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Invasive and native plant response to fire in a Pennsylvania Piedmont woodland

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INVASIVE AND NATIVE PLANT RESPONSE TO FIRE IN A PENNSYLVANIA PIEDMONT WOODLAND

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ABSTRACT: *Fragmentation and habitat conversion promote establishment of invasive species. Hibernia County Park, the research site, is located in the Piedmont region of southeastern Pennsylvania. To address issues of invasive species management, Chester County Parks and Recreation carried out a prescribed fire in April 2006. The goal of this research was to assess the response of native and invasive understory vegetation to one dormant-season fire. We expected that there would be a significant decrease in understory plant cover, invasive species, woody stems, and trees with vines. Understory plant diversity was expected to increase. Fifteen forest plots were randomly located within a 5.9 hectare patch of woodland. A baseline vegetation survey was conducted in May-June 2005 with post-burn assessments in May-June 2006, 2007, 2008, 2010 and 2011. Researchers utilized 30-meter point intercept transects to gather data every 0.3 m for presence counts, species richness, and Shannon-Weiner diversity. Stem counts of woody species <2.5cm dbh were acquired within a 30 x 1 meter belt transect. Researchers identified trees in a 30 x 5 meter section of each transect and noted presence of vines. Baseline data revealed Japanese honeysuckle (Lonicera japonica) and multiflora rose (Rosa multiflora) as the dominant invasive species. Data analysis included a paired samples t-test for difference of means for baseline and post-burn year 6 averages. Results determined a significant difference at the p=0.05 level in point-intercept counts for Japanese honeysuckle and multiflora rose (decrease), invasive and native woody stems (increase), and species richness for woody stems (increase). T-test results were not significant for point-intercept species richness, Shannon-Wiener Species index, and number of trees with vines. A burn treatment plan is recommended to address management of invasive species.*

Keywords: *prescribed fire, invasive plants, Piedmont forest, Lonicera japonica, Rosa multiflora*

INTRODUCTION

Forest fragmentation and disturbance have long been significant processes in human-dominated landscapes. In the eastern United States, human disturbance has influenced the composition and distribution of forests since the end of the last ice age (Dunmore 2000). Native American communities engaged in small-scale modification of their surroundings that included the use of fire (Russell 1983; Cronon 1983). European settlers ramped up the scale of landscape fragmentation and ecological disturbance. Much of the northeastern U.S. was deforested by the 1800s (Cronon 1983).

Continued disturbance and fragmentation of forested landscapes have changed the composition and diversity of eastern forests (Abrams 1992, Dyer 2006, Lorimer et al. 1994, and Shumway et al. 2001). Fragmentation increases edge habitat which alters well-established microclimates that native plant species have adapted to over evolutionary time (Matlack 1994; Kolb and Diekmann 2004). These edge habitats experience frequent disturbance which makes them susceptible to colonization by opportunistic weedy species some of which are introduced or invasive plants. As forest patches decrease in size and associated edge area increases, interior forest habitat decreases along with native plant diversity (Yurkonis and Meiners 2004; Saladyga 2006).

To assess the impact of invasive species in a native ecosystem, Yurkonis and Meiners (2004) examined the effects of Japanese honeysuckle (*Lonicera japonica*) in a successional-stage ecosystem. The results of their research showed that species richness declined with increasing intensity of Japanese honeysuckle invasion, and that Japanese honeysuckle was strongly associated with the loss of local diversity. The authors suggest that the invasion of Japanese honeysuckle disrupted community dynamics by inhibiting seed germination and establishment of other species (Yurkonis and Meiners 2004; Saladyga 2006).

In order to evaluate mechanisms for decreasing or inhibiting invasive plants in forest ecosystems, Dolan and Parker (2004) designed an experiment that applied two disturbance treatments to the forest understory. The objective was to determine how prescribed fire and mechanical understory removal affect woody species regeneration and herbaceous species diversity. They found that burning and mechