive and methods of prevention and control. There are many different options to control buckthorn. I chose two mechanical methods that removed the above ground portion of the plant (cut and cut plus girdle) in order to see how buckthorn affects the surrounding plant community. Using transect lines, the surrounding plant community was monitored for four months after one year of treatment. At the end of the study, the regrowth of buckthorn was assessed. It was found that species richness did not differ between the treated plots and the control plots. However the cut plus girdle stumps contained on average 40%-50% fewer new buckthorn sprouts than just the cut stumps, suggesting that cutting and girdling is more effective than cutting along.

Tree-of-heaven (*Ailanthus altissima* Miller [Swingle]) can be managed easily with herbicide injection. However, the potential herbicide translocation to neighboring trees must be evaluated before widespread recommendations for herbicide injections. We assessed the nontarget translocation of imazapyr (Arsenal), an herbicide commonly used to manage woody vegetation in forests, from injected tree-of-heaven to neighboring noninjected stems. Targeted imazapyr injections not only killed all injected tree-of-heaven, but also killed 17.5% of neighboring (within 3 m) noninjected tree-of-heaven and eight other tree species 62 weeks after treatment. Nontarget mortality from herbicide translocation decreased as the distance from injected tree-of-heaven increased (up to 3 m) and as stem diameter

of noninjected plants increased. The plausible modes of inter- and intraspecific herbicide translocation include root grafts, mutually shared mycorrhizal fungi, root exudation and absorption, and/or leaf senescence. Because tree-of-heaven is clonal, patch size and vegetation heterogeneity will be an important determinant of herbicide injection protocols. In forest environments with many small patches (i.e., high edge to interior ratio) or mixed species stands, nontarget hardwoods are at an increased risk of mortality. In isolated large patches (with lower edge to interior ratio) or dense monospecific clones, injection risk to nontarget species will be relatively low.

Japanese stiltgrass (*Microstegium vimineum*) is an exotic invasive species that can dominate forest understories and suppress native herbaceous and woody species. This study had two objectives: 1) to assess directed spray herbicides for controlling *M. vimineum*; and 2) to collect a set of factors that affect management of *M. vimineum* on the diverse properties of the Connors Hollow, WV, watershed. At 3 weeks following glyphosate and sethoxydim treatments, only glyphosate treatments showed significant differences in cover and mean percent change in height growth over the controls and other herbicide treatments. No significant differences in species richness were detected among herbicide treatments, although the three of four glyphosate treatments ranked lowest in richness. In discussions related to controlling *M. vimineum*, landowners helped to identify 12 major factors and 44 subcategories and issues affecting management of the invasive grass. End-of-season measurements and continued discussion of causal factors are slated for early in the fall of 2007.

Glossy buckthorn (*Frangula alnus*) is an exotic invasive shrub within many Midwestern wetlands and adjacent ecotones, including those found in several National Wildlife Refuges. Where glossy buckthorn becomes established, it can form a dense homogenous monoculture, outcompete native shrubs, and alter other ecosystem processes. Active management of glossy buckthorn is critical to minimize the spread of this species, and to restore or rehabilitate those areas presently impacted. We tested the efficacy of herbiciding and scorching on glossy buckthorn survival. Treatments were implemented

in concert with management efforts currently practiced at Seney National Wildlife Refuge in Upper Michigan. One year after applying 20% glyphosate to cut buckthorn stumps, we found no difference in resprout density between this concentration of herbicide applied by sponge to stumps, scorching stumps with a propane torch, or untreated controls (*p* > 0.05). Additional low-volume spraying of 5% glyphosate to resprouts the following year significantly (*p* < 0.001) reduced resprout density as compared to scorching and controls, with no difference between scorch treatments and the controls.

Low-volume herbicide spraying reduced seedlings by 96% and 91% one and two years following treatment, with no difference in seedling density between scorching treatments and controls. The most effective management option for reducing glossy buckthorn appears to be repetitive herbicide application, possibly for more than two years.

Management of invasive species often targets a particular life stage in structured

populations. Evaluating the success of management requires measuring the survivorship and

reproductive success of the targeted stage class, as well as assessing the possibility for

increased fitness in the non-targeted stage class due to a release from density dependence.

Management of the invasive biennial, Alliaria petiolata (garlic mustard) focuses on removing

adults by pulling or clipping and is applied early or late in the reproductive season. We

evaluated the effectiveness of different management types (unmanaged, clipped, pulled) and

timing (early or late) on survival and fitness of targeted adult plants and non-targeted, cooccurring

juveniles. Viable seeds were produced by adults that were unmanaged, pulled early

in the season and clipped at midheight early in the season. Unmanaged and pulled adults

produced significantly more seeds than clipped plants; unmanaged plants produced seeds

that were significantly heavier than seeds from clipped or pulled plants. Germination was

lower for seeds from pulled plants than for seeds from unmanaged or clipped plants. The

clipping treatment was most successful at reducing fecundity, but also resulted in the highest

survivorship of co-occurring juveniles. Our study highlights the necessity of examining fitness

of plants in the non-targeted life stage in order to fully evaluate the effectiveness of different

management techniques. These results should be applicable to management of other stage structured

invasive species.

*Lygodium microphyllum* (Cav.) R. Br. is a non-native invasive fern that has become a serious

problem in many habitats in southern Florida. The effectiveness of fire and/or triclopyr ester in killing

*L. microphyllum*, the time and amount of herbicide required for inspections and re-applications, and

the effects of these treatments on a southern Florida pine flatwoods community were examined. These

treatments were: (1) herbicide application with bimonthly inspection and re-application if necessary, (2)

herbicide application with biannual inspection/re-application, (3) prescribed fire to reduce *L. microphyllum* biomass followed by biannual inspection and herbicide application, and (4) untreated controls. All fireand/or herbicide treatments killed standing *L. microphyllum*, and the prescribed fire reduced by aboutone-half the amount of subsequent herbicide, but not the time, required to kill regrowth. No treatmentprevented *L. microphyllum* regrowth, and every treatment had at least one new frond at the end of thethree-year study. Fire and/or herbicide treatments did not permanently decrease native species cover,richness, evenness, or diversity (Shannon’s *H’*), and native species cover increased following biannualherbicide and fire/biannual herbicide treatments. Two-month inspection/retreatment intervals were notmore effective than six-month intervals. *Lygodium microphyllum* can return to former amounts of biomassand cover within a few years of burning. Waiting too long to inspect and retreat negates the benefits ofusing fire to reduce *L. microphyllum* biomass.

Amur honeysuckle (Lonicera maackii (Rupr.) Herder), a large deciduous shrub from China, has invaded many forests in eastern/central United States. The species was removed by cutting and herbicide application from a recently hydrologically restored section of a bottomland hardwood forest in central Ohio, and the response of understory plants, especially herbaceous species, was measured. Plots were established in uncleared and cleared sections, and percent cover of each herbaceous understory species was estimated monthly. One season after several years of Lonicera removal efforts, no significant association was discovered between percentage of Lonicera cover and total understory species abundance. There was, however, a direct correlation between elevation and honeysuckle abundance; L. maackii abundance was negatively associated with low elevations, likely due to hydrologic factors. Plant species diversity (H) and richness (s) increased with elevation but were not significantly different

on plots with honeysuckle removal (H ¼ 0.86 ± 0.08 vs. 0.78 ± 0.09 and s ¼ 4.4 ± 0.19 vs. 4.2 ± 0.2 species/m2, respectively) despite the fact that understory light levels measured by densiometer were significantly higher (*a* ¼ 0.003) in cleared versus uncleared sections. Native and invasive species were found in similar proportions in the two sections, and significant sprouting and regrowth of L. maackii were observed throughout the cleared section. Although the removal of L. maackii altered the characteristics of the plant species assemblage, the value of this management remains questionable in the years immediately following treatment.

Management methods for invasive species vary in their restoration success in the presence or absence of herbivores. We investigated the performance of understory plants after management of the invasive shrub Amur honeysuckle using two herbicide-based methods (cut/paint and basal application) in fenced and unfenced plots. The cut/paint method resulted in the removal of above-ground stems, while the basal application method resulted in the dead stems remaining in place. Light level in the cut/paint treatment was higher than in the basal application treatment, which was higher than in the control (no management) treatment. Across fencing treatments, fruit production, height, and subsequent recruitment of transplanted jewelweed were greater in the cut/paint treatment. Across management treatments, jewelweed plants were taller in the fenced treatment. Native species richness was generally

higher in the cut/paint and basal application treatments than in the control treatment. There were more jewelweed recruits, more jewelweed fruits, and greater native species richness in the cut/paint treatment than in the basal application treatment in fenced plots, but these measures were similar in both management treatments in unfenced plots. Thus standing dead stems of Amur honeysuckle offered protection from damage in the presence of herbivores, offsetting the advantage of the cut/paint method seen in the fenced plots. There was a trend for more leaves of transplanted wild ginger in the basal application treatment. There were more invasive garlic mustard and more Amur honeysuckle seedlings in the cut/paint treatment than in the control treatment. Our results illustrate the complexities involved in selecting appropriate restoration management techniques given herbivore pressure, differential species response, and presence of multiple invasive species. In our study, we demonstrated that the basal application honeysuckle management method (and therefore perhaps similar methods that leave the dead stems standing) led to increased understory plant restoration success when compared to the cut/paint method.

**1.**

Restoration of habitats invaded by non-native plants should include both the removal of invasive

plants and re-establishment of native plant communities. To develop appropriate restoration

strategies and quantify the effects of invasions, experiments that evaluate multiple removal methods

and native community responses to those removal methods are needed.

**2.**

We evaluated the response of native plant communities to removal of the invasive grass

*Microstegium vimineum* (Japanese stiltgrass) in eastern forests in the USA. At eight field sites in

southern Indiana, we applied three common removal treatments and compared native community

responses among treatments and to untreated reference plots.

**3.**

After 2 years of treatment, native community responses to *Microstegium* removal varied significantly

among methods and plant functional groups in autumn 2006. Graminoid richness was greater

when the invader was removed with hand-weeding, while graminoid biomass was lower in plots

treated with post-emergent herbicide compared to reference plots. Forb richness was greater with

hand-weeding and post-emergent herbicide compared to plots treated with post-emergent plus

pre-emergent herbicides or untreated plots. Forb biomass was greater across all removal treatments.

Overall native community diversity was 24% greater when the invasion was removed with handweeding

and 21% greater with post-emergent herbicide compared to reference plots. No positive

response in plant diversity occurred with post-emergent plus pre-emergent herbicide.

**4.**

By spring 2007, graminoid percentage cover was greater with hand-weeding but not with

herbicide treatments compared to untreated plots. However, forb cover was greater across all

removal treatments compared to plots where the invader was not removed. The density of native

tree seedlings was 123% greater in post-emergent herbicide treated plots than in untreated plots,

indicating that the invasion was inhibiting tree recruitment.

**5.**

*Synthesis and applications.*

Our results demonstrate that multiple techniques can be used to control invasive plants but that the responses of native plant communities vary among removal methods. Further, greater native plant diversity and biomass following removal shows that invasions were suppressing native plant communities. Management of plant invasions should consider not only the effectiveness of removal methods but also how different methods influence native plant responses.

Chemical, mechanical, and biological methods are used to manage invasive plants, but their effectiveness at removing specific plant invaders while preserving native communities varies widely. Chemical methods are used most extensively but the nontarget effects of some herbicides can have lasting effects on native plants. Nonchemical methods are needed for sites containing rare or threatened native species and where the cost of herbicides is prohibitive. Here we evaluate multiple nonchemical methods for removing Japanese stiltgrass, a nonnative annual grass that is rapidly invading eastern U.S. forests. We applied mowing, hand weeding, and spring and fall fire treatments to replicated plots at three forested sites in southern Indiana and compared the response of Japanese stiltgrass and native plants to untreated reference plots. Mowing and fall fires applied just before seed set were the

most effective methods for removing Japanese stiltgrass. Mowing decreased invader cover by 70% and biomass by 95%, whereas fall fires reduced cover by 79% and biomass by 90% compared to reference plots. Spring fire reduced Japanese stiltgrass cover, but not biomass, and hand weeding did not significantly reduce invader cover or biomass compared to untreated plots. There were no significant differences in the response of the overall native plant community or of specific native plant functional groups to the removal treatments. In summary, mowing and properly timed fall fires may be effective nonchemical methods for managing Japanese stiltgrass invasions and restoring native communities. Future research should focus on evaluating the responses of Japanese stiltgrass, native species, and other plant invaders to removal treatments conducted over successive growing seasons across a range of invaded habitats.

Chinese privet is a major invasive shrub within riparian zones throughout the southeastern United States. We removed privet shrubs from four riparian forests in October 2005 with a GyrotracH mulching machine or by handfelling with chainsaws and machetes to determine how well these treatments controlled privet and how they affected plant community recovery. One year after shrub removal a foliar application of 2% glyphosate was applied to privet remaining in the herbaceous layer. Three ‘‘desired-future-condition’’ plots were also measured to assess how well treatments shifted plant communities toward a desirable outcome. Both methods completely removed privet from the shrub layer without reducing nonprivet shrub cover and diversity below levels on the untreated control plots.

Nonprivet plant cover on the mulched plots was 60% by 2007, similar to the desired-future-condition plots and higher than the hand-felling plots. Both treatments resulted in higher nonprivet plant cover than the untreated controls. Ordination showed that after 2 yr privet removal plots were tightly grouped, suggesting that the two removal techniques resulted in the same plant communities, which were distinctly different from both the untreated controls and the desired-future-condition. Both treatments created open streamside forests usable for recreation and other human activities. However, much longer periods of time or active management of the understory plant communities, or both, will be required to change the forests to typical mature forest plant communities.

The first step in restoration often involves the removal of invasive plants, but few studies have determined if the response of plant communities matches management goals. The shrub Morrow’s honeysuckle (Lonicera morrowii Gray) is one of a suite of exotic bush honeysuckle

species that have become pervasive woody invaders in eastern North America. In 2004, we tested four control methods (cut, mechanical removal, stump application of glyphosate, and foliar application of glyphosate) during late spring and early autumn within a degraded meadow at Fort Necessity National Battlefield, Pennsylvania, U.S.A. Our restoration goals are to control Morrow’s honeysuckle, restore native vegetation, and mimic the conditions present in the mid-1700s. We established forty-five

5 *3* 5–m plots to measure woody species; five plots of each treatment method were treated in spring, whereas the remaining five were treated in autumn. We maintained five control plots. Before control, mean density of Morrow’s honeysuckle was 67,920 ± 4,480 shrubs/ha. Foliar application of herbicide and mechanical removal were most effective at reducing the number of shrubs (≥62%). Overall, our treatments were less successful (26–68% reduction) than reported control efforts of other bush

honeysuckle species; the sheer number of shrubs coupled with their open habitat made control efforts difficult. Spring treatments, particularly cut and mechanical treatments, had higher metrics of herbaceous community quality. However, continued restoration efforts, including follow-up treatments, White-tailed deer (Odocoileus virginianus) control, and the planting of native seeds and saplings, should be employed to favor the establishment of native seedlings and herbs.

Giant cane (Arundinaria gigantea) is a native bamboo species that was once

abundant in wetlands and riparian areas throughout the Southeastern United States. As part of

an effort to identify competitive-dominant native species that can be utilized to maximize the

restoration of riparian ecosystem functions/services and reduce non-native community

invasibility, we transplanted cane clump divisions into areas either dominated by or recently

cleared of Chinese privet (Ligustrum sinense), an invasive non-native shrub. We quantified cane

survival and growth in the presence of privet and other plants including several common

invasive non-natives. Removal of mature privet via a cut and paint application of glyphosate

herbicide resulted in 100% mortality. Cane survival was high in both the high and low-light

conditions provided by the opposing privet treatments. During the first year, there was little

cane growth or expansion in either privet treatment. In the second year, cane growth and

expansion in the Privet-Present treatment was also very low. However, during the second year

in the Privet-Removed treatment, cane genets produced more ramets, increased in genet area,

and developed ramets that were taller and thicker. Despite very high recruitment and cover of

Japanese stilt grass (Microstegium vimineum) and other common invasive non-natives in the

Privet-Removed treatment, transplanted cane genets continue to grow and expand. Our future

research will continue to monitor the rate of cane growth as we investigate whether cane can

compete with the common non-native invasive species that are dominant at this site and at

other riparian ecosystems throughout the region.

Controlling species invasions is a leading problem for applied ecology. While

controlling populations expanding linearly or exponentially is straightforward, intervention in

systems with complex dynamics can have complicated, and sometimes counterintuitive,

consequences. Most invasive plant populations are stage-structured and density-dependent—

a recipe for complex dynamics—and yet few population models have been created to explore

the effects of control efforts on such species. We examined the demography of the invasive

biennial plant Alliaria petiolata (garlic mustard) on the front of its spread into a natural area

and found evidence of strong density dependence in vital rates of first-year rosette and

second-year adult stage classes. We parameterized a density-dependent, stage-structured

projection model using field-collected data. This model produces two-point cycles with

alternating years in which adults vs. rosettes are more prevalent. Such population dynamics

match observations in natural populations, suggesting that these complicated population

dynamics may result from deterministic rules. We used this model to evaluate simulated

management strategies, including herbicide treatment of rosettes and clipping or pulling of

adult plants. Management of A. petiolata by inducing mortality of either rosettes or adults

will not be effective at reducing population density unless the induced mortality is very high

(.95% for rosettes and .85% for adults) and repeated every year. Indeed, induced mortality

of rosettes can be counterproductive, causing increases in the stationary distribution of A.

petiolata density. This species is typical of many invasive plants (stage-structured, short-lived,

high fertility) and exhibits common forms of density dependence. Thus, the management

implications of our study should apply broadly to other species with similar life histories. We

suggest that management should focus on managing adults rather than rosettes, and on

creating efficient control in targeted areas of the population, rather than spreading less

efficient efforts widely.

Exotic invasive plant species differ in their effects on indigenous vegetation as

evidenced by research evaluating community response to their removal. We used a removal

approach to quantify the response of a mesic woodland to the removal versus retention of an

invasive plant, Hesperis matronalis (dame’s rocket) from paired treatment plots over 3 y. Cover

of H. matronalis did not differ between control and treatment plots prior to removal, declined

in the removal plots and remained significantly lower in cover compared to the control plots.

Removal did not significantly affect species richness and species diversity (evenness, Shannon

and Simpson) at the plot scale, but did result in increased species richness overall in the

removal plots in the last sampling year when compared to control plots. Non-metric

multidimensional scaling ordination analysis indicated a significant compositional change in

the spring plant composition of plots over the 3 y, reflecting an increase in exotic woody

species. Exotic woody plants, especially Rosa multiflora and Euonymus alatus, increased in cover

in response to H. matronalis removal. In the 3 y, neither native nor exotic forbs, nor native

woody plants responded to the removal of H. matronalis in a statistically significant manner.

The increasing cover of woody invasive plants in response to the removal of H. matronalis has

important management implications for restoration of degraded communities.

The Australian tree Melaleuca quinquenervia (melaleuca) formed dense monocultural forests

several decades after invading parts of Florida and the Caribbean islands. These dominant forests have

displaced native vegetation in sensitive wetland systems. We hypothesized that native plant diversity

would increase following recent reductions in density of mature melaleuca stands in south Florida. We

therefore examined data on changes in melaleuca densities and plant species diversity derived from

permanent plots that were monitored from 1997 to 2005. These plots were located within mature melaleuca stands in nonflooded and seasonally-flooded habitats. Two host-specific biological control agents of melaleuca, Oxyops vitiosa and Boreioglycaspis melaleucae, were introduced during 1997 and 2002, respectively. Also, an adventive rust fungus Puccinia psidii and lobate-lac scale Paratachardina pesudolobata became abundant during the latter part of the study period. Overall melaleuca density declines in current study coincided with two to four fold increases in plant species diversity. The greatest declines in melaleuca density as well as the greatest increases in family importance values and species diversity indices occurred in nonflooded as compared to seasonally seasonally flooded habitats. Most pioneer plant species in study sites belonged to Asteraceae, Cyperaceae, Poaceae, and Ulmaceae. The rapid reduction in melaleuca density and canopy cover during the study period may be attributed to self-thinning accelerated by the negative impact of natural enemies. Densities of other woody plants, particularly Myrica and Myrsine, which were sparsely represented in the understory by a few

suppressed individuals also declined during the same period, possibly due to infestation by the generalist lac-scale. These findings indicate that natural-enemy accelerated self-thinning of melaleuca densities is positively influencing the native plant diversity and facilitating the partial rehabilitation of degraded habitats.

Asiatic shrub honeysuckles (*Lonicera maackii, L.* x *bella* complex) are widespread

invaders of Midwestern forests, damaging both plant and animal habitat. Techniques for

the elimination of honeysuckle are not well evaluated in the literature. Stem cutting with

application of 20% glyphosate to the stubs is widely used, but is not completely successful.

It is also fairly painstaking, uses significant quantities of concentrated herbicide, and

is purportedly ineffective in spring. Our objective was to develop control techniques

which capitalized on the physiological characteristics of understory shrubs, relying on a

timed cutting regime and limited or no herbicide application. In one experiment we

evaluated whether cutting after leaf expansion followed by foliar spraying or cutting

regrowth were effective means of control. In a second experiment we evaluated the effect

of cutting height and regrowth spraying on control. Cutting near ground level just after

leaf expansion followed by spraying or cutting regrown foliage with dilute (0.9%) glyphosate

proved as effective as published results for stem cutting and concentrated glyphosate

application. There are significant benefits to adopting early season cutting and

midsummer retreatment as a control technique, particularly for private landowners.

Dense Japanese barberry (Berberis thunbergii) stands have spread beyond manicured landscapes and are associated with a paucity of both tree regeneration and herbaceous plants in some forest stands. Studies over 2 years evaluated the effectiveness of various treatment alternatives to control barberry. A total of 375 barberry clumps at three study areas were selected for the first study in 2006. Treatments included directed flame using a 100,000 BTU propane torch on the following schedule: (1) pre-leafout and no follow-up treatment in July, (2) pre-leafout with directed flame in July, (3) post-leafout and no follow-up treatment, (4) post-leafout with follow-up treatment, and (5) untreated controls. Clumps treated once had higher mortality (45%) than untreated clumps (3%), but timing of initial treatment did not affect clump mortality. Clumps treated twice had the highest mortality of all (74%). All propane torch treatments reduced clump size, on average, by nearly 75%. Size of untreated clumps increased by 13%. In 2007, a two-step process to control barberry was examined for 1100 clumps at six study areas. Initial treatments (prescribed burning, mechanical mowing with a drum chopper or with a brush saw) were applied to reduce the size of established barberry clumps. The second, follow-up treatments in mid-summer that treated new sprouts included foliar application of triclopyr or glyphosate, directed flame, and untreated controls. All initial treatments were equally effective in reducing clump size. Mortality differed among follow-up treatments: untreated controls (14%), directed flame (40%), and herbicide (93%). Surviving clumps having no follow-up treatment recovered to half of their original size by the end of the growing season. Size of surviving clumps did not differ among the other follow-up treatments and averaged 20% of the original size. Excellent control of Japanese barberry can be achieved using either propane torches or herbicides. Propane torches provide a non-chemical alternative where in parks, nature preserves, or forests where herbicide use is restricted and where barberry infestations are still light.

Restoration sites are vulnerable to plant invasions due to habitat and resource alteration. We conducted an invasive plant-removal study at a wetland restoration in the North Carolina Piedmont, a site dominated by the non-native invasive, Microstegium vimineum. Paired plots (M. vimineum handweeded

and unweeded) were established and maintained to monitor response of plant species richness

and diversity. Plots increased from 4 to 15 species m-2 after three growing seasons of M. vimineum

removal and 90% of the newly establishing species were native. Weeding ceased in the fourth growing

season and M. vimineum rapidly re-invaded. Formerly weeded plots increased to 59% (±11% SE) M.

vimineum cover, 25 of 51 plant species disappeared from the plots, and species richness decreased to an average of8 species m-2. Our results show that we can quickly establish an abundant, diverse community with invasive removal, but that persistent effort is required to monitor and maintain the long-term viability of this community.

Restoration of communities invaded by exotic plants requires effective eradication of the invader and reestablishment of the resident plant community. Despite the commonly cited need for techniques to accomplish such goals, studies that test strategies for removing invasive plants, monitor effects on resident communities, and incorporate replicate sites are generally lacking. Microstegium vimineum is an exotic annual grass that is rapidly invading forests in the eastern United States and threatening

to reduce biodiversity and inhibit forest regeneration. I conducted a field experiment at eight sites over two growing seasons in southern Indiana to evaluate handweeding (HW), a postemergent grass-specific herbicide (POST), and the postemergent herbicide plus a preemergent herbicide (POST 1 PRE) for removing Microstegium. Compared to reference plots (REF), the three treatments each reduced Microstegium biomass at the end of the growing seasons to relatively low levels. However, after the second year of the experiment, POST and POST 1 PRE resulted in very little spring cover of Microstegium, but HW plots were significantly reinvaded. HW and POST, but not POST 1 PRE, increased resident plant community productivity and spring resident community cover compared to reference plots. The amount of light at the research sites did not alter the effectiveness of treatments, but the recovery of resident communities was positively correlated with light availability under HW and POST 1 PRE. These results indicate that natural systems invaded by Microstegium can be restored using the POST or HW treatments, which will effectively remove the invasion and allow the resident plant community to recover when used over multiple growing seasons.

Vegetation management, using prescribed fire and herbicides, is used in forestry applications to reduce

competition with desired species, improve wildlife habitat, and meet other silvicultural objectives.

Although plant communities resulting from such treatments are generally known, it is unclear how

pre-treatment plant community structure may influence specific plant community responses. Therefore,

to examine how species dominance may impact response of plant communities to vegetation management, we compared the top contributors to plant biomass (kg ha−1) among prescribed fire and herbicide (imazapyr) treatments within intensively managed pine stands in east-central Mississippi, USA. Ninety-two species of 390 collected comprised 95% of plant biomass and six species comprised 55% of total biomass. Dominant species may have restricted plant diversity. Prescribed fire with and without imazapyr improved species richness but did not control some highly competitive species. None of the treatments tested is necessarily an optimal solution to control well-established understory plant species. Although management prescriptions consider exotic and invasive plant species, control of well-established native species should also be considered to tailor vegetation management to meet forestry and wildlife habitat objectives. More research is needed concerning plant response to multiple herbicide tank mixtures with and without prescribed fire to optimize future vegetation management for multiple objectives.

Amur honeysuckle recovery following treatments annually and only in 1-year, during 2002 to 2009, was compared in the forests of Radnor Lake State Natural Area in Nashville, TN. Annual treatment areas had significantly lower mean Amur honeysuckle plant counts than 1-yr treatment areas for both # 1 m (3.3 ft) and . 1 m plant heights and on both sloped and level areas, except for plants # 1 m tall on level areas, which most likely indicated more soil moisture increasing seedling establishment and root sprouting in the first year after treatment. The significant, positive Pearson’s product moment correlations for Amur honeysuckle counts of plants # 1 m tall, with arboreal basal area and with canopy species diversity in the level areas of the annual treatment plots, were also most likely evidence for the importance of greater soil moisture during the first year after treatment for greater Amur honeysuckle recovery. For land managers interested in native vegetation restoration, guidance is provided to plan for long-term, invasive plant species treatment and recovery monitoring.

Japanese climbing fern (Lygodium japonicum) is an invasive vine that has been identified as an economic and ecological threat in forest ecosystems of the Southeast. In two separate studies, we examined the use of directed sprays of glyphosate, imazapyr, and metsulfuron-methyl herbicides, alone and in combination, for control of Japanese climbing fern and for impacts to associated vegetation in mixed bottomland hardwood–cypress forests at two first terrace sites of the Apalachicola River in north Florida. Two yr after treatment, various rates of glyphosate alone generally provided greater percent control (84 to 95%) than imazapyr alone (225 to 86%) or metsulfuronmethyl alone (25 to 53%). Combinations of 2% glyphosate and imazapyr and/or metsulfuron-methyl resulted in 81 to 97% control at 2 yr after treatment, with no significant differences among the combination treatments or 2%

glyphosate alone. Change in percent cover of associated vegetation groups was not influenced by treatment except for one location where graminoid cover increased 1 yr after metsulfuron-methyl treatment but decreased after imazapyr or glyphosate application. Species richness of dominant understory vegetation remained nearly constant at both locations regardless of treatment. These data indicate that glyphosate alone or in combination with imazapyr or metsulfuron-methyl will provide effective, although not complete, control of Japanese climbing fern, and that directed herbicide sprays minimally impact nontarget vegetation.

Various studies have identified methods for effectively controlling Japanese stilt grass [*Microstegium vimineum* (Trin.) A. Camus]. However, the effect of *M. vimineum* control treatments on native flora has not been documented. This is ofparticular interest because an effective *M. vimineum* control method that minimizes impact on native vegetation should beconsidered the most desirable technique. This study investigates the effects of various control treatments on *M. vimineum*,and the associated native understory community, on an upland and bottomland hardwood site in central WV (38°46’08”N,

81°03’ 52”W). Control treatments examined in the study included: a low-volume glyphosate application (6 ounces per acre); both a single (early June) application and a double application (early June and August) of fenoxaprop-p-ethyl (13 ounces per acre); and mechanical control (weed whip). In the first growing season following the treatments, single applications of fenoxaprop-p-ethyl provided greater than 95 percent control of *M. vimineum* at both sites. Mechanical control also proved to

be very effective. In addition to showing an increase in species diversity, fenoxaprop-p-ethyl treated plots also exhibited posttreatment species richness values that were significantly higher than all other treatments (P < 0.05). The results of this study suggest that this selective herbicide has the potential to be used to restore native plant communities in *M. vimineum* infested areas of mixed hardwood forests.

Japanese barberry is listed as an invasive shrub in 20 states and four Canadian provinces. Control of Japanese barberry was evaluated using several two-step processes over 16 mo using a total of 1,100 clumps at six study areas. Initial treatments in spring (prescribed burning, mechanical mowing with a brush saw or rotary wood shredder) reduced the size of established barberry clumps. Follow-up treatments in midsummer to kill new ramets that developed from surviving root crowns were foliar applications of triclopyr or glyphosate, directed heating with a propane torch, and untreated controls. Mortality was defined as the absence of ramets from a root crown and not the mortality of individual ramets of a given clump. Clump mortality and size of new ramets did not differ among initial treatments. However, larger clumps had higher survival and larger sprouts than smaller clumps 16 mo after initial

treatment. Effectiveness of follow-up treatments varied by clump size. Two follow-up treatments of directed heating using propane torches were as effective as herbicides for clumps that were initially smaller than 120 cm. For clumps with pretreatment sizes of 120 cm and larger, clump mortality following herbicide treatments (90%) and directed heating (65%) was greater than for clumps that had no follow-up treatments (35%). Although clump sizes did not differ between follow-up methods 1 yr after treatment, both follow-up treatments resulted in smaller clumps than untreated controls. Effective control of Japanese barberry can be achieved in a single growing season by integrating an early-season initial treatment (prescribed fire or mechanical) that kills the aboveground tissues with a midseason

follow-up treatment such as directed heating or targeted herbicide application.

Japanese climbing fern (*Lygodium japonicum*) is an invasive species prevalent through the southeastern United States that grows on, around, and intermingles with native groundcover in a variety of forest ecosystems. Management of this species can be problematic because herbicide control must also ensure minimal impact to native plants, particularly in ecosystems undergoing restoration and recovery from disturbance. We tested 3 herbicides (glyphosate, imazapyr, and metsulfuron methyl) at various rates, alone and in combination, to evaluate their efficacy for fern control and impacts to non-target, native groundcover in a longleaf pine (*Pinus palustris*) ecosystem subject to dormant season burns and

hurricane and salvage logging disturbances. All herbicide treatments reduced Japanese climbing fern cover by 77–98% at 1 yr following treatment, but at 2 yr there was considerable re-growth on imazapyr and metsulfuron-methyl treated plots. Glyphosate applied alone as a 2 or 4% solution provided 91–98% fern control after 2 yr, and there was no significant improvement using combinations of glyphosate with other herbicides. Climbing fern cover increased by 70% in the untreated control. We found a significant correlation between reduction in fern cover and increase in other vegetation, though species composition changed minimally. Species richness at 2 yr after treatment increased by 2–3 species following application of glyphosate alone or in combination, and decreased on the untreated control. We recommend directed spray applications using 2% glyphosate solutions for efficient control. Using this approach on matted fern should result in little detriment to native groundcover, even with this broad-spectrum herbicide.

Tree-of-heaven (*Ailanthus altissima* [Mill.] Swingle) is one of the most widely

distributed exotic invasive tree species in the United States and has become naturalized

throughout the central hardwood forest. It opportunistically establishes in areas associated

with silvicultural regeneration treatments and extirpation often requires the targeting of

individual trees due to the close proximity of native co-occurring stems. Further, treeof-

heaven is a prolifi c root and stump sprouter, and extirpating this exotic invasive tree

species requires not only killing the aboveground stem but also ensuring that lateral roots

are killed. Th e study was designed to test the effi cacy of fi ve individual tree treatments in

killing stems and preventing sprouting: EZ-Ject® (granulated glyphosate), full basal bark

(triclopyr ester), hack and squirt (picloram/2,4-D), hack and squirt (glyphosate), and tree

injection (picloram/2,4-D). Th e mortality and sprouting of sapling-sized tree-of-heaven

developing in two naturally regenerating hardwood stands were investigated. We treated

410 stems. Treatments provided eff ective top kill compared to the untreated control group

with treatment top dieback fi gures ranging from 91 to 100 percent compared to less than

15 percent for the untreated control. Treatment areas were examined for the occurrence and

type of sprouts (basal stem, root collar, and lateral root). Th e EZ-Ject® glyphosate treatment

exhibited 33-percent total sprouting in 2006 and 5 percent in 2007 compared to a range of

3 to 12 percent for other treatments in 2006 and 0 to 2 percent for all other treatments in

2007. Th is study indicates that all forms of sprouting should be considered when control

options are tested and that EZ-Ject® applications with glyphosate may not provide thorough

control of sprouting.

In 2002, a 5-acre section of forest at the North Carolina Museum of Art Park underwent an invasive species removal treatment to prevent ecological damage caused by these invasive species and to aesthetically improve the park. Treatment was targeted specifically at non-native woody shrubs, especially *Elaeagnus umbellata* and *Ligustrum sinense*. This forested area was used as a case study to examine the effects of invasive species removal on the understory of the forest. When compared to an adjacent nontreated area of forest, the treatment was effective at decreasing the cover of both *Elaeagnus umbellata* and *Ligustrum sinense*. The reduction in invasive shrub cover also increased park sightlines, accomplishing the aesthetic goal. Despite the success of the treatment in removing the target invasive species, eight years later the total cover of invasive species was not different between the two areas. This was largely due to a much higher average cover of *Microstegium vimineum* in the treated area. Possible explanations for this difference include competitive release and the introduction of disturbance. There was no observed difference between the understory communities of the nontreated and treated areas. Also, invasive shrub cover was correlated with both canopy cover and proximity to the forest edge. This study shows that successful invasive species removal can lead to further invasion by other species. Furthermore, removal of invasive species may not lead to an increase in native species cover or richness. Finally, this study supports the observation that forest edges and open canopies are often associated with invasion processes.

Low-intensity fires were important for maintaining the structure of Eastern deciduous forests (EDFs)

for thousands of years before European settlement of North America, though fire suppression became

a standard management practice in the 1930s. More recently, prescribed fires have been reintroduced

to EDF habitats to aid in the restoration of native plant diversity, but invasions of non-native species

such as Microstegium vimineum (Japanese stiltgrass) may increase prescribed fire intensity and suppress

colonization of native species. As fire becomes a more common management tool in these habitats, it is

vital to predict fire temperature effects on the native and non-native species present in the system. In this study, we found that prescribed fires in areas invaded by Microstegium can be 250–300 ◦C hotter than fires in nearby native-dominated areas.Wethen compared the effects of fire on germination rates of six native and three non-native EDF understory species representing the range of functional groups common in this habitat. We manipulated both fire intensity (temperature and length of exposure) and type of fire effect (direct flame and indirect furnace heat) to generate germination curves and make predictions about potential prescribed fire effects on populations of these species. There were very different responses among species to both direct (flame) and indirect (furnace) heating. Germination of three native species, Lycopus americana (American water horehound), Verbesina alternifolia (wingstem), and Vernonia gigantea (tall ironweed), showed signs of being stimulated by heating at low temperatures, while germination of all non-native species (M. vimineum, Elaeagnus umbellata, and Schedonorus phoenix) were inhibited at these lower intensities. High fire intensity (temperatures above 300 ◦C) effectively killed most species, though one native species, Senna hebacarpa (American senna) and one non-native species, E. umbellata (autumn olive), were capable of tolerating 500 ◦C temperatures. We conclude that high-intensity prescribed fires in habitats invaded by Microstegium may reduce seed germination of some non-native species, but may also inhibit the regeneration of native understory species.

Garlic mustard, a biennial Eurasian species, has extensively invaded eastern North American deciduous forests. We studied effects of 3 years (2005–2007) of annual removal of second-year garlic mustard plants on first-year plants and native spring herbaceous species in upland and lowland woods. Treatments compared removal of second-year plants in mid-March (early treatment) or mid-May (late treatment) to a control. We recorded first- and second-year plants and native herbaceous species percent cover on April 19 and 20. First-year plant cover was higher on control than treatment plots;

however, in the upland woods only control and late treatment plots differed significantly. First-year plant cover was less in removal than control plots, indicating reduced seed input; however, we found no difference in cover of second-year plants between late treatment and control plots. Results suggest second-year plants strongly compete with younger conspecifics, and their removal decreases first-year plant mortality. Removal of second-year garlic mustard did not significantly affect total cover of native herbaceous species. Second-year plants complete vegetative growth before late May and might impact early developing native species more than later growing species. We tested effect of removal of garlic

mustard on native species in 2 phenological categories: spring- and summer-dominant species. We found no treatment effects on summer-dominant species. However, early treatment plots had significantly more cover of spring-dominant plants than late treatment and control in the upland woods. Indicator Species Analysis indicated a majority of spring (75%) and summer (50%) dominant species maximized performance in the early treatment.

Coral ardisia (Ardisia crenata) has been present in Florida for more than 100 yr as an ornamental and has become invasive in hammocks of natural areas. This plant forms dense understory cover, often greater than 90%, which can suppress native plant recruitment and growth. Results from herbicide trials at two sites in Florida indicate that a single foliar treatment applied as a spot application of triclopyr amine, triclopyr ester, glyphosate, imazapic, dicamba, triclopyr amine + imazapic, or triclopyr ester + fluroxypyr reduced Ardisia crenata to less than 13% at 12 mo after treatment (MAT). A single treatment of imazapic (2.4 g ae L21) or imazapic (2.4 g ae L21) + triclopyr (10.8 g ae L21) reduced cover of mature plants to less than 0.5% and seedlings to less than or equal to 4% at 12 MAT. Native plant cover was less than 5% prior to treatment indicating that dense infestations of Ardisia crenata may suppress native vegetation. In the dense infestations of Ardisia crenata observed in this study, nontarget damage

was not a concern due to the rarity of native plants. However, applicators should use caution applying triclopyr and imazapic when small shrubs and trees are present in the treatment area. Additional follow-up treatments will be required for control of seedling and possible resprouts at 12 MAT.

The predominance of *Lonicera maackii* (Rupr.) Herder (Amur Honeysuckle) in central

Kentucky has made it a significant invasive for continued community interaction studies. To better

understand the dynamics of vegetation succession with respect to this species and overall species

richness, quantitative floristics of two macroplots were made at the summit (312 m) of Dead Horse

Knob (Rucker’s Knob) near Berea, in Madison County, east-central Kentucky. An old abandoned

cemetery was cleared of *L. maackii* and a macroplot (20 x 12 m) served as a test plot, while a second

macroplot was placed within a dense thicket of *L. maackii* to serve as a reference plot. Thirty quadrats

(1 x 1 m) were randomly placed within each macroplot as a means to determine species frequency. A

full floristic survey was then conducted of each macroplot. Results from frequency data suggest that

native annual and perennial species will quickly recolonize an area after removal of Amur

Honeysuckle and become the most important components of the site. Likewise, floristic data

demonstrated nearly a three-fold increase in species richness (60 taxa) in the test macroplot after

removal of Amur Honeysuckle compared to species richness (21 taxa) in the reference macroplot. In

the absence of Amur Honeysuckle, vegetation has resulted in a significantly different floristic

assemblage between macroplots. Frequency data from the cleared test macroplot indicate that *L.*

*maackii* will remain viable through seedling recruitment, and without further control or disturbance, an

understory thicket of Amur Honeysuckle will undoubtedly be reestablished at this site.

Japanese barberry (*Berberis thunbergii* DC) is a non-native shrub currently found in 31

states and four Canadian provinces. We examined the effectiveness of directed heating using 400,000

BTU backpack propane torches to control Japanese barberry infestations at two study areas in southern

Connecticut. Each study area had eight 50-m x 50-m plots. Treatment combinations included a pre-leafout or post-leafout initial treatment with propane torches to reduce the size of established clumps

and an early (late June), mid (early July), or late (late July) follow-up treatment to kill sprouts that

developed from surviving root crowns. All treatment combinations were equally effective and reduced

barberry abundance (a surrogate for cover) from 31% prior to treatment to only 0.5% the following

autumn (i.e., a 98% reduction). All treatment combinations were also equally effective in reducing the

size of surviving barberry to an average of only 11 cm compared with 74 cm for untreated clumps.

Estimated labor costs using propane torches for both initial and follow-up treatment was 2.5 hr/ha for

every 1% pretreatment abundance (e.g., 25 hr for a 1-ha stand with 10% abundance). Because timing of

initial treatments (pre-leafout vs. post-leafout) and follow-up treatment (early, mid, late) were equally

effective in reducing Japanese barberry abundance and height of surviving stems, initial treatments

can be completed from March-June and follow-up treatments can be completed from June-August in

southern New England. For habitat restoration projects on properties where herbicide use is restricted,

directed heating with propane torches provides a non-chemical alternative that can effectively control

invasive Japanese barberry.

Autumn olive (*Elaeagnus umbellata)* was planted during the

reclamation process to reduce erosion and improve nitrogen content of the soil.

However, since its establishment, *E. umbellata* has spread prolifically and control

measures are difficult. The primary objective of this case study was to evaluate

the effectiveness of various control methods on eradication of *E. umbellata* in

varying degrees of infestation. A two-phase case study was conducted at *The*

*Wilds* conservation center in Cumberland, OH. Phase 1 began in 2007-2008 to

evaluate three treatments in areas with moderate cover (15-30%) of *E. umbellata:*

mechanical removal, foliar herbicide, and dormant stem herbicide. Nine 200m2

study plots were established with three replications of each treatment.

Effectiveness of each treatment was evaluated in 2009 through tracking 225

individual shrubs. The foliar herbicide controlled 98% of *E. umbellata*; dormant

stem herbicide achieved 71 % and the mechanical treatment controlled only 15 %.

Statistical comparisons indicated the foliar and dormant stem herbicides were

more effective (*P* = 0.0008) than mechanical removal. This suggests that foliar

applications can be a reliable tool for control of *E. umbellata* in areas with a 15-

30 % density level. Based on these findings, phase 2 of this study was initiated in

2010 to evaluate removal techniques in dense shrub infestations (95-100 %).

Treatments included a combination of mechanical clearing then a chemical

treatment of stumps to reduce re-sprouts. The fracture treatment was most

effective during the second phase (63 %), when compared to the cut-stump (46 %)

mechanical treatment (*P* = 0.004). Results demonstrate that a combined

mechanical-chemical approach is efficient in dense infestations. Mechanical land

clearing through fracture and re-sprout treatment appeared to be most effective in

*E. umbellata* control and the most cost effective in dense cover; however

replicated studies are needed to provide conclusive information about the fracture

re-sprout treatment.

The eradication of garlic mustard (*Alliaria petiolata*) from natural populations has proven

to be difficult; however, manual removal efforts can be effective at reducing or eliminating small populations when repeated for several years, exhausting the seed bank. We evaluated a variety of manual removal methods for efficacy in reducing viable seed production in garlic mustard. Plants were uprooted and evaluated for subsequent viable seed production based on four variables: (1) height (short, tall), (2) phenological stage (flowering, early-fruiting, late-fruiting), (3) deradication (root removed from uprooted plant), and (4) disposal method (hang, scatter, pile). Uprooting plants at the flowering stage prevented production of any viable seed, while early- and late-fruiting plants were still able to produce viable seed. Fruits initiated on taller plants (≥ 40 cm) produced significantly (P < 0.01) more viable seed than those on short plants (≤ 35 cm). Deradication of uprooted plants did not offer an advantage in reducing viable seed production. There were no significant differences in viable seed production between groups of plants subjected to different disposal methods. Garlic mustard root systems left in the ground after aboveground portions of the plants were removed at four phenological stages (budding, flowering, early-fruiting, and late-fruiting) either did not resprout or produced short-lived sprouts that died without flowering. Our findings suggest that pulling garlic mustard before fruit initiation will reduce seed production, regardless of the disposal method employed or whether roots are left intact.

Disturbed natural areas frequently experience invasion by introduced plant species that can reduce native biodiversity. Biological control can suppress these introduced species, but without restoration another introduced species can invade. Integration of biological control with concurrent revegetation can both aid in weed reduction via interspecific plant competition and establish a restored native plant community. This 3-year study investigated an integrated approach to controlling the introduced

annual Mile-a-minute weed (Persicaria perfoliata [L.] H. Gross [Polygonaceae]) using the biocontrol weevil Rhinoncomimus latipes Korotyaev (Coleoptera: Curculionidae) and restoration planting using a native seed mix. A fully factorial design tested weevils and seeding, separately and together, using insecticide to eliminate weevils. The weevils together with the native seed mix reduced P. perfoliata percent cover in 2009 and 2010, and peak seed cluster production in 2010, compared to the insecticide−no seed control treatment. Persicaria perfoliata final dry biomass was reduced by 75% in 2010 and by 57% in 2011 in the weevils plus seed treatment compared to the control, with weevils

having the greatest effect in 2010 and the seed treatment having the greatest impact in 2011. Results suggest an additive effect of biocontrol and seeding in suppressing P. perfoliata. Seeded treatments also developed the highest native plant species richness and diversity, comprised of spontaneous

recolonization in addition to species from the seed mix. Results support the use of integrated management of this invasive weed, with suppression through biological control and native revegetation together helping prevent reinvasion while restoring native plant biodiversity.

Application of glyphosate to cut stumps is broadly viewed as an effective way to control

invasive woody shrubs like the buckthorn species (Rhamnus cathartica L. and Frangula alnus Mill.).

Since the primary cost associated with this control method is labor, identifying factors that improve

efficacy is important. The objective of this research was to determine the effect of glyphosate concentration and soil moisture on the control of buckthorn using the cut-stump method. More than 600 mature buckthorn plants were cut and treated with glyphosate at concentrations between 0 and 41% active ingredient during October in soils varying from dry to moist. While increased glyphosate concentration improved control rates, soil moisture played a dominant role. In moist soils, the impact of glyphosate concentration was insignificant (z=-1.723, p=0.085), and between 40% and 60% of treated buckthorn plants escaped control at all glyphosate concentrations. In dry soils, however, control rates increased significantly with higher concentrations of glyphosate (z=-8.84, p < 10-15), achieving up to 98% control with 41% glyphosate. Root exudates of two three-year old field-grown buckthorn seedlings that were treated with high glyphosate concentrations in dry soils using cut-stump treatments contained detectable glyphosate comparable to control rates of mature plants. These results suggest that using the highest labeled concentration of herbicide in relatively dry soil conditions will provide optimum effectiveness with control rates up to 98%.

For the last 23 years, low-severity prescribed fire has been used to decrease shade and fire tolerant tree species, increase oak (Quercus spp.), and increase herbaceous plant diversity in the East Woods of The Morton Arboretum, Lisle, Illinois, USA. The impacts of these fires on the belowground ecosystem have yet to be measured. Soil (0 to 10 cm) and litter samples were collected 12, 19, and 24 months following the most recent fire on 40 plots in burned and un-burned control areas. Soil physical, chemical, and biological properties were measured and compared with vegetation composition and structure from these same plots. Compared to un-burned controls, burn plots had greater canopy openness, greater herbaceous richness, and a lower spring/summer herbaceous ratio. Burned plots had higher soil moisture content, pH, electrical conductivity, Ca2+, Mg2+, K+, Na+, NO3−, total N, particulate organic matter (POM), total organic C, and potential N mineralization. Soil microbial biomass and respiration, texture, color, aggregate stability, and hydrophobicity were not different in burned compared to un-burned plots. Indices of litter and soil invertebrate diversity were also not affected by prescribed fire. Three stepwise least squares models predicted woody richness, herbaceous richness, and spring/summer herbs with aspect, litter invertebrate richness, and soil factors (pH, potential N mineralization, C/N ratio, Mg2+, Bray P, and soil invertebrate Simpson index). These results

confirm others showing prescribed fire to increase soil nutrient availability. Forest structural changes with fire appear correlated with soil nutrient availability. Decreased soil C, nutrient retention, invertebrate diversity, or increased hydrophobicity and the presence of exotic plants is often observed with high-severity fire; but, these negative impacts do not appear to be present with these long-term, low-severity fires.

Elimination of Asiatic shrub honeysuckles (*Lonicera* spp.) from preserves and conservation areas in eastern North America is difficult because bird dispersal reintroduces seeds from shrubs in the neighborhood. To reduce this problem, honeysuckle control must be instituted on a broad scale and involve public participation. Many techniques for honeysuckle control are beyond the capabilities

and inclinations of volunteers and local landowners. In a replicated study, we evaluated two suitable techniques and applied them in spring, early summer, late summer, fall, and winter 2009. These were stem cutting followed by painting with 18% glyphosate, and stem cutting followed by spraying of regrown shoots with 1% glyphosate about 40 days later. We regarded the spraying of regrown shoots

as more practical for neophytes. Overall, cutting followed by stump treatment is more effective, killing 75–85% of individuals in spring and early summer, and *>*90% later in the year. Cutting and spraying regrowth was most effective in spring (56% killed), and poorer thereafter (20–40% killed). The result for spring was much lower than previously observed. Death rates for the cutting and regrowth spraying treatment were not affected by shrub size, but the amount of regrowth after spraying responded strongly to size. Cutting and regrowth spraying may be suitable in situations where reducing the competitive effects and reproduction of individuals is sufficient, or the resources to treat stumps with concentrated glyphosate are limited.

Garlic mustard, an invasive exotic biennial herb, has been identified in the

Upper Peninsula of Michigan, but is not yet widely distributed. We tested the effectiveness

and impact of management tools for garlic mustard in northern hardwood forests.

Six treatment types (no treatment control, hand-pull, herbicide, hand-pull/herbicide, scorch,

and hand-pull/scorch) were applied within a northern hardwood forest invaded by garlic

mustard. We sampled understory vegetation within plots to compare garlic mustard

abundance (distinguishing first and second year plants) and native plant diversity before

and after treatment. Results immediately following treatment indicated that garlic mustard

seedling abundance was significantly reduced by herbicide, hand-pull/herbicide, scorch,

and hand-pull/scorch treatments, and that adult abundance was reduced by all treatments.

However, sampling of treatment sites one year later showed an increase in seedling

abundance in herbicide and hand-pull/herbicide plots. Adult garlic mustard abundance after

one year was lower than the control with the exception of the hand-pull plots where adult

abundance did not differ. After one year, understory species richness and Shannon’s

Diversity were lower in the herbicide and pull/herbicide treatments. Based on these results,

we conclude that single-year treatment of garlic mustard with hand-pulling, herbicide,

and/or scorching is ineffective in reducing garlic mustard abundance and may inadvertently

increase the success of garlic mustard, while negatively impacting native understory species.

Japanese stiltgrass is one of the most aggressive, rapidly spreading invasive plants in the eastern United States. Management guidelines state that mowing can help manage Japanese stiltgrass but that mowing is most effective when done late in the season after the plants begin to flower and before they set seed. In this study, I tested the effectiveness of mowing at three different times between mid-June and early September in 2009 and 2010, as well as mowing twice in 1 yr and for two consecutive years. The effectiveness of mowing Japanese stiltgrass was determined by measuring percentage of cover, biomass, seed production, and the number of stems in the summer following mowing. All mowing treatments significantly reduced percentage of cover, biomass, seed production, and the

number of Japanese stiltgrass stems the following year. In 2009, all of the mowing treatments significantly reduced biomass, percentage of cover, and seed production. The latest mow, at the end of August, resulted in a slightly greater reduction of cleistogamous seeds. In 2010, the earliest mowing treatment, in mid-June, did not reduce cover and biomass as much as the other mowing treatments. Overall, these results suggest that mowing can be an effective control method for Japanese stiltgrass and that mowing any time after June should be effectively equivalent, although later mowing may provide some marginal advantage.

Japanese stiltgrass, an annual grass species native to eastern Asia, has become a serious invasive-plant problem in the eastern United States. We compared the efficacy of herbicides and nonchemical options found effective for controlling stiltgrass in earlier studies, with organic herbicides and herbicides used at reduced rates in a wooded floodplain along the lower Connecticut River. We compared the effect of 2 yr of conventional and alternative treatments on cover of other nonnative and native species. Four blocks of 18 plots (3 by 4 m [9.8 by 13.1 ft]) were established in May 2008. Treatments included directed heating with a propane torch (June, July), hand-pulling (July), mowing with a string trimmer (July, August), foliar applications of household vinegar [5% acetic acid] (June, July) and the herbicides imazapic (June), pelargonic acid (June, July), and pelargonic acid plus pendimethalin (June). The following herbicides were applied at labeled doses and at one-fourth labeled doses: fenoxaprop-p-ethyl

(July), glufosinate (August), and glyphosate (August). Stiltgrass cover and height were evaluated periodically, and plant samples were collected in autumn of 2008 and 2009 to determine the number of viable seeds produced. Final evaluations were conducted in June 2010 after 2 yr of treatment. Stiltgrass cover averaged 88% on untreated plots in fall. All treatments reduced stiltgrass cover and seed production. The least-effective treatments were hand-pulling, pelargonic acid, and vinegar in July. Direct heating, mowing, and vinegar in June reduced seed production by more than 90%. All treatments containing imazapic, pelargonic acid plus pendimethalin, fenoxaprop-p-ethyl, glufosinate, and glyphosate completely prevented stiltgrass seed production in the second year of treatment. Effective control of stiltgrass can be achieved during a 2-yr period with a variety of herbicides, including herbicides at one-fourth of the labeled dose, and through nonchemical treatments.

Disturbed natural areas frequently experience invasion by introduced plant species that can reduce native biodiversity. Biological control can suppress these introduced species, but without restoration another introduced species can invade. Integration of biological control with concurrent revegetation can both aid in weed reduction via interspecific plant competition and establish a restored native plant community. This 3-year study investigated an integrated approach to controlling the introduced annual Mile-a-minute weed (*Persicaria perfoliata* [L.] H. Gross [Polygonaceae]) using the biocontrol weevil *Rhinoncomimus* *latipes* Korotyaev (Coleoptera: Curculionidae) and restoration planting using a native seed mix. A fully factorial design tested weevils and seeding, separately and together, using insecticide to eliminate weevils. The weevils together with the native seed mix reduced *P. perfoliate* percent cover in 2009 and 2010, and peak seed cluster production in 2010, compared to the insecticide−no seed control treatment. *Persicaria perfoliata* final dry biomass was reduced by 75% in 2010 and by 57% in 2011 in the weevils plus seed treatment compared to the control, with weevils having the greatest effect in 2010 and the seed treatment having the greatest impact in 2011. Results suggest an additive

effect of biocontrol and seeding in suppressing *P. perfoliata*. Seeded treatments also developed the highest native plant species richness and diversity, comprised of spontaneous recolonization in addition to species from the seed mix. Results support the use of integrated management of this invasive weed, with suppression through biological control and native revegetation together helping prevent reinvasion while restoring native plant biodiversity.

Management of invasive species in forests often includes combinations of prescribed fire and herbicides. However for most efficient management, evaluations of these tools should include whole-population responses of targeted plants. In this study, we evaluated how the timing and frequency of prescribed fire and herbicide application affected population growth of the invasive annual grass Microstegium vimineum (stiltgrass) using periodic matrix population models. We conducted an experiment in M. vimineum invaded deciduous forests in Indiana, USA to compare effects of spring and fall prescribed fires combined with pre- or post-emergent herbicide on M. vimineum populations and to build matrix population models predicting long-term population responses to these management treatments across multiple life-history stages. We found that spring fires were effective at reducing population growth rates during the year of treatment but there was no effect of burning on M. vimineum populations the following year. Similarly, fall prescribed fires were effective at reducing seed production, as well as numbers of seedlings and adults following fires, but had no long-term effect on population growth rates. Post-emergent herbicide alone was the only treatment that reduced M. vimineum population growth beyond 1 year. Seedbank survival had the highest life-stage elasticity across all treatments, indicating that novel management methods specifically designed to exhaust seedbanks for three or more years may be needed to prevent M. vimineum population resurgence after cessation of treatments.

Cogongrass [Imperata cylindrica (L.) Beauv.] is a warm-season, rhizomatous grass native to southeast Asia that has invaded thousands of hectares in the southeastern United States. Its negative impacts on pine forests have been well documented, and aggressive control is widely recommended. Although repeated herbicide treatments are effective for suppression, integrated strategies of prescribed burning coupled with herbicide treatment and revegetation are lacking in pine systems. In particular, longleaf pine forests, which are typically open, fire-dependent, communities, are highly susceptible to cogongrass, which is a pyrogenic species. To address management goals for cogongrass control and herbaceous restoration in longleaf pine forests better, field studies were conducted in southwestern

Alabama from 2010 to 2012. Two longleaf pine forests with near-monotypic stands of cogongrass in the understory were selected for study. Treatments included combinations of winter prescribed fire, spring and fall glyphosate herbicide treatments, and seeding a mix of native, herbaceous species. Data were collected for three growing seasons following study initiation, and included seasonal herbaceous species cover and final cogongrass shoot and rhizome biomass. Species richness and diversity were calculated and analyzed to ascertain treatment effects over the duration of the study. Burning slightly improved cogongrass control with glyphosate, but had no effect on total cover, species richness, or species diversity. Three glyphosate treatments reduced total vegetative cover and nearly eliminated cogongrass cover, shoot, and rhizome biomass. Glyphosate and glyphosate + seeding also increased herbaceous

species richness and diversity. However, aboveground productivity in treated plots was significantly lower than productivity in the untreated control, which was almost exclusively cogongrass. These studies indicate that glyphosate and integrated strategies utilizing glyphosate and seeding are very useful for cogongrass management and increasing herbaceous species richness and diversity in longleaf pine.

Tree-of-Heaven (TOH) is a highly invasive woody species incurring substantial investment in control efforts across its extensive adventive range. A recently isolated strain of the fungus *Verticillium albo*-*atrum* has been found to cause near 100 % mortality of TOH in laboratory and field tests. We assessed plant communities in experimentally infected TOH stands 5–6 years post treatment and compared them to uninfected control stands. We found no statistically significant differences in introduced or native species cover between treated and control stands. Healthy TOH stands often harbor substantial populations of native and introduced invasive species, and on average, successful control of overstory TOH by *V. albo*-*atrum* did not alter vegetation cover in these communities. *V. albo*-*atrum* appears to be a promising tool in targeted control of TOH that carries a relatively low risk of opportunistic weed replacement.

We conducted a three-year field experiment to determine if amending soils with mulched European buckthorn (*Rhamnus cathartica*) can limit reinvasion, and whether two methods of incorporation—tilling or surface application—produce similarresults. Mulch (a high carbon:nitrogen [C:N] material) may reduce reinvasion by stimulating soil microbial immobilizationof N. Converting the woody waste generated during buckthorn removal into mulch would also eliminate both the needto remove this waste from restoration sites and the expense of acquiring amendments from elsewhere. We found that

adding buckthorn mulch to soils, whether tilled or not, did not decrease either buckthorn reinvasion or soil N availability. The mechanical disturbance of tilling, however, caused a large, prolonged reduction in reinvasion by killing a previously unrecognized but major contributor to reinvasion—small buckthorn individuals (most < 5 cm tall) that were undetected during initial removal. Recruitment of new individuals occurred during the experiment, but recruitment rate decreased rapidly over time, suggesting that buckthorn seeds are short-lived. Three major recommendations emerge: (1) buckthorn

mulch should not be used to limit reinvasion; (2) tilling can greatly reduce reinvasion by killing buckthorn individuals that are undetected during initial removal; and (3) because buckthorn seeds appear to be short-lived, reinvasion can be reduced by repeated, annual follow-up control of undetected and newly recruited individuals.

Efforts to suppress an invasive weed are often undertaken with the goal of facilitating the recovery of a diverse native plant community. In some cases, however, reduction in the abundance of the target weed results in an increase in other exotic weeds. Mile-a-minute weed (*Persicaria perfoliata* (L.) H. Gross (Polygonaceae)) is an annual vine from Asia that has invaded the eastern United States, where it can form dense monocultures. The host-specific Asian weevil *Rhinoncomimus latipes* Korotyaev (Coleoptera: Curculionidae) was first released in the United States in 2004 as part of a classical biological control program. At three sites invaded by mile-a-minute weed, biological control was integrated with pre-emergent herbicide use and two densities of native plantings. After 2 years, native plant cover differed significantly and was greater than 80% in the plots with plantings and pre-emergent herbicide but less than 30% in the planting treatments without herbicide. Where mile-a-minute cover decreased at the two sites with the greatest pressure from exotic plants, plots were dominated by another exotic weed, *Microstegium vimineum* (Trin.) A. Camus, Japanese stiltgrass. The combination of biocontrol, pre-emergent herbicide, and revegetation with native plants suppressed mile-a-minute weed, prevented invasion by Japanese stiltgrass, and increased the abundance of native plants. The selection of the management strategies used to control mile-a-minute weed determined the extent of recovery of the native plant community.

Chinese privet (*Ligustrum sinense* Lour.) is a non-native invasive shrub that has become ubiquitous throughout the southeastern United States. There is a large infestation of privet at Congaree National Park in South Carolina, and the National Park Service is interested in controlling it with dormant-season foliar herbicide treatments. The primary objective of this study was to determine which combination of herbicide and applicator provides the most effective control of privet, while minimizing damage to non-target plants. Another objective was to document impacts of privet invasion on Congaree’s plant communities. Seven vegetation plots were installed in each of five large privet populations, and one plot outside of each population in a similar un-invaded area. Herbicide treatments were applied in January of 2012, and consisted of the herbicides glyphosate, metsulfuron, and a combination applied with both backpack sprayers and mistblowers. Measurement plots were set up using the protocols of the Carolina Vegetation Survey.

Chinese privet invasion significantly affected native plant communities at Congaree National Park. Density of canopy tree stems from 1-5cm dbh was lower in invaded than un-invaded plots, suggesting that privet may inhibit canopy regeneration. Invaded areas had a lower density of native shrubs and understory trees and lower cover of sedges. A significant negative correlation was found between privet abundance and species richness, herbaceous cover, and density of canopy tree stems. However, cover of *Microstegium vimineum* was higher in un-invaded plots, suggesting that Chinese privet may also inhibit the establishment of other invasive species.

The efficacy of Chinese privet control did not differ among herbicide types, but it did differ between the two applicators. Mistblowers achieved more effective control of privet, in part due to their greater height of spray. All treatments appeared to be highly effective below the maximum height of spray. The height of some privet stems exceeded the reach of both applicator types.

Tests for non-target impacts showed that for most variables, no treatments differed from control plots. The greatest non-target impacts detected were to sedges and winter-green species from treatments containing glyphosate. The backpack-metsulfuron treatment showed a significant decrease in tree and shrub cover (<50cm height), and the mistblower-glyphosate treatment showed a small decrease in fern cover as compared to the control. Mistblowers showed fewer impacts overall. No treatments significantly impacted species richness.

No single combination of herbicide and applicator met all objectives. However, mistblowers showed a number of advantages for both privet control and non-target impacts. Glyphosate, despite greater impacts to some graminoid species, may be preferred for its soil-binding properties. Height of privet must be considered in planning treatments. Benefits from the removal of privet are expected to outweigh the negative impacts of herbicide application.

Two factors that can degrade native plant community composition and structure, and hinder restoration efforts, are invasive species and chronic overbrowsing by ungulates such as white-tailed deer. Beginning in 2007, the effectiveness, costs, and impacts of Japanese barberry control treatments and herbivory on nonnative and native plant communities was examined at eight study areas over 4 to 5 yr. Prescribed burning and mechanical mowing by wood shredder or brush saw were utilized as initial treatments to reduce the aboveground portion of established barberry and were equally effective. Without a follow-up treatment, barberry had recovered to 56 to 81% of pretreatment levels 50 to 62 mo after initial treatment. Follow-up treatments in mid-summer to kill new sprouts included directed heating and foliar herbicide applications. Relative to untreated controls, follow-up treatments lowered barberry cover

50 to 62 mo after initial treatment by at least 72%. Although all follow-up treatments were equally effective, the labor cost of directed heating was four times higher than for herbicide applications. Follow-up treatment type (directed heating vs. herbicide) had minimal impact on species other than barberry. White-tailed deer herbivory had a larger impact on other species than did barberry control treatments. Native grass and fern cover was higher outside of exclosures. Areas inside exclosures had higher cover of Oriental bittersweet and multiflora rose, but not Japanese barberry. Thus, recovery of native communities will require more than simply removing the dominant invasive species where deer densities are high. Excellent reduction of Japanese barberry cover can be achieved using either directed heating or herbicides as follow-up treatments in a two-step process, but other invasive plants may become a problem when barberry is removed if deer populations are low.

Japanese barberry (*Berberis thunbergii*) is an invasive shrub that can

suppress forest regeneration and increase the risk of exposure to Lyme disease. In 2008,

we began a study in central Connecticut to examine the effi cacy of treating barberry

infestations during the dormant season (October-March). Techniques included

basal spray (triclopyr in oil) and clearing saw cutting with a wet-blade application of

triclopyr. Dormant season techniques were compared with a glyphosate foliar spray

applied in September. Foliar application resulted in a greater reduction of barberry

cover (94 percent) compared to basal spray (84 percent) and wet-blade treatments

(74 percent). Treatment eff ectiveness did not diff er among months for either of the

dormant season techniques. Labor costs did not diff er among techniques, averaging

0.13 hours/acre/percent cover (i.e., 3.9 hours for a 1 acre stand with 30 percent

barberry abundance). Th ere was a large diff erence among treatments in amount of

herbicide applied with 0.6 (±0.1), 1.4 (±0.4), and 2.8 (±0.4) ounces/acre/percent cover

for wet-blade clearing saw, foliar spray, and basal spray applications, respectively. While

not as effective as foliar spraying, wet-blade clearing saw and basal spray applications

provide an opportunity to control barberry during the dormant season. Wet-blade

clearing saw technique can reduce the amount of applied herbicide.

The invasive-exotic *Rhamnus cathartica* has been growing in parks and natural areas of

North America for over 100 years where it has replaced native vegetation. Chemical herbicides have

limited success on *R. cathartica* and often require follow-up applications. This multiyear study is the first

to investigate the efficacy of *Chondrostereum purpureum*, the active agent in Chontrol Peat Paste (CPP),

as a biological herbicide for *R. cathartica*. The objective of this study was to determine the efficacy

of CPP and Roundup on *R. cathartica* trees by comparing re-growth/mortality rates of mechanically

wounded trees treated with either herbicide. *Rhamnus cathartica* trees were girdled or cut and received

either CPP or Roundup applications in late-fall (LF), early-summer (ES), and late-summer (LS) at Assiniboine Park in Winnipeg, Canada. All trees were evaluated for mean re-growth, number, and condition of basal sprouts during spring following each application. It was expected that trees treated with CPP would show less re-growth than those that were solely mechanically wounded (controls). In LF, the most effective mechanical/herbicide combination for reducing overall stem re-growth was found to be the cut treatment followed by Roundup. In ES, however, the most effective treatment combination for suppressing re-growth was the CPP application to girdled trees as conditions were optimal for inoculation of trees. These results will allow herbicides to be effectively applied over a longer duration of the season and have implications for the development of future management protocol for *R. cathartica* in urban parks and natural areas.

Invasive Amur honeysuckle (Lonicera

maackii) has reduced diversity, growth, and reproduction

of native herbs in the Midwest USA. These effects

may be compounded by browsing from overabundant

white-tailed deer (Odocoileus virginianus). We used

experimental treatments of honeysuckle (present,

absent, removed) and deer (present, excluded) to

measure their independent and interactive impacts on

diversity, richness, and abundance of herbs in a

deciduous forest in southwestern Ohio, USA. Species

diversity and richness of herbs were not affected by

honeysuckle or deer. Honeysuckle reduced abundance

of annuals, graminoids, spring perennials, and summer

perennials; deer decreased abundance of annuals

and spring perennials, but increased abundance of

graminoids. A deer 9 honeysuckle interaction showed

that when honeysuckle was absent or removed,

browsing by deer kept abundance of annuals and

spring perennials low. Effects of honeysuckle and deer

also were assessed for the three most abundant herbs:

honeysuckle reduced abundance of Carex rosea and

Sanicula odorata, and deer reduced abundance of

Viola soraria. Herb abundance varied seasonally and

annually. Honeysuckle and deer reduced number of

leaves/stem of Maianthemum racemosum and a

deer 9 honeysuckle interaction indicated that the

negative effect of honeysuckle was released only when

deer were excluded. Herb abundance and M. racemosum

rebounded to or near to control levels after

removal of honeysuckle. Our findings revealed that

impacts of invasive honeysuckle or overabundant deer

were not the same across all levels of biological

organization (i.e., individual species, growth forms,

community measures of species diversity/richness).

Measuring impacts of these species at multiple levels

of biological organization, considering deer 9 honeysuckle

interactions, and collecting data for several

years to account for seasonal and annual fluctuations

will help guide management plans. The rapid response

by herbs to removal of honeysuckle demonstrated the

resilience of this community and is a hopeful sign for

restoration of native understory herbs.

Microstegium vimineum is an invasive grass introduced from Asia that has spread throughout

riparian areas of the eastern United States threatening native riparian vegetation. Postemergence (POST) herbicides registered for aquatic use were evaluated for control of M. vimineum on two riparian restoration sites in the Piedmont and Upper Coastal Plain of North Carolina. This study found that standard and lower than standard rates of diquat, fluridone, flumioxazin, glyphosate, imazamox, and imazapyr reduced weed stem density and biomass at 6 and 30 weeks after treatment (WAT). Both rates of bispyribac and penoxsulam provided less control of M. vimineum. Visual ratings showed both rates of diquat, flumioxazin, imazamox, and imazapyr controlled 63-100% of M. vimineum at 6 WAT and 84-100% at 30 WAT. Fluridone and glyphosate provided slightly less control. Bispyribac and penoxsulam treatments provided less control at 6 and 30 WAT compared to the other treatments. Plots treated with both rates of diquat, flumioxazin, imazamox, and imazapyr were nearly devoid of all vegetation at 30 WAT. Recommendations include POST application of lower than standard rates of diquat, flumioxazin, fluridone, glyphosate, imazamox, and imazapyr on riparian restoration sites infested with M. vimineum. Immediate vegetation management measures including temporary and permanent plant cover

should be employed on treated sites where weeds are completely eradicated to prevent erosion.

An invasive shrub, Chinese privet (Ligustrum sinense Lour.), was removed from heavily infested riparian

forests in the Georgia Piedmont in 2005 by mulching machine or chainsaw felling. Subsequent herbicide

treatment eliminated almost all privet by 2007. Recovery of plant communities, return of Chinese privet,

and canopy tree growth were measured on removal plots and heavily invaded control plots in 2012

approximately five years after complete removal of privet. Plant communities were also measured on

three ‘desired future condition’ plots which were never heavily infested with privet. These areas provided a goal condition for plant communities on removal plots. Approximately 7% of mulched plots and 3% of felling plots were re-infested by Chinese privet. In contrast, non-privet herbaceous plants covered 70% of mulched plots and 60% of felling plots compared to only 20% of untreated control plots and 70% in desired plots. Both mulched and felled plots had more plant species than the control plots, and mulched plots had more species than felled plots. Analysis of similarity (ANOSIM) and non-metric multidimensional scaling (NMS) ordination indicated that control, removal, and desired future condition plots had three distinct plant communities but the methods used to remove privet did not result in different communities. There was no difference in growth of canopy trees in removal and control plots five years after removal. Removing Chinese privet from riparian areas is beneficial to plant communities, promoting biodiversity and secondary succession while progressing toward a desired condition regardless of the method used to remove it.

Shifts in plant-community composition following habitat

degradation and species invasions can alter ecosystem

structure and performance of ecosystem services. In temperate

North American woodlands, invasion by aggressive

Eurasian shrubs has produced dense thickets with depauperate

understory vegetation and increased rates of litter

decomposition and nutrient cycling, attributes that could

impair storage of carbon as soil organic matter (SOM). It

is important to know if such impairment has occurred and,

if so, the extent to which restoration can return this service.

We used an oak-woodland restoration chronosequence in

northeastern Illinois to contrast structural and functional

attributes of unrestored areas dominated by Rhamnus

cathartica (common buckthorn) with areas that had undergone

buckthorn removal and ongoing, active management

for less than 1 to 14 years. With increasing age, restored

areas had higher understory plant diversity and cover (p <

0.0001 and 0.005, respectively) and higher litter mass (p

= 0.018). These structural differences were associated with

some evidence of reduced soil erosion (p = 0.027–0.135) but

greater soil CO2 efflux (p = 0.020–0.033). Total particulate

organic matter (POM) in the soil increased with restoration

age, which was driven by increases in the slow-turnover,

mineral-associated SOM fraction. However, variance was

high and relationships were only weakly significant (p =

0.082 and 0.083 for total POM and mineral-associated

SOM, respectively). Our results suggest that, in addition to

better documented biodiversity benefits, beneficial changes

to ecosystem properties and processes may also occur with

active, long-term restoration of degraded woodlands.

A survey of nonnative invasive plants was conducted within the boundary of Lake Raleigh Woods Nature Preserve, a nature preserve on North Carolina State University’s Centennial Campus situated West of Lake Raleigh. This survey revealed that there was an abundance of undesired plants existing within the nature preserve. There were roughly ten acres of autumn olive (*Ellaeagnus umbellata*) growing in the heart of Lake Raleigh Woods. Without intervention, this nonnative invasive plant could continue to spread and out-compete desired native plant species. To inform management practices, an herbicide trial was initiated to study the effectiveness of different herbicide and application method combinations for controlling autumn olive. The study was a 3 x 4 factorial design with three application methods and four herbicides. Herbicide treatments were: glyphosate, imazapyr, triclopyr and a mixture containing aminocyclopyrachlor, imazapyr, and metsulfuron. Application methods were: cut stump application, foliar application, and basal bark application. A ‘cultural control’ and nontreated check was included for comparison. Treatments were arranged in a randomized complete block design with four replications. Individual experimental units (plots) consist of three autumn olive subsamples. Visual ratings for control and stem count data was collected for statistical analysis. The cut stump treatment was the most effective application method across all herbicides for control of autumn olive, while triclopyr was the most effective herbicide across all application methods. The trial was repeated over two years with nearly the same results.

Non-native invasive glossy buckthorn *(Frangula alnus* P. Mill.) threatens timber

regeneration and land restoration efforts by suppressing economically and ecologically

important seedlings. Cutting of buckthorn was hypothesized to decrease its survival,

height, cover, and stem density and increase recruitment; increase white pine seedling

height, cover, density, survival, and increase species richness and cover of other vascular

plant species. Five replicates of four treatments: (1) control, (2) 1-cut at the start of the

growing season, (3) 3-cuts, and (4) 4-cuts, completed over one growing season were

applied to 5 X 5 m plots at MacDonald Lot in Durham, NH. Cutting increased white pine

seedling relative height growth, buckthorn density and survival, and decreased buckthorn

height and cover. Height, cover, density and survival of white pine seedlings, buckthorn

recruitment, and species richness and cover of other vascular plants remained unchanged.

Left unmanaged, buckthorn may further suppress white pine growth stalling timber

harvests.

Lonicera maackii (Rupr.) Herder (Amur honeysuckle) is one of the most important invasive plants in the Ohio Valley. Because of its phenology and dense canopy, L. maackii can exclude native herbs and interfere with regeneration of woody plants. In 2005, in a county park in southwest Ohio, I established modified Whittaker plots in four stands with a gradient of L. maackii cover ranging from 24 yr old to 40 yr old. The L. maackii canopies were removed by herbicides in fall 2005. Plant cover was monitored from 2005 to 2013. After 8 yr, there was an increase in species richness and herbaceous cover at all sites. Herbaceous species turnover was generally greater at sites with greater initial L. maackii cover. All of the most-common herbaceous species increased or maintained their coverage; most of the species that increased were those that bloom in late spring or summer. The abundances of other invasive species also increased, including Alliaria petiolata (M. Bieb.) Cavara & Grande (garlic mustard). However, A.

petiolata abundance peaked 2–6 yr after L. maackii removal, suggesting that this increase, frequently seen after L. maackii removal, may be transitory. Previous studies have not shown such a

decline after an initial increase in A. petiolata, but few studies have extended over this length of time. Ash (Fraxinus L.) decline caused by the emerald ash borer may now be affecting the recovery of these stands.

An important goal of restoring fire to upland oak-dominated communities that have experienced fire exclusion is restoring

groundcover plant species diversity and composition indicative of fire-maintained open habitats. Treatment-driven

declines in rare forest specialists and increases in widespread ruderals and competitive non-native species, however, could

negate the benefits of ecological restoration in these ecosystems. We tested the effects of treatment-related disturbances

on native groundcover vegetation, density and proliferation of patches of an invasive grass, Japanese stiltgrass (*Microstegium*

*vimineum*), and the net effects of treatment and the invasive grass on native groundcover vegetation. Results from

multiple years of monitoring at two replicate sites in north Mississippi showed that thinning and burning significantly

increased both groundcover species richness and the abundance of species indicative of fire-maintained open habitats.

We found subtle increases in forest species in response to treatments, whereas most native ruderals did not increase

significantly in response to the treatments over the long term. The density and competitive effect of the invasive Japanese

stiltgrass increased dramatically at both sites in response to the restoration treatments. However, new patches of

Japanese stiltgrass established in response to the treatments only at the site with the more recent history of agricultural

disturbance. Results suggest that fire restoration treatments were effective in the absence of past agricultural disturbance

and in areas lacking Japanese stiltgrass. At sites with a history of agriculture and large populations of Japanese stiltgrass,

effective restoration may require eradication of Japanese stiltgrass and reintroduction or augmentation of competitive,

native specialists of fire-maintained open habitats.

Effective control of Nepalese browntop (*Microstegium vimineum*) is important to land managers in the eastern United States because invasions can suppress native vegetation, thus decreasing vegetation diversity and habitat quality for many wildlife species. We evaluated the effectiveness of herbicides with varying selectivity (glyphosate, imazapic, and clethodim) at full rates and half rates (based on labeled rates for annual grass control) on the control of japangrass and their effects on non-target vegetation. We conducted our experiment in three forested areas in east Tennessee. We measured species coverage using point transects before treatment, 60 days after treatment (60DAT), and one year after treatment (1YAT). Japangrass coverage 60DAT was similar for all six treatments (0%–8%), but differed from coverage in control plots (83%). The coverage of japangrass in all treatments was less than control plots 1YAT (10%–35% vs. 68%). However, full rates of glyphosate (2qt/ac) and imazapic (8oz/ac) were most effective in controlling japangrass 1YAT (17% and 10%, respectively). Percent coverage of non-target vegetation 60DAT and 1YAT were similar among the treatment and control plots. Our results suggest full rates of glyphosate and imazapic are the most effective postemergence options to control japangrass. Multiple applications should be evaluated across years and sites to gain a better understanding of the long-term effects of herbicide applications.

Chinese tallowtree is an invasive tree found throughout the southeastern United States and in California. Its negative effects can be seen in numerous natural and managed ecosystems, including bottomland hardwood forests, pastures, pine plantations, and along lakes, ponds, streams, and rivers. Despite its troublesome presence for many decades, relatively few effective control strategies are available. Root sprouting following management efforts is a major impediment to successful control. Studies were conducted in Alabama and Louisiana at three locations to test several herbicides for cut stump, basal bark, and foliar individual plant treatment (IPT) methods. Herbicide treatments included triclopyr amine and ester formulations, imazamox, aminopyralid, aminocyclopyrachlor, and fluroxypyr. Data were collected just before leaf senescence at one and two growing seasons after treatment and included Chinese tallowtree foliar cover, number of stump or root collar sprouts, and number of sprouts originating from lateral roots within a 1-m radius of each tree. For the cut stump and basal bark studies, most herbicide treatments prevented sprouting from the stump or root collar region better than they did from the lateral roots. Aminopyralid reduced total sprouting better than all other treatments in the cut stump study. The high rates of aminocyclopyrachlor and fluroxypyr resulted in the highest mortality in the basal bark study. Aminocyclopyrachlor reduced total sprouting better than all other herbicides in the foliar treatment study. Triclopyr amine and ester formulations, which are commercial standards,

did not consistently control Chinese tallowtree across these IPT studies. These studies provide some promising treatments to increase the number of effective tools that can be used to manage Chinese tallowtree. Additional research is needed to address the prolific nature of lateral root sprouting following any of these treatment methods.

1. While many ecosystems depend on fire to maintain biodiversity, non-native plant invasions

can enhance fire intensity, suppressing native species and generating a fire–invasion

feedback. These dynamics have been observed in arid and semi-arid ecosystems, but fire–invasion

interactions in temperate deciduous forests, where prescribed fires are often used as management

tools to enhance native diversity, have rarely been investigated.

2. Here we evaluated the effects of a widespread invasive grass on fire behaviour in eastern

deciduous forests in the USA and the potential effects of fire and invasions on tree regeneration.

We planted native trees into invaded and uninvaded forests, quantified fuel loads, then

applied landscape-scale prescribed fires and no-burn controls, and measured fire behaviour

and tree seedling and invasive plant performance.

3. Our results show that fires in invaded habitats were significantly more intense, including

higher fire temperatures, longer duration and higher flame heights, even though invasions did

not alter total fuel loads. The invasion plus fire treatment suppressed native tree seedling survival

by 54% compared to invasions without fire, and invasions reduced natural tree recruitment

by 66%.

4. We also show that invasive plant biomass did not change from one season to the next in

plots where fire was applied, but invader biomass declined significantly in unburned reference

plots, suggesting a positive invasive grass–fire feedback.

5. Synthesis and applications. These findings demonstrate that fire–invasion interactions can

have significant consequences for invaded temperate forest ecosystems by increasing fire intensity

and reducing tree establishment while promoting invasive plant persistence. To encourage

tree regeneration and slow invasive spread, we recommend that forest managers remove

invasions prior to applying prescribed fires or avoid the use of fire in habitats invaded by

non-native grasses.

1. Invasive plants, herbivores and site management history can play crucial roles in determining

plant community composition. The net effects of invasive species on plant communities

are well known, but we have a poor understanding of the relative contributions of direct competitive

effects of invasive species and their interactions with herbivores and management

practices. Understanding interactions among plant invasions, herbivores and management history

is critical for predicting and managing long-term ecological effects of invasions on native

communities.

2. We investigated the effects of the invasive annual grass Microstegium vimineum, vertebrate

herbivory, site management history and their interactions on seedling performance of five

native tree species in six forest sites. Half of the sites had been subjected to recent timber harvesting,

and half had not been managed for timber for at least 20 years. We evaluated tree

seedling survival and biomass after two growing seasons in blocked split-plots where the invasive

grass was present or experimentally removed and where vertebrate herbivores were

excluded by fencing or allowed onto the plots.

3. Removal of the invasive grass and herbivore exclosures both had positive effects on seedling

survival. Survival of all species was significantly increased by removal or by the interaction

of removal with exclosure or timber harvest history. There was a significant interaction

between exclosure and removal on seedling biomass where seedlings were larger in exclosure

treatments with the invasive removed but smaller in exclosure treatments when the invader

was present. Mean seedling biomass was 79\_6% greater in harvested sites than in

non-harvested sites. The significant positive effects of removal and recent timber harvest on

the biomass of two Quercus species suggest strong impacts of invasion and management history

on this important genus.

4. Synthesis and applications. An invasive grass directly inhibited tree seedling performance

but effects depended on herbivore exclusion treatment, timber harvest history and tree species.

Our results suggest that forest management strategies should incorporate invasive plant

control given that regeneration of desirable tree species can be influenced by plant invasions

and their interactions with herbivores and previous management practices.

Research was conducted on control methods for Oriental bittersweet (*Celastrus orbiculatus*),

pale swallow-wort (*Cynanchum rossicum*), and Morrow’s honeysuckle (*Lonicera morrowii*) near

Long Island Sound in Groton and East Lyme, Connecticut. These nonnative, invasive plants threaten

the health of ecosystems at these sites and many other areas throughout the Northeast. For the Oriental bittersweet study, vines were treated at one of three timings (April, August, or November) in 2003 and evaluated in the summer of 2004. Treatments consisted of triclopyr ester formulations applied to the basal bark of uncut vines, or of triclopyr amine or glyphosate formulations applied to the stump surface

of cut vines. The experiment was repeated with a different set of vines treated in 2004 and evaluated

in 2005. Cut-stump herbicide treatments were generally more effective than basal-bark treatments at

killing bittersweet vines. All cut-stump herbicide treatments were effective in reducing vine survival

and number and length of sprouts. Pale swallow-wort plots were established in areas of high infestation

near the shore. Treatments applied in July 2003, and again in August 2004, included hand pulling,

cutting, application of glyphosate or triclopyr amine to cut stems, or foliar sprays of glyphosate or

triclopyr amine. By July 2005, glyphosate foliar sprays and cut-stem treatments with glyphosate or

triclopyr caused the greatest reduction in the amount of swallow-wort, and the glyphosate treatments

were most effective in reducing swallow-wort vigor. Triclopyr foliar sprays injured swallow-wort, but

long-term control was not better than that provided by annual hand pulling, cutting, or no treatment.

For Morrow’s honeysuckle, herbicide treatments were applied to freshly cut stumps in August 2005,

and were evaluated in May 2006. Treatments consisted of glyphosate, triclopyr amine, or triclopyr ester,

each applied at low or high doses. All triclopyr treatments reduced the number and length of sprouts,

and both glyphosate treatments completely prevented sprouting from honeysuckle stumps. Our study

provides land managers with effective control methods for three highly invasive plants.

While negative impacts of invasive species on native communities are well

documented, less is known about how these communities respond to the removal of established

populations of invasive species. With regard to invasive shrubs, studies examining native

community response to removal at scales greater than experimental plots are lacking. We

examined short-term effects of removing *Lonicera maackii* (Amur honeysuckle) and other

non-native shrubs on native plant taxa in six mixed-hardwood forests. Each study site

contained two 0.64 ha sample areas—an area where all non-native shrubs were removed and

a reference area where no treatment was implemented. We sampled vegetation in the spring

and summer before and after non-native shrubs were removed. Cover and diversity of native

species, and densities of native woody seedlings, increased after shrub removal. However,

we also observed significant increases in *L. maackii* seedling densities and *Alliaria petiolata*

(garlic mustard) cover in removal areas. Changes in reference areas were less pronounced

and mostly non-significant. Our results suggest that removing non-native shrubs allows

short-term recovery of native communities across a range of invasion intensities. However, successful restoration will likely depend on renewed competition with invasive species that

re-colonize treatment areas, the influence of herbivores, and subsequent control efforts.

Non-native grass invasions have the potential to change natural and prescribed fire regimes by altering

fuels, which in turn may promote further invasion. We examined if invasion by Microstegium vimineum, a non-native annual grass, resulted in a positive invasion-fire feedback in eastern deciduous forests managed with prescribed fire and how this response varied across the landscape. Using paired invaded and uninvaded plots embedded in forest stands subjected to prescribed fire, we quantified differences in fire intensity and fuel loads, and fire effects on M. vimineum seedbank emergence, performance and spread. Invaded sites had less leaf litter and fine woody fuels, and increased fire intensity. Although fire reduced emergence of M. vimineum from the soil seedbank, sites subjected to prescribed fire had greater M. vimineum biomass and higher recruitment than unburned sites. Soil moisture strongly modulated M. vimineum response to fire, such that fire facilitated M. vimineum invasion more in wetter than drier sites. These findings indicate that deciduous forests are vulnerable to positive invasion-fire feedbacks, although the positive effect of fire may be less pronounced where soil moisture is limiting. The interaction between soil moisture and fire effects can inform management decisions regarding where to combine prescribed burning with intensive invasive control measures such as torching, hand pulling, and herbicide application.

Chinese privet is an invasive shrub that commonly infests roadsides and bottomland forests across the southeastern United States. Its aggressive growth and ability to prolifically sprout from the root collar and shallow lateral roots makes control very difficult. Individual plant treatment methods such as low-volume basal bark herbicide application with triclopyr are commonly used for Chinese privet control. However, little research has been done to examine optimal triclopyr concentrations and application timings for the low-volume basal bark method. Furthermore, little is known regarding basal bark treatment efficacy when plant size varies. To address these questions, field studies were conducted from 2009 to 2011 at two locations in east-central Alabama near Auburn and Opelika. The triclopyr butoxyethyl ester formulation was applied in January or March to Chinese privet shrubs across a range of sizes in a commercially available basal oil carrier at 24 (5% v/v\_1), 48 (10% v/v\_1), and 96 g L\_1 (20% v/v\_1). Additionally, a triclopyr butoxyethyl ester ready-to-use formulation (90 g L\_1) was applied at 100% v/v\_1. Canopy defoliation, sprout height, and mortality were quantified at 6, 12, and 18 mo after treatment. Triclopyr at all concentrations was highly effective in defoliating Chinese privet and reducing height of new basal sprouts. However, mortality was concentration dependent. The 90 and 96 g L\_1 treatments resulted in 88 and 89% mortality across timings, while the 24 and 48 g L\_1 treatments resulted in 63 and 76% mortality. March applications were less effective as basal diameter increased, especially at the lower triclopyr concentrations where mortality fell to less than 40%. These results indicate that triclopyr is an effective treatment for Chinese privet control, but efficacy is influenced by concentration, application timing, and plant size.

Negative effects of non-native invasive plants have been well documented, but few studies have examined long-term impacts of non-native plant removal on both native and non-native plant community composition. This case study compared consequences of three non-native invasive removal methods (chemical, mechanical, and a combination of the two), applied to all exotic species, on native and non-native abundance, richness (total number of species), and community composition in two forested sites over six growing seasons. Important nonnative vegetative components in pre-treatment and control plant communities included the vines English ivy (*Hedera helix* Linnaeus, 1753), Japanese honeysuckle (*Lonicera japonica* Thunberg, 1784), oriental bittersweet (*Celastrus orbiculatus* Thunberg, 1784), and clematis (*Clematis terniflora* De Candolle, 1817), and the shrub Chinese privet (*Ligustrum sinense* Lourero, 1790). In all removal treatments, nonnative herbs, tree seedlings, and shrubs declined over six years, and native herbs’ and tree seedlings’ cover and richness increased. Time to implement treatments varied widely (844 person hours / ha for combination vs. 44 h / ha for chemical), but treatment effects only differed for native shrub density (highest in control treatment at one site), and native herb, shrub, and tree seedling richness (highest in mechanical and combination treatments at one site). Treatment did not affect cover or richness of non-native herb and tree seedlings, or shrub density and richness. Native species cover and richness increased as exotic species cover declined for all treatments in this study, suggesting that seed supplementation is not always necessary for community recovery. Spot-application of herbicides to foliage or girdled trees did not significantly hinder native plant community recovery, and no native species except poison ivy (*Toxicodendron radicans* (Linnaeus) Kuntze, 1891), which was intentionally removed, had its abundance or cover reduced by treatments. Even after treatment, clematis and Chinese privet remained important community components, demonstrating the difficulty in controlling these non-native species. Treatment effects were more pronounced at one site, perhaps due to imperfect selection of control plots, legacy land-use effects, or light limitation. This study supports the need for long-term treatment and measurement to accurately determine native plant community responses to non-native invasive removal.

The vine Euonymus fortunei (Turcz.) Hand.-Mazz. is invading forests of the eastern United States; as a result, removal of E. fortunei has become a priority of resource managers. This study examined the effectiveness of five techniques for eliminating E. fortunei, restoring plant species richness, and enhancing recolonization by woody species. In 2003, the following five treatments were applied: burn with a propane torch, light exclusion by plastic tarp, burn and glyphosate application, cut (simulated grazing) and glyphosate application, mow and glyphosate application, plus an untreated control. Each treatment was replicated four times in a randomized block design located in a heavily E. fortunei–invaded forest remnant in Lexington, KY. Vegetation was surveyed in 2004, 2005, 2006, 2007, and 2013. Across years, most treatments were associated with reduced E. fortunei cover and increased total species richness. Over time, E. fortunei cover increased across treatments, such that by 2013, no difference in E. fortunei cover was detectible among treatments. Some differences in total and native species richness among treatments were still perceptible by 2013. Increased E. fortunei cover was correlated with decreased ground-layer species richness, native species richness, sapling richness, and sapling density. Light exclusion by plastic tarp, a method absent from many management recommendations, was unique in its long-term reduction of E. fortunei cover and its association with increased total species richness, but use of plastic tarps may have drawbacks. This study quantified the long-term community effects of removing an established invasive species from a mature, urban forest. Removal allowed native plants, notably woody species, to reestablish.

Japanese stiltgrass (*Microstegium vimineum*) is an invasive grass that poses a major threat to native biodiversity and restoration efforts in invaded areas. Preliminary research suggests that there may be potential biological control agents that can be used in a classical biological control program in the United States. We compiled a test plant list for submission to Technical Advisory Group for Biological Control Agents of Weeds. Using a phylogenetic approach, we chose 59 plants species that will help to

determine the host specificity of any potential biological control agents for Japanese stiltgrass. We will submit this test plant list to TAG-BCAW for review and comment. We also investigated non-chemical control methods for Japanese stiltgrass. Several studies suggest that mowing can be an effective control method, but none have explicitly explored the effects of mowing height. Additionally, no studies have

assessed the effectiveness of leaf mulch as a management strategy. We explored the

effects of mowing timing, mowing height, and leaf mulch addition on Japanese

stiltgrass in White Clay Creek State Park in Newark, DE. In 2014, we established

small plots at two sites: secondary forest understory and early successional field. Plots

were mowed at one of three heights (10 cm, 5 cm, 0 cm) in late August before seed

set. In 2015, we established small plots in secondary forest understory. Treatments

included leaf mulch addition in April (3 cm or 8 cm), mowing in July (0 cm or 10 cm),

and mowing in September (0 cm or 10 cm). Treatments were compared to untreated

plots. Vegetation surveys were conducted prior to treatment and at the end of the

season. Aboveground biomass was harvested and sorted into Japanese stiltgrass vegetation and all other vegetation before drying and weighing. Seed spikelets were

counted, dried, and weighed. All treatments except the 3-cm leaf mulch addition

reduced cover and biomass of Japanese stiltgrass. Mowing at ground level in July or

September were the most effective treatments, reducing Japanese stiltgrass cover,

biomass, and seed production by as much as 99%. The 8-cm leaf mulch addition also

reduced Japanese stiltgrass cover, biomass, and seed production, but not as effectively.

However, mowing at ground level also significantly reduced the cover and biomass of

the resident plant community, which implies that land managers should consider the

composition and desirability of the resident plant community when choosing their

management strategy.

Lastly, we explored the effect of cutting at different internodal regions on

Japanese stiltgrass growth in the field and stem cutting growth in the greenhouse. No

studies have investigated the effectiveness or viability of Japanese stiltgrass stem

cuttings, which could be useful for large-scale production for a biological control

program or future experiments. In July 2014, we established samples at two sites in

the White Clay Creek State Park System: a secondary forest understory and an early

successional field. Each sample had ten stems of Japanese stiltgrass that were all cut at

the same internodal region: below the first node, below the second node, below the

third node, below the fourth node, or below the fifth node. Treatments were compared

to uncut samples. Maximum height and seed spikelet presence data were collected

weekly. The stem remnants from the Japansese stiltgrass that was cut were planted in

the greenhouse and monitored for stem survival, maximum height, and date of first

seed emergence. At the end of the season, aboveground biomass from field and

greenhouse plants was harvested and seed spikelets were sorted into chasmogamous (CH) and cleistogamous (CL) seed spikelets before drying and weighing. In the field

experiment, all cutting treatments reduced Japanese stiltgrass biomass and seed

production. However, stems cut at higher nodes recovered better than stems cut at

lower nodes and had greater height, biomass, and seed production at the end of the

season. Additionally, Japanese stiltgrass height and biomass were greater at the

sunnier site. These results suggest that mowing height is important and effects may

vary by light conditions. In the greenhouse experiment, >99% of stem cuttings

survived and produced seed. Biomass and seed production did not differ among

treatments, but stem cuttings from higher nodes produced seed more quickly. These

results suggest that stem cuttings are an efficient and viable method for propagating

Japanese stiltgrass.

In many forest ecosystems, fire is critical in maintaining indigenous plant communities, but can either

promote or arrest the spread of invasive species depending on their regeneration niche and resprouting

ability. We examined the effects of cutting and burning treatments on the vegetative response (cover,

stem density) and root resources of Oriental bittersweet (Celastrus orbiculatus), a liana invasive to

North America that was introduced from East Asia. Treatments were control, spring cut, spring burn,

spring cut & burn, summer cut, fall cut, fall burn, fall cut & burn, and fall herbicide. Cover was reduced

the greatest by herbicide and summer cutting treatments, but increased more in the second year on moraine soils than on sandy soils. Burning and cutting & burning combined resulted in a resprout density four times greater than stem density prior to treatment for stems <2.5 mm diameter than cutting alone. For stems, across all diameter classes, there was a more than 100% increase in stem density with burning and almost a 300% increase in stem density with cutting & burning in the spring. Density of resprouts and root-suckers, and survival increased with increasing stem size. While cutting of C. orbiculatus during the growing season (summer) reduced total nonstructural carbohydrates by 50% below early growing season levels and 75% below dormant season levels, burning did not significantly reduce total nonstructural carbohydrates. Thus, Oriental bittersweet is quite responsive to burning as a disturbance and resprouting and root-suckering creates additional opportunities for growth and attainment of the forest canopy. The positive response of Oriental bittersweet to burning has important implications for management of invasive lianas in fire-dependent forest landscapes.

Question: Planting or seeding native species after control of invasive species can

limit re-invasion and hasten establishment of native species. Ruellia simplex

(Mexican petunia) invades floodplain forests in Florida, and is controlled with

glyphosate herbicide. Will herbicide application used to control this weed allow

establishment of native vegetation and limit R. simplex?

Location: Floodplain forest altered by stormwater run-off, Lake Jesup Conservation

Area, Sanford, FL, US.

Methods: We evaluated re-vegetation following herbicide application to control

R. simplex. For re-vegetation, we planted or seeded native species (Andropogon

glomeratus, Juncus effusus, Panicum longifolium, Solidago fistulosa) and

measured stem density, percentage cover, above-ground biomass and species

richness for 1 yr. We compared the results to those from control plots (i.e. no

herbicide, no re-vegetation) and plots where R. simplex was sprayed with herbicide

but not planted or seeded with native species.

Results: Unassisted re-colonization (i.e. plots where R. simplex was sprayed but

not planted or seeded with native species) did not result in native plant restoration.

Re-vegetation treatments (i.e. plots where R. simplex was sprayed and

planted or seeded with native species) did not restore native vegetation; nor did

re-vegetation treatments reduce R. simplex stem density, percentage cover or

biomass compared to control plots. However, total species richness, including

native and exotic species richness, increased in plots planted with a native plug

mix compared to control plots (i.e. no herbicide, no re-vegetation). Native species

failed to germinate in all seeding treatments. Plugs had adequate survival

(2–57% depending on species) but did not prevent re-invasion of R. simplex.

Re-invasion of R. simplex occurred in plots despite application of glyphosate herbicide

and re-vegetation treatments.

Conclusions: Re-vegetation by seeding or planting did not establish native vegetation

in the first year, instead, R. simplex reinvaded. Abiotic and biotic site conditions,

e.g. invasive species propagule pressure and altered soil nutrients, may

have limited seed germination and survival of planted seedlings. More research

is necessary to determine if a reduction in invasive species propagules through

repeated herbicide application coupled with planting native species results in

native plant restoration in the longer term.

Removal of invasive species is a common management goal to maintain native species

composition and wildlife habitat. Due to the time and effort necessary to remove invasive species, it is

important to clearly understand the benefits that will be gained through removal and what methods will

best achieve those results. This study evaluated the response of native plant understory communities

to the removal of invasive species that fell into a range of functional groups including perennial herbs

(*Microstegium vimineum, Liriope muscari*), vines (*Lonicera japonica, Lygodium japonicum, Hedra*

*helix*), shrubs (*Ligustrum sinense*), and trees (*Albizia julibrissin, Triadica sebifera*). Eight invasive

plant species were removed from twenty-seven 1-m2 plots for 8 y in an upland mixed hardwood–pine

and riverine woodland within the Ocmulgee National Monument, Macon, Georgia. Species richness,

herbaceous cover, and woody species number was measured 2 y before removal and each year during

removal. Mechanical removal reduced invasive species richness, cover, and number, however all measures of native species diversity remained unchanged. Overall, common species remained common but there was some turnover in less common species over the 8 y. During the study period, the area experienced an exceptional drought and it is likely that native species recovery after invasive species removal was hindered by these extreme weather conditions. Invasive species may be a determinant of native species composition, but environmental factors like drought may be a more important determining factor.

1. Most research on dynamics and impacts of plant invasions has evaluated patterns and effects over

brief time periods (i.e. <4 years). As such, little is known about the persistence of invasions and

their long-term impacts on native species.

2. To experimentally evaluate longer-term effects of invasions, we established field plots with native

tree and herbaceous species and then invaded half of the plots with the most widespread invasive

grass in the eastern United States (Microstegium vimineum). Over 8 years, we quantified invader

and native plant biomass, native plant diversity, and tree density and size.

3. Microstegium was dominant during the first 4 years of the experiment, constituting more than 60%

of herbaceous plant biomass in the plots, and native herbaceous biomass was 57% lower and diversity

was 44% lower in invaded vs. control plots. However, both Microstegium and herbaceous native species

declined in later years. By the end of the experiment, Microstegium was only 2% of community

biomass, and there was no difference in native herbaceous biomass in invaded and control plots.

4. We applied a fire treatment in years 6 and 7 to test if repeated disturbance is required to maintain

invader dominance and to evaluate how this common management practice in eastern US forests

affected invasive and native plants. Tree density was 65% lower and tree diameters were 28–51%

smaller on average in fire-treated compared with control quadrants, resulting in significantly greater

light availability in fire-treated areas. Consequently, Microstegium and native herbaceous species

biomass increased significantly where fire was applied. However, only native species were persistent,

and after 8 years, Microstegium was nearly absent, regardless of the fire treatment.

5. Synthesis. The invasive grass was initially abundant and suppressed native species, but invader

decline over time corresponded with succession to native herbaceous species dominance when fire

was applied, and to native tree dominance without fire such that after 8 years, the initial effects of

invasion were no longer apparent. Thus, our data provide some of the first experimental evidence

that while the initial effects of plant invasions can be dramatic, invaders and their impacts may

decline over time.

Fig buttercup is a perennial herb native to Europe, temperate Asia, and northern Africa. In eastern North America, fig buttercup competes with native spring ephemerals, complicating control techniques. If chemical control could be shifted earlier in the year, the potential to negatively impact spring ephemerals would be reduced. We tested glyphosate applications on fig buttercup in northern Virginia under three early phenological phases (preflowering, early flowering, and 50% flowering) to assess the effectiveness of early-season treatment. Treating when approximately half of the plants in the population were in flower resulted in a 95% decline in fig buttercup. Treating when the first

flower in the population had emerged resulted in a 90% decline. No later phenological phases were treated. Control of fig buttercup led to an increase in cover of Japanese stiltgrass, an invasive grass.

Soil diaspore banks are important temporal refuges for forest plants and, although

fern spore banks are prevalent, they are understudied in relation to forest management practices. As

urbanization increases, understanding the dynamics of spore bank resources in urban forests

becomes increasingly important. Urban forests tend to have a greater propensity for species

invasions and present challenges to plant species management not encountered in other managed

forests. We studied the impacts of Lonicera maackii removal on fern assemblages aboveground and

in diaspore banks in an urban forest. The diaspore bank assemblage had greater richness and

abundance of ferns compared to the aboveground assemblage. Six years after management

implementation, plots from which L. maackii was removed had fewer fern species and fewer ferns in

the spore bank than paired control plots in which the shrub was not removed. Two nonnative ferns

typical of residential ornamental plantings and with characteristics of potentially invasive species

were also found in control plot spore bank assemblages. Environmental variables including pH and

amount of leaf litter contributed to differences between spore bank fern assemblage structure in

removal and control areas. These results indicate the need for further studies of fern diaspore banks

in managed, urban eastern forests.

*Lonicera maackii* (Amur honeysuckle) is known to dominate the shrub layer of forests, resulting in a dramatic decrease in ground cover, species diversity, and changes in ecosystem processes such as decomposition. Land managers have been removing *L. maackii* for some time now, but few studies have examined the potential for reinvasion of a restored site. We measured the plant community and ecosystem function in a restored forest and field (*L. maackii* removal and seeding of native plants) and in a control forest (*L. maackii* dominating), along an urban riparian stretch, five through seven years after *L. maackii* restoration. We found that removing *L. maackii*, along with modest efforts to re-introduce native grasses and forbs, can result in a shift in the plant community and some ecosystem properties and processes. Restored sites had higher species richness, greater available soil nitrogen, and faster nitrogen mineralization rates. We also found lower soil pH and that more soil organic matter accumulated over time in the restored treatments. While we found that removal of *L. maackii* and seeding of native plants can lead to a change in some ecosystem processes within ten years in

riparian forests, we encourage scientists and managers to continue efforts on longer-term studies to better understand ecosystem structure and function after removal of the invader.

Fire-promoting, open-canopy ecosystems are under threat of conversion to a fire-deterring, closed-canopy condition due to woody encroachment. This conversion of vegetation structure has been fostered by introduced woody plant species. We performed a field experiment to quantify growth, survival, and establishment success of six invasive, woody species along a managed longleaf pine savanna–wetland gradient in the Sandhills of North Carolina, USA. We investigated the effects of prescribed fire, fire history, dispersal, and abiotic conditions on the invasibility of sites along the gradient. Across 18 study sites, seeds of the six woody species were sown using three sowing methods that mimicked primary and secondary dispersal; each site contained paired plots located in savanna and savanna-wetland ecotone vegetation communities. We identified sowing treatment, abiotic conditions, seedling size, and prescribed fire as important factors for controlling woody invasion, as they prevented

5 of 6 study species from establishing in the landscape. However, the landscape was not immune to

invasion. At the end of the 42-month study period, three species had established in unburned sites. In sites burned after seedling emergence, only one species, Pyrus calleryana, survived and established. We found P. calleryana survival and establishment to be a function of seedling size, soil humic matter content, and sowing treatment. Successful invasion and establishment of woody individuals in open-canopied systems increases the likelihood of fire-deterrence and further woody encroachment, threatening ecosystem integrity.

Invasive glossy buckthorn (Frangula alnus) hampers management of white pine (Pinus strobus) in the northeastern USA, especially when these species co-establish following harvest activities. Our objective was to test the effects on pine sapling growth of a simple, quick, and novel silvicultural procedure involving local buckthorn stem removal. We identified 75 five-year-old pine saplings in a Durham, NH, forest regeneration area that was clearcut in 2009 and which was heavily invaded by buckthorn. All selected pine saplings were surrounded primarily by glossy buckthorn. Around each of 50 of these pine saplings, a 1 m radius was cleared (‘cut only’ treatment) and for half of these there was a follow-up herbicide application (‘cut +herbicide’ treatment). Remaining saplings were untreated controls. After one growing season, pines responded to treatment with increased terminal leader biomass (+75%), basal stem diameter (+12%) and bark starch (+140%). Treated pines displayed even greater diameter increase (+29%) after two growing seasons. None of these variables differed across the two treatments. Height of treated pines did not differ from controls, even after the second growing season. When herbicide was used, there were 86% fewer buckthorn sprouts in treated areas, but pine mortality

was five times greater (n=5) than in the cut only treatment (n=1). Our results show that, regardless of

herbicide use, those pines cleared of surrounding vegetation and not subject to post-treatment mortality exhibited increased vigor and growth, suggesting a greater potential to eventually outgrow competing buckthorn and thus more rapidly reach commercial size.

Non-native glossy buckthorn (Frangula alnus Mill.) is invasive in forests of the northeastern

USA but little is known of its effects on tree regeneration. We tested whether killing buckthorn

stems before logging reduces its post-logging abundance and increases the density and height of

eastern white pine (Pinus strobus L.) seedlings. Three 0.4 ha plots were clearcut, three were thinned,

and three were left as controls. Each plot had previously been divided into three subplots that

received different buckthorn treatments during the two years before logging. Buckthorn treatments

were (1) stems cut at base five times; (2) stems cut once then heat killed four times; (3) untreated

control. Three years post-logging, buckthorn density and stem height were unaffected by logging but

equally reduced by the two buckthorn treatments. Buckthorn reduction increased density and height

of pine seedlings, and seedling height also increased with logging. In the fifth year post-logging,

pine height growth and biomass were greater in clearcut than in thinned treatments, greater in areas

of buckthorn removal and, within treated subplots, greater in areas with low buckthorn density

than in thickets of recovering buckthorn. Thus, although buckthorn inhibited regenerating pine,

pre-logging destruction of buckthorn stems reduced such competition for at least four years.

Biological invasions by woody species in forested ecosystems can have significant impacts on forest management and conservation. We designed and tested several management options based on the physiology of Chinese tallow (*Triadica sebifera* [L.] Small). Specifically, we tested four treatments, including mastication, foliar herbicide, and fire (MHfolF), mastication and foliar herbicide (MHfol), dormant-stem herbicide and fire (HdorF), and dormant-stem herbicide (Hdor), to determine their efficacy in reducing the density and regeneration of this highly invasive tree species. Mastication treatments were significant in reducing density the first year but not after 3 years. Prescribed fire significantly reduced density combined with previous treatments. Regeneration coverage was highest on those sites with mastication, which was not affected by the addition of prescribed fire. Overall, we found that the most comprehensive treatment (MHfolF) was more effective in reducing density but

did not result in a difference in the amount of regeneration after treatment.

Land-use and forest management practices may facilitate the invasion success of non-native plants in forests. In this study, we tested if agricultural land abandonment and subsequent forest management contributed to the invasion success of Chinese tallow (Triadica sebifera (L.) Small) in the maritime forest of Parris Island, SC. We compared the abundance of Chinese tallow between disturbed and remnant forests, described Chinese tallow establishment patterns in relation to forest management activities, and characterized the structure and composition of disturbed and remnant forests in order to better understand relationships between stand characteristics and invasibility as indicated by Chinese tallow abundance. We found that stands in agricultural land use in 1939 but reforested with slash pine (Pinus elliottii Englem.) since the 1970s (i.e., disturbed forests) had significantly more Chinese tallow stems than stands that remained forested since 1939 (i.e., remnant forests). Remnant forests had significantly greater woody species richness and were more variable in species composition and structure than disturbed forests. Disturbed forests were dominated by early successional, shade intolerant species with a denser woody understory, while remnant forests included species associated with late successional habitats. The number of forest management events was positively associated with Chinese tallow abundance, explaining 34% of the total variation in stem density. Chinese tallow individuals commonly established immediately after forest thinning and their numbers increased exponentially through time. Our findings

support that Chinese tallow establishment was strongly related to anthropogenic disturbance including historical agricultural land-use and forest management. This suggests that Chinese tallow invasion may be a symptom, rather than the driver, of the ecological degradation induced by persistent human perturbations.

Both invasive species and deer herbivory are recognized as locally important drivers

of plant community dynamics. However, few studies have examined whether their effects are

synergistic, additive, or antagonistic. At three study areas in southern New England, we examined

the interaction of white-tailed deer (Odocoileus virginianus Zimmermann) herbivory and three levels of invasive shrub control over seven growing seasons on the dynamics of nine herbaceous and shrub guilds. Although evidence of synergistic interactions was minimal, the separate effects of invasive shrub control and deer herbivory on plant community composition and dynamics were profound. Plant communities remained relatively unchanged where invasive shrubs were not treated, regardless if deer herbivory was excluded or not. With increasing intensity of invasive shrub control, native shrubs and forbs became more dominant where deer herbivory was excluded, and native graminoids became progressively more dominant where deer herbivory remained severe. While deer exclusion and intensive invasive shrub control increased native shrubs and forbs, it also increased invasive vines. Restoring native plant communities in areas with both established invasive shrub thickets and severe deer browsing will require an integrated management plan to eliminate recalcitrant invasive shrubs, reduce deer browsing intensity, and quickly treat other opportunistic invasive species.

North America’s remaining natural grassland communities provide habitat for native

flora and fauna. We conducted a study to compare the efficacy of herbicides in control of the invasive Japanese honeysuckle (*Lonicera japonica* Thunb.) applied at times when most native plant species are dormant. Six herbicide mixtures (glyphosate, glyphosate + imazapyr, glyphosate + imazapic, imazapyr, triclopyr + diflufenzopyr, and metsulfuron methyl + diflufenzopyr) were applied once each in three seasons to assess the effect of application timing of each mixture on honeysuckle control. Herbicides were applied with a CO2 pressurized sprayer at three sites in a randomized complete block design. Pretreatment sampling indicated that Japanese honeysuckle constituted over 70% of plant cover at the study sites. Post-treatment sampling was conducted 60 days, 180 days, 420 days, and 540 days after the final application. All mixtures in all application seasons decreased percent cover of honeysuckle with varying effectiveness. Results indicate that the glyphosate, imazapyr, and metsulfuron methyl + diflufenzopyr mixtures are particularly effective at controlling Japanese honeysuckle when applied at any time between October and April with suitable temperatures. Many native grasses and broadleaf forbs not found during pretreatment sampling also emerged post-treatment, benefiting from either application

timing or indicating herbicide tolerance.

For many of the shrub species invading temperate

deciduous forests, extended leaf phenology contributes

substantially to annual carbon gains, helping to make

possible rapid growth and spread. We carried out a pair

of proof-of-concept studies to evaluate the susceptibility

of such shrubs to foliar herbicide treatment during the

period of delayed senescence, i.e. well after it is typically

attempted. We first evaluated leaf-level physiology in

four species that lose leaves late in autumn; photosynthetic

rates were comparable (80–111%) to those

reported for the same species in summer. While preliminary,

this finding provides a strong indication that

diverse shrub taxa remain susceptible to control into

late autumn. In addition, we conducted a field trial

involving one of these species (Lonicera maackii) to

directly evaluate the effectiveness of foliar treatment in

November; applications included glyphosate and two

concentrations of aminocyclopyrachlor plus metsulfuron

methyl. Treatments killed (72%) or severely

injured (14%) target plants, inducing greater cambial

damage in plants that retained greater fractions of their

canopy or had smaller canopy widths; there were no

statistically significant differences among application

types. This study demonstrated that late autumn can be

a viable period in which to treat weedy species that

delay senescence strongly, such as the many invasive

Lonicera species in North America. Given that climate

change and urbanisation are further delaying senescence

in invasive plant populations, our study serves as a call

for further investigation into what promises to be an

increasingly viable opportunity for weed control in

deciduous forests.

Cogongrass [Imperata cylindrica (L.) Beauv.] is an invasive grass in the southeastern United

States, and its impacts strongly affect the region, especially Florida. Herbicide strategies

have been limited to glyphosate in natural areas and imazapyr in managed pine forests and

non-crop areas where its soil residual activity is of less concern. This lack of options has raised

concern for herbicide resistance, which has never been documented for I. cylindrica. Land

managers have also reported variable I. cylindrica control, especially with glyphosate.

To determine whether herbicide resistance was a possible explanation, we examined

glyphosate response of I. cylindrica from 12 Florida populations. We also tested

aminocyclopyrachlor with and without glyphosate and flumioxazin with glyphosate. Results

indicated that herbicide performance was similar across I. cylindrica populations: glyphosate

and aminocyclopyrachlor reduced I. cylindrica biomass by 78% and 76%, respectively, and the

combined tank mix reduced cogongrass biomass by 91%. Flumioxazin tank mixed with

glyphosate did not improve control compared with glyphosate alone. There were no

differences in pretreatment I. cylindrica shoot height, with the exception of two panhandle

populations that were shorter. Subsequent harvests indicated few differences in shoot and

root plus rhizome weights among untreated controls for almost all populations, with the

exception of one of the initially shorter panhandle populations. Our findings indicate that

variability in glyphosate efficacy, as suggested by managers, is unlikely due to any conferred

resistance. Other abiotic factors such as drought and shade and applicator factors such as

carrier water quality should be examined to better understand this issue. Additional studies

examining non-target impacts of aminocyclopyrachlor should be conducted to determine its

potential fit into I. cylindrica management.

Since its introduction to the United States in 1852, Chinese privet (Ligustrum sinense Lour.)

has spread throughout the Southeast, invading many natural areas. Manual control by cutting

or shredding is one of the most common strategies many land managers employ. However,

rapid sprouting from the root collar and lateral roots commonly results in poor control.

Cutting followed by either glyphosate or triclopyr application to the stumps is generally

effective, but the efficacy of these herbicides in relation to treatment timing and L. sinense

root collar diameter has not been evaluated. The objective of this experiment was to

determine the effectiveness of glyphosate and triclopyr cut stump treatments compared with

cutting alone at spring and fall timings across a range of L. sinense size classes. Studies were

conducted at two locations in Auburn, AL. Treatments included cut stump + no herbicide, cut

stump+ glyphosate (120 g L-1), or cut stump + triclopyr (90 g L-1). Treatments were applied

to at least 50 experimental units each at April and November timings. Root collar diameter

was recorded for each stem, stems were cut 2.5 cm above the ground, and herbicide

treatments were applied within 30 s. Ligustrum sinense mortality and sprouting were

quantified 6, 12, and 18 mo after treatment. Both glyphosate and triclopyr amine were very

effective in controlling L. sinense at both spring and fall timings. However, glyphosate

provided slightly better results than triclopyr when lateral sprouting was included.

Application timing also was significant, with a lower percentage of sprouting following

November treatments than April treatments. Stem size influenced treatment success, as larger

stumps tended to sprout more than smaller stumps. These results indicate L. sinense can be

controlled with cut stump herbicide treatment using either glyphosate or triclopyr with spring

or fall timings at concentrations much lower than typically used.

Invasive shrubs in forest understories threaten biodiversity and forest regeneration in the

eastern United States. Controlling these extensive monotypic shrub thickets is a protracted process

that slows the restoration of degraded forest land. Invasive shrub removal can be accelerated by

using forestry mulching heads, but evidence from the western United States indicates that mulching

heads can promote exotic species establishment and mulch deposition can reduce native plant species abundance. We compared the effectiveness of the mulching head and the “cut-stump” method for controlling the invasive shrub Amur honeysuckle (Lonicera maackii), as well as their impacts on native plant community recovery, in mixed-hardwood forests of Indiana. After two growing seasons, mulching head treatment resulted in greater L. maackii regrowth and regeneration. The recovery of native plant abundance and diversity following shrub removal did not differ between the two methods. However, mulch deposition was associated with increased abundance of garlic mustard (Alliaria petiolata), an invasive forb. Increasing mulching head treatment depth reduced L. maackii regrowth, but additional study is needed to determine how it affects plant community responses. The mulching head is a promising technique for invasive shrub control and investigating tradeoffs between reducing landscape-scale propagule pressure and increased local establishment will further inform its utility.

The Appalachian region of the United States is home to the largest temperate deciduous

forest in the world, though surface mining has caused significant forest loss. Many former

coal mines are now dominated by invasive plants, which often inhibit establishment of

desirable species, especially slower-growing native trees. Autumn-olive (Elaeagnus umbellata

Thunb.) is a nonnative, nitrogen-fixing shrub that was historically planted on former

coalfields, but now impedes reclamation. To better understand the influence of E. umbellata

management practices on hardwood establishment, we evaluated two common management

practices: cutting and cut stump herbicide treatment. Planted native tree species, including

black cherry (Prunus serotina Ehrh.), pin oak (Quercus palustris Münchh.), and red maple

(Acer rubrum L.), were monitored for survival and performance over two growing seasons

following E. umbellata removal. In each plot, we also measured plant-available nitrate (NO3

-) and ammonium (NH4 +) in soils using ionic exchange membranes. At the end of the first

growing season, native tree survival was high, and the presence or absence of E. umbellata had

little effect on tree survival or growth, despite the higher plant-available nitrate where

E. umbellata was present. By the end of the second growing season, native tree survival

dropped to 20% to 60% and varied among E. umbellata treatments. Survival was highest when

E. umbellata was cut and treated with herbicide, though tree growth was similar across all

treatments without E. umbellata. When establishing native trees to replace E. umbellata,

cutting and herbicide application treatment of the invader resulted in the highest overall

efficacy (100% control), though the most cost-effective method may be to simply cut mature

stands despite regrowth, as this resulted in equivalent native tree growth over 2 yr. While this

allowed E. umbellata regeneration, it provided sufficient invader control to allow initial tree

establishment. Cutting and herbicide application treatment resulted in less E. umbellata

regeneration and appears to provide greater assurance that established trees will persist over

the long term.

*Lonicera maackii* (Amur honeysuckle) is a non-native species that has invaded forest stands throughout the eastern United States. This research examined using aerially applied glyphosate in autumn 2013 to control *L. maackii* in oak-hickory forest stands in Missouri, U.S.A. We targeted the spraying time period when *L. maackii* was still green and most native plants were dormant. Across treatment units, the mean difference in *L. maackii* stem density significantly declined (*p*=0.004) by 5.4 stems per plot from spring 2013 to summer 2014 when compared to control units which increased by 1.8 stems per plot. Treated units with a high initial infestation level of *L. maackii* (*>*50% cover) had a significant (*p*=0.004) decline in the mean difference in *L. maackii* cover of -50.0% per plot between spring 2013 and summer 2014 compared to an average increase of 9.2% in the controls. Similar results were found for treated units with a low initial infestation level of *L. maackii* (10–50% cover). Mortality of native overstory and understory trees post-treatment was negligible. In the ground layer of forest stands with a low initial *L. maackii* infestation level, native non-spray-sensitive forb cover per plot significantly increased (*p*=0.023) relative to controls between summer 2013 and summer 2014 while native spray-sensitive species cover significantly decreased (*p*=0.021) during the same period. These results suggest that an aerial application of glyphosate can provide an *L. maackii* control option, but with trade-offs in compositional shifts in the native ground-layer vegetation.

The relevance of diversity–invasibility studies to the conservation of biodiversity has been

questioned on grounds that species-rich assemblages may not deter invasion by competitively superior invaders. Few studies have compared the competitive effects of invaders on native species individually vs. in mixture. Using field experiments, we measured competition between an invasive grass, *Microstegium* *vimineum*, and six species of large native groundcover plants. We first examined whether planting six native species was more effective than planting an equivalent number of a single species in competitively suppressing *Microstegium*. Using a split-plot design, naturally occurring patches of *Microstegium* were treated with one of the two planting treatments or a control. We monitored *Microstegium* emergence and percent cover through 2015 and into the spring of 2016. We then tested the competitive effect of *Microstegium* on plantings of native species within *Microstegium* patches using a removal experiment in 2016. Although initial transplant survival was high in spring 2015, subsequent mortality during the growing season was also high in both planting treatments and, thus, there was no evidence of competitive suppression of *Microstegium*. In contrast, removal of *Microstegium* benefited the growth (and flowering)

of native transplants in 2016, and all native species were more or less equally affected. These results suggest that neither high native diversity nor the presence of certain native species is likely to be effective in constraining the abundance of invaders demonstrated to have strong competitive effects on most or all native species under conditions that favor both native diversity and the invader.

We designed several treatments to directly control an invasive tree, Chinese tallow [*Triadica sebifera* (L.) Small] on Parris Island Marine Corps Recruit Depot located in Beaufort, SC. We examined the response of the plant community to four treatment series: 1) control (C), 2) mastication (M), 3) fire (F), and 4) combination of mastication and fire (MF). We found that mastication significantly reduced midstory density of all species. However, without fire, midstory density increased to levels similar to those without mastication within 2 years. The MF treatment reduced midstory density over the course of the study, resulting in an increase in important oak species. The MF treatment also increased ground flora richness, without reducing the richness of regenerating tree species. Our results show that MF resulted in a positive response from the native community.

Callery pear (Pyrus calleryana Decne.) was introduced to North America as an ornamental

tree in the early 1900s. Due to widespread planting, P. calleryana has become common

throughout the eastern United States and has invaded natural areas, especially disturbed

areas. Prescribed fire is a common management technique in prairie ecosystems to mimic

natural disturbances. We tested the effectiveness of prescribed fire as a control technique for

P. calleryana in a managed prairie system. Fire top-killed all established P. calleryana

individuals. However, these individuals responded to fire with 3 to 4 epicormic sprouts each.

Similar sprouting behavior occurred in 2-yr-old seedlings. Exposed seeds, fruits, and 1-yr-old

seedlings were killed by fire. Established P. calleryana were single-stemmed individuals before

exposure to fire. After the prescribed fire, they all were multistemmed, which increased the

potential flower-bearing stems within the prairie. We conclude that fire alone is not a suitable

technique for managing P. calleryana invasion. Cut and herbicide application methods are

labor-intensive. However, combining cut and spray methods with prescribed fire may be

effective. Fire removes standing grass and forb biomass, leaving exposed P. calleryana stems,

which would make locating individuals and directly applying herbicides easier.

*Lonicera maackii* is a non-native shrub that has invaded eastern and midwestern North American deciduous forests, altering the ecosystem functions and reducing biodiversity. Managers tasked with controlling *L. maackii*, being resource limited, require effective methods that are quick and easy to use without inflicting extensive nontarget damage. This study explores prescribed fire and seasonal basal applications of triclopyr as control methods and examines their extent of off-target damage. Paired-split plots were established to implement seasonal basal bark treatments within burned/unburned units where individual *L. maackii* were tracked to determine mortality and the hyperlocal impacts of management. Basal bark treatments were found to kill 98.4% of *L. maackii* without regard to the dormancy status of *L. maackii*. Off-target cover was reduced similarly for all herbicide application seasons while richness and Shannon diversity showed statistically different seasonal impacts but were biologically small. Prescribed fire did not impact *L. maackii* mortality, interact with herbicide efficacy, or alter the extent of off-target damage post-treatment. Basal bark applications of triclopyr are an effective means of control, unrelated to application timing.

Urban forests are threatened by land cover change and invasive species but little is known about how they are changing over time. Furthermore, although management is sometimes used to maintain native communities, we have little information about the long-term outcomes of forest management actions. In this study, we examined current status and long-term changes in 35 urban forest plots in DuPage County, Illinois (USA). From 1979 to 2014, in five-year intervals, presence/absence of all woody species was recorded in the plots. Environmental conditions in and surrounding the plots were measured in the field or with GIS. With these data, we analyzed

trends and changes in the community, looked for evidence of biotic homogenization, and examined drivers of non-native species. We found a significant change in community composition over time but no evidence of biotic homogenization in either managed or unmanaged plots. There was a significant increase in non-native species richness over time but no change in richness of other species groups. Vegetation management such as fire prescription and clearing seemed to somewhat decrease the number of non-native species, but did not increase the number of more desirable species. Distance to agriculture and deer control frequency determined the variation in both non-native species abundance and richness. Overall, we conclude that the management activities

were able to slow down the spread of some undesirable species but did not prevent their increase over time. More consistent management, as well as collaboration with stakeholders outside the forest preserves, is likely needed to maintain native communities.

The invasive shrub, *Lonicera maackii*, is known to change forest ecosystem communities and functions; however, few have studied the potential for this prolific invader to return after forest restoration. We studied the forest understory, canopy, seed bank, and incoming *L. maackii* seed rain in a riparian urban forest five to nine years after *L. maackii* removal and restoration efforts. We found the restored areas maintained a native canopy, but by nine years post-management efforts,

*L. maackii* was becoming more important along multiple transects due to many small individual seedlings. The restored areas had greater herbaceous cover and species richness when compared to the control area (*L. maackii*-dominated). *Lonicera maackii* was not common in the seed bank during the study but was more prevalent in the seed rain of the restored forest with a tree canopy than in the restored open field without a tree canopy. While our results support the premise that removing *L. maackii* returns the community to a more native state, the study also shows that the native

state would not last without additional minor intervention. Monitoring beyond ten years post-removal will be key to telling the whole reinvasion story, but management efforts every five to ten years could suffice to keep a restored forest dominated by native species.

To test the impact of management intensity on long-term success of ecological restoration in urban forest patches, we analyzed vegetation structure and community composition in 3 large urban parks in New York City, 15–20 years after restoration was initiated by removal of climbing invasive woody plant species and planting of native trees. Analysis using data from 30 plots, 7626 records of species abundance, and >6000 records of management reveals significant relationships between differences among plant communities of restored plots and intensity of restoration treatment, measured as number of days on which restoration management activities occurred. Less intense management was also more episodic, suggesting that consistent timing is also important to

achieving desired long-term outcomes in plant community composition and structure. These findings indicate the importance of site-specific approaches and consistency in ongoing management to long-term positive outcomes of ecological restoration in urban forest patches.

Invasive plant species suppress native

trees through a variety of mechanisms. A non-native

shrub, Berberis thunbergii, has been shown to depress

native tree seedling densities in eastern North American

deciduous forests, but the mechanisms remain

unclear. We attempted to identify the mechanisms

leading to decreased native tree seedling densities in

Berberis-invaded understories by experimentally

measuring survivorship and growth of three common

eastern deciduous tree seedlings, Prunus serotina,

Quercus alba, and Q. velutina. First, we reared native

tree seedlings in soil samples extracted from Berberis invaded

and control forest plots to determine if early

growth and survival varied between medias. Then, we

introduced surviving seedlings into three classes of

in situ field subplots: control (outside Berberis invasion),

invaded (Berberis present), and managed subplots

where Berberis removal occurred following nonchemical

best practice guidelines. Slight decrease of

early-stage seedling survivorship and growth occurred

in extracted soils from invaded plots. Seedling

survival differed between field subplots, with seedlings

either showing no differences between invaded

subplots (Q. alba) or faring better (P. serotina and Q.

velutina) compared to managed subplots. Invaded

subplots were about 1.18–1.30 \_C cooler with

583–709 lumens m-2 less light exposure compared

to control or managed subplots. Additionally, managed

and invaded subplots had increased moisture

levels (12.0–14.9%) compared to control subplots.

Seedling compromise was due to a legacy effect from

Berberis disruption via soil sample extraction and/or

management. Our findings contrast with other studies

that show dense, invasive species outcompeting native

tree seedlings and unsuccessful native restoration in

Berberis stands.

In eastern deciduous forests of North America, invasive shrubs are increasing in richness and

abundance at the expense of native species across taxa. Invasive shrubs create an understory

that is more dense than both recent and historical preinvasion conditions. Interest in invasive

shrub removal to restore native habitat is growing, but our understanding of natural

regeneration following treatment of a diverse invasive shrub community is lagging. Using an

invasive shrub removal experiment, we provide insight into the effect of repeated removal of a

suite of 18 invasive shrub species dominated by border privet (Ligustrum obtusifolium Siebold

& Zucc.). In 2009, invasive shrubs were removed from five 20-m-diameter treatment plots,

each with a paired control plot. Seven years later, we find an increase in plant diversity, native

understory species abundance, and overstory tree species regeneration for individuals under a

meter in height. For plants 1 to 4 m in height, the removal treatment has a positive effect on

understory woody species, but there has been no change in regenerating overstory trees. A

lack of overstory tree regeneration to greater heights is not surprising, given the time frame

and the closed-canopy conditions. However, other factors, such as white-tailed deer

(Odocoileus virginianus Zimmermann) browse, could be serving as an impediment to taller

tree regeneration in the forest understory. An ambient sampling approach in unmanaged,

invaded, and uninvaded forest has been used in other studies to estimate the potential impacts

of invasive shrub species to native plant communities. However, in this study the ambient

sampling approach underestimated the impacts of invasive shrubs compared to their

experimental removal. Overall, invasive shrub removal increased plant diversity and allowed

passive natural regeneration of native plants that exceeded native cover in the unmanaged,

ambient forest under minimal invasive shrub abundance.

Species-specific growth rate and its response to interspecific competition can determine the winners and losers in forest stand development following disturbance. In the southeastern US, Chinese tallow [*Triadica sebifera* (L.) Small], a non-native, fast-growing, invasive tree readily displaces native species. However, its rapid early height growth may not compensate for its shorter ultimate stature and earlier senescence when competing with fast growing native tree species of larger stature and longer lifespans. In this study, we compared the growth and competitiveness of Chinese tallow to two native species, slash pine (*Pinus elliottii* Englem.) and sweetgum

(*Liquidambar styraciflua* L.), using two datasets representing different spatial scales. Plot data from Parris Island, South Carolina obtained by conducting stem analyses, were used to determine height and diameter growth patterns in relation to age and competition. Landscape-scale data from the U.S. Forest Inventory and Analysis (FIA) program were used to determine the relationship of relative importance value (rIV) and periodic annual DBH increment along a competition gradient. We found that Chinese tallow displayed faster diameter and height growth initially, but slowed down considerably after eight years, compared to slash pine. Slash pine was the least tolerant of competition among the three species, and competition had less effect on the growth of Chinese tallow and sweetgum. Our findings suggest that stand-replacing disturbance favors the rapid growth of Chinese tallow for the first decade, even under intense competition. Further, the establishment of native tree species would require effective control of Chinese tallow immediately following disturbance. Efforts to manage Chinese tallow while promoting the growth of native trees may include site preparation to reduce initial abundance of this invasive species, artificial regeneration of native species to provide them ‘head-start’ during the first few years of

growth, and release treatments early in stand development to reduce competition for native species.

In the Gulf of Mexico coastal region, prescribed fire has been increasingly used as a

management tool to restore declining native ecosystems, but it also increases the threat posed by

biological invasion, since the treated sites are more susceptible to invasive species such as Chinese

tallow (Triadica sebifera). We chose Mississippi Sandhill Crane National Wildlife Refuge (MSCNWR), a fire-managed landscape, to examine the potential effect of prescribed fire and landscape/community features on tallow invasion and spread. We took a complete survey of roadways and fire lines for tallow and measured a systematic sample of 144 10 \_ 3 m2 rectangular plots along two selected roadways and a simple random sample of 56 0.04-ha circular plots across burn units. We used pair correlation function for marked point pattern data, zero-inflated negative binomial models for count data, as well as multivariate Hotelling’s T2 test, to analyze the effect of prescribed fire and landscape/community characteristics on tallow invasion and spread along habitat edges and into interiors. Our results show that tallow spread along habitat edges and into interiors in a spatially clustered pattern. Tallow invasion risk decreases with the distance to seed trees and shrub coverage, and with the time since last fire if seed trees are outside the effective seed dispersal range (~300 m), but increases with the time since last fire if seed trees are within the effective seed dispersal range. Tallow seedling (\_2 years old) densities increase with the time since last fire and with increasing overstory tree basal area, but decrease with the distance to seed trees. Tallow-invaded interior plots have significantly shorter mean fire return intervals (2.7 years), lower shrub coverage (8.6%), and are closer to edges (20.3 m) than non-invaded plots (4.3 years, 18.4%, 167.6 m, respectively).

The invasive shrub *Rhamnus cathartica* L. (common buckthorn) dominates the understory of many temperate forests of eastern North America. Common buckthorn outcompetes native understory species for light, forming monospecific stands that suppress plant and animal diversity. Removing common buckthorn is a common management priority within its invasive range. In recent years, forestry mowing has become popular in removing common buckthorn. This control method removes a midstory of common buckthorn, increasing light availability to the lower understory (which could favor buckthorn regeneration) and creating a layer of mulch on the forest floor (which could suppress buckthorn regeneration). Here we investigate whether and how increased light availability and increased ground cover (mulch) resulting from forestry mowing affects buckthorn

regeneration from the seed bank. We evaluated buckthorn germination, survival, and early growth in response to a factorial combination of shading treatments and buckthorn mulch depth treatments in an oak forest in Minnesota, U.S.A. Increased light availability increased buckthorn seedling survival and growth, whereas increasedmulch depth did not significantly affect

the number of buckthorn establishing from seed over one growing season and winter. Thus, removing buckthorn by forestry mowing (or any other method) is likely to facilitate buckthorn reestablishment by increasing light availability at the ground.

Ailanthus altissima, perhaps the best-known example of an entrenched invasive weed tree in North America, was introduced to the Eastern U.S. roughly 240 years ago. The biological control of A. altissima has been a topic of interest since the discovery of a destructive naturally occurring Verticillium wilt disease of A. altissima in 2002. After nearly 20 years of research, an augmentative commercial release of this disease agent, Verticillium nonalfalfae, could be initiated in the near future. However, a few questions still remain: i) does the interaction of V.

nonalfalfae with the less virulent V. dahliae inhibit the biological control effectiveness of V. nonalfalfae, and ii) do climate and A. altissima stand variables affect this biological control’s efficacy? To help answer these questions, a three-year field inoculation study including 3,245 A. altissima trees in 13 sites across four hardiness zones of Pennsylvania and Virginia, U.S. was implemented. Disease progressed and spread at similar rates in A. altissima trees co-inoculated with V. nonalfalfae and V. dahliae as those inoculated with V. nonalfalfae alone, with no

indication of disease progression changing in co-inoculated trees. Verticillium dahliae alone resulted in lower levels of disease, and no disease spread. Similar results were seen in a supplemental greenhouse inoculation study. Despite slight regional variation of disease progression and spread correlated to climate or stand variables, V. nonalfalfae always caused severe disease and spread rapidly to other A. altissima trees through the forested plots. Our results support the use of V. nonalfalfae as a biological control agent throughout the mid-Atlantic

region of the U.S. regardless of stand and climate variables, and including sites where trees are already infected with V. dahliae.

There is emerging interest in using prescribed fire to manage bottomlands for wildlife habitat, invasive species control, and overall forest function. We evaluated the feasibility of conducting prescribed fires in bottomland hardwood forests in west-central Alabama as part of a broader strategy to control the invasive shrub Chinese privet (*Ligustrum sinense*). We used 22 small-scale plots (0.04 hectares) in areas with residual slash from privet cutting operations and initiated prescribed fires on each to assess the overall feasibility and the relation of in-stand weather (i.e., microclimate), stand composition, and litter measurements to fire behavior. Overall, prescribed fire ignition was difficult, and only half the trials successfully burned >10 percent of the plot. We found that stand composition was most correlated with percent plot burned, and plots with higher proportions of tree species with flammable leaf traits (e.g., *Quercus* spp.) tended to burn best. Although further investigation is warranted, managers interested in using prescribed fire for bottomland hardwoods likely face short time windows and limited forest conditions in which fires can be reliably set.

To successfully reduce overall invasive plant cover over time, an effective treatment plan must be

established such that mortality exceeds new colonization and resprouting growth rates. However,

few evaluations of the effects of long-term, consistent treatment at different intervals exist. We report the effects of treatment intensity on Old World climbing fern [Lygodium microphyllum (Cav.) R. Br.], Brazilian pepper (Schinus terebinthifolia Raddi), and punktree [Melaleuca quinquenervia (Cav.) S. F. Blake] as part of a large restoration project that has been underway for 6 yr in Telegraph Swamp at Babcock Ranch Preserve, a 27,520-hectare (68,000-acre) conservation area in Florida, USA.We found that at the end of the 6-yr period, for all three species, average live cover did not exceed 5% across all transects. In addition, dead foliar cover was higher than live cover for all three invasive plants, indicating progress toward restoration goals.We also found that percent live cover of L. microphyllumwas significantly reduced only after four or more treatments were applied during the 6-yr period, as opposed to when three or fewer treatments were applied. Reductions in percent cover of live foliage were apparent only when the treatments were applied more often than biennially, as opposed to less often than biennially. Additionally, we found higher L. microphyllum cover in clear-cut and replanted cypress stands than in natural stands. Based on these findings, we conclude that treatments applied four or more times, or more often than biennially, were more effective at significantly reducing advanced invasions of L. microphyllum, S. terebinthifolia, and M. quinquenervia, especially where previous management activities or their effects may have increased the cover of invasive plants.

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.

Greater knowledge of plant flammability can improve prescribed fire effectiveness and wildfire mitigation strategies by improving fire behavior predictions in physics-based fire models and supplementing Firewise plant listings with flammability indices. Seasonal and regional changes in flammability parameters were estimated for yaupon (*Ilex vomitoria*), Chinese privet (*Ligustrum sinense*), greenbrier (*Smilax* spp.), and Chinese tallow (*Triadica sebifera*) within the Post Oak Savannah, Blackland Prairie, and Pineywoods Ecoregions of Texas. Foliage (yaupon, privet, and greenbriar) and wood (tallow) samples were collected in the dormant (February) and growing (August) seasons. Wood samples were collected from Chinese tallow due to dormant season leaf-off. Samples were evaluated using thermogravimetric analysis to estimate relative spontaneous ignition temperature (RSIT) and gas-phase maximum mass loss rate (GP-MMLR). RSIT and GP-MMLR are estimates of plant ignitability and combustibility. Yaupon was the most ignitable species during both seasons and across all three ecoregions. Chinese privet dormant season ignitability was similar to yaupon in the Post Oak Savannah and Blackland Prairie. Greenbrier exhibited the greatest growing season combustibility combined with moderate ignitability. Chinese tallow wood exhibited substantially greater ignitability and combustibility in the growing season. Collectively, all species exhibited seasonal and ecoregion variances in ignitability, while combustibility varied little relative to season and ecoregion. These data provide insight into potential species-specific contributions to fire behavior that may aid in more informed fire management planning.

Callery pear (Pyrus calleryana Decne.) is rapidly spreading in the United States, gaining attention

in the last two decades as a serious invasive pest. Recommended control methods include

foliar, basal bark, cut stump, and hack-and-squirt application of herbicides, but there are few

published studies with replicated data on efficacy. Four readily available herbicidal active ingredients and a combination of two active ingredients were tested for control efficacy against

P. calleryana in old-field areas and loblolly pine (Pinus taeda L.) understory. Basal bark applications

(triclopyr, triclopyr þ aminopyralid), foliar applications (glyphosate, imazapyr), and a

soil application (hexazinone) effectively killed P. calleryana with the exception of hexazinone at

one site, where rainfall may not have been optimal. Foliar application of glyphosate provided

the most consistent control. Our results demonstrate efficacy of registered herbicide formulations

for P. calleryana control in two geographic locations and two habitat types. The need for

development of integrated pest management programs for P. calleryana is discussed.

Understanding the long-term success of ecosystem restoration following invasive plant removal is challenging. Long-term experiments are costly and slow to yield results, while management decisions must often be made immediately. Alternatively, retrospective studies can leverage contrasting historical management strategies to provide insight into long-term vegetation

responses. We used a retrospective approach to evaluate how management techniques and site characteristics affected reestablishment of an invasive shrub, Rhamnus cathartica (common buckthorn), in midwestern North America. Following removal, buckthorn re-establishes rapidly from resprouts and seeds, so follow-up control is required but often lacking. We hypothesized that revegetating using native herbaceous seed after removing buckthorn increases herbaceous cover that competitively suppresses buckthorn regeneration, to a degree. We surveyed 46 management units at 24 sites. Revegetated units had higher herbaceous cover, lower buckthorn cover, and half the ratio of buckthorn:herbaceous cover compared with unseeded units. These effects, although considerable on average, were detected against a background of high variance. Seeding

increased herbaceous cover and reduced buckthorn relative abundance more strongly on less acidic, more clayey soils and where follow-up herbicide was not applied. Additional variability in revegetation impacts may have arisen from buckthorn resprouts having a head-start on planted seeds. Only one site had both seeded and unseeded management units. This lack of

blocking—a common challenge in retrospective studies—reduced statistical power. This investigation illustrates how retrospective studies can offer relatively inexpensive first assessments of long-term effects of management techniques; for more rigorous inference, researchers can partner with managers to conduct long-term experiments.

In this case study, we used point mapping data to evaluate long-term treatment of invasive

tree-of-heaven [Ailanthus altissima (Mill.) Swingle]. This study at the Buffalo National

River included 21 project areas ranging in size from 0.02 to 11.3 ha and spanned 5 to 8 yr

depending on the site. The control techniques varied depending on the year and included

the application of herbicide, which also varied over the course of the study and included imazapyr,

triclopyr, and triclopyrþfluroxypyr. Treatments during the first year reduced local

A. altissima populations by an average of 66%. Long-term repeated treatments led to decreases

of at least 90% in 70% of the project areas and at least 73% in 95% of the project areas. Only one

project area was found to support no plants during the final treatment year. Ailanthus altissima

increased at most project areas during an unusually wet year and was more likely to increase

than decrease in intervals >1 yr with no treatment. Over the temporal and spatial scales of this

case study, we observed high levels of control that will likely meet the specified levels and ecological benefits required in many similar efforts. Land managers must, however, make a

long-term commitment of resources to achieve lasting control of this invasive species.

This study examined the response of princess tree (*Paulownia tomentosa*) to different disturbances and its potential to spread throughout its current range in the U.S. The study was established in Shawnee State Forest in southern Ohio, USA, which has historically experienced disturbances from mining, logging, ice storms and wildfire. Plots were established for vegetation sampling where fire had occurred with and without princess tree present, and where no fire had occurred with and without princess tree present. To determine the influence of disturbance types on the density of princess tree, redundancy analysis (RDA) was used. High stem density of princess tree seedlings occurred in areas that experienced high fire intensities and herbicide treatment. Seedlings on southwest slopes increased in abundance as the time from the last logging activity increases. Princess tree saplings were present in greater densities in areas that experienced medium fire intensities and the highest ice storm damage. Sapling density is greatest as ground cover and vegetation height increases and slope decreases. Princess trees reach maximum stem density on northeast slopes in areas not impacted by the 2009 fire. All disturbances considered, including wildfire, have created conditions conducive to princess tree growth and expansion into forest areas.

The Chinese tallow tree (*Triadica sebifera*, hereafter, tallow) is a nonnative invasive species that has invaded diverse ecosystems including forests, prairies and wetlands in the Gulf Coastal Plain of the southeastern United States. We proposed a landscape (ecosystem)-level modeling framework of tallow invasion and applied it to a fire-managed landscape to evaluate the effect of prescribed fire on tallow invasion and ecosystem invasibility. A spatially random sample consisting of 55 0.04-ha circular plots was installed in a landscape of appropriately 2,900 ha in the Mississippi Sandhill Crane National Wildlife Refuge in 2015. These plots, plus ten additional tallow-invaded plots from another study were measured in May-June of 2015 and remeasured in November of 2018. Across the entire landscape, pine flatwoods (invasion probability =0.52) were generally more susceptible

to tallow invasion than pine savannas (invasion probability = 0.16) (p = 0.002), and the former had a greater number of tallow seedlings and saplings (p < 0.001), but fewer large tallow trees (p = 0.07) than the latter. The effect of fire on tallow invasion is two-fold and changes with fire return intervals and ecosystem conditions. Fire may promote seed germination and seedling recruitment, but recurrent fires top-kill or even completely kill young seedlings and saplings. Large proportions of invaded plots and abundant tallow seedlings and saplings that accumulate in pine flatwoods are essentially attributed to their high overstory tree basal area but relatively low shrub/grass coverage. On sites near roadways or with tallow seed trees, short fire intervals tend to increase

invasion probability and the abundance of tallow seedlings and saplings, whereas long fire intervals increase the abundance of large tallow trees. Under current fire treatments, pine flatwoods are more susceptible to seedling colonization and sapling establishment, while pine savannas favor the growth and development of large tallow trees.

Non-native grass invasions are altering fuels and fire behavior in forests, with uncertain consequences for tree regeneration and forest dynamics. We examined whether invasion by *Microstegium vimineum*, the most widespread invasive grass in the eastern United States, interacts with prescribed fire to reduce tree regeneration and evaluated how such interactions might influence long-term regeneration dynamics in the Central Hardwoods Region. Using paired invaded and uninvaded plots subjected to fall or spring burning, we quantified differences in pre-fire juvenile tree regeneration, fire intensity, and survival and resprouting rates of naturally established juvenile trees of varying sizes and species. Field data were then used to parameterize the Forest Vegetation Simulator (FVS), a forest growth and yield simulation model. Prior to burning, seedling density was 43% lower in invaded than uninvaded plots and the seedling size-class distribution skewed toward larger individuals, suggesting grass invasion and fire previously acted as a filter on small tree regeneration or that invasion occurred in areas with larger and fewer trees. Burning resulted in similar rates of fuel consumption among treatments, with 1-h, 10-h, and 100-h fuels decreasing an average of 23%, 42%, and 18.5% respectively. However, invaded plots exhibited lower flame lengths, shorter fire residence times, and smaller burned areas than uninvaded plots, indicating lower fire intensity. Despite experiencing lower fire intensity, invaded plots had 46% higher mortality of small trees (*<*3 mm stem diameter) and nearly 54% lower post-fire seedling persistence overall compared to uninvaded plots. Resprouting rate was positively related to seedling size and decreased marginally with invasion. Both a structural equation model and FVS simulations demonstrated that grass invasion had large, negative effects on seedling resprouting, regardless of fire intensity effects. Post-fire sapling persistence did not differ with invasion status. These results suggest that, while grass invasion can have varying effects on fire intensity, it consistently alters forest dynamics by reducing the resilience of tree regeneration to fire. Lengthening the time between prescribed fire applications in grass-invaded forests may be necessary to allow juvenile trees to reach an adequate size to survive burning.

Multiflora rose (Rosa multiflora [MFR]) is an invasive, nonnative plant that has invaded many temperate forests across the eastern United States, often outcompeting native plants for sunlight and other resources. Herbicides can control MFR, but they can also reduce nontarget plant species and threaten aquatic ecosystems. In a black cherry-red maple forest in the Erie National Wildlife Refuge in Pennsylvania, the US Fish and Wildlife Service introduced prescribed goat-browsing as an exploratory control method. In four treatments, browsed, browsed/herbicide, cut/herbicide, and an unmanaged reference, we evaluated preliminary effects of these treatments on MFR and non-MFR herbaceous vegetation. For MFR, the browsed treatment had 56% lower leaf/stem mass ratios and 35% shorter stem lengths than the reference; the leaf/stem ratio in the cut/herbicide treatment was 55% lower than the reference. Stem density was not reduced because goats did not kill the MFR plants in this first year of treatment. The herbicide treatment had fewer non-MFR plants than the reference treatment. Light levels at ground level did not differ among the treatments. Overall, 33% of trees in the browsed treatment were affected by the goats, with 9% being completely girdled; red maple and ironwood were the most commonly browsed species. Preliminary results suggest that goats can be an effective control for MFR, however long-term success will be best evaluated after consecutive treatment seasons. Goats may increase tree mortality and shift tree species composition in stands dominated by trees with high browsing rates, but effects on diverse stands may be less pronounced.

Invasive shrubs often present extremely difficult challenges for individual plant treatment approaches due to multiple basal stems with complex branching patterns. Basal bark and cut stump individual plant treatments have been the standard methods for managing large statured shrubs while hack and squirt has been disregarded as operationally too difficult. However, hack and squirt is a more discriminant treatment technique that may lead to a reduction in herbicide use. Here, we evaluated the speed, herbicide use, and performance of a reduced hack and squirt approach using single hacks per stem injected with 0.5-ml of either aminocyclopyrachlor (240 g l-1) or aminopyralid (240 g l-1) against conventional low volume basal bark treatment with triclopyr ester (96 g l-1) and cut stump treatment with triclopyr amine (180 g l-1). The experiments were conducted on three sub-tropical shrub species: *Eugenia uniflora*, *Lagerstroemia indica*, and *Schinus terebinthifolia*. Across species, we found the reduced hack and squirt approach resulted in comparable treatment efficacy to basal bark and cut stump treatment, was faster than cut stump treatment, and used less herbicide and carrier than basal bark treatment. A single hack per stem is a significant shift for hack and squirt treatment, which typically employs a narrow or continuous spacing of hacks around the entire circumference of each stem. Future work should seek to clarify the applicability over a wide range of invasive shrubs.

Seed limitation represents a fundamental constraint to the restoration of native plant communities, and practitioners often apply seed additions to overcome this barrier. However, surprisingly few studies have experimentally tested whether seed additions can increase diversity in herbaceous communities of oak woodlands, which have undergone large-scale transformation due to logging, altered fire regimes and invasion by non-native species. Previous studies suggest that structural (thinning of woody biomass) and process-based (prescribed fire) restoration treatments alone are unlikely to restore the full breadth of taxonomic and functional diversity in the herb layer, which accounts for most species in woodland ecosystems. 2. To explore whether seed additions can improve restoration outcomes in an oak woodland, we sowed high-diversity seed mixes in paired transects (seeded vs. controls) along a topographic gradient in a degraded site undergoing restoration with non-native shrub removal, selective tree thinning and prescribed fire. Seed mixes contained native forbs, grasses and sedges from locally sourced material (n = 169 total species) in the regional species pool, and were designed to match species' habitat affinity to appropriate locations along the topographic gradient. The herb flora was sampled pre-seeding, and for two consecutive years after additions. 3. Seed additions significantly altered community and functional composition, and increased native species richness by 29% (43.0 vs 55.4), and floristic quality by 30% relative to controls. However, fewer than half of the sown species were established 2 years after planting, suggesting that dispersal and establishment limitation are both important barriers to the recovery of the herb flora in oak woodlands. 4. We also tested if species' sown abundance, conservatism or functional group predicted establishment success. Species sown at high abundances and less conservative species recruited the most reliably. Grass and forb establishment rates were more dependent on seeding rate than sedges or legumes, and the mechanisms behind this trend merit further investigation. 5. We found that adding high-diversity seed mixes in conjunction with non-native shrub removal, canopy thinning and burning, can accelerate recovery of herbaceous communities in a highly degraded woodland.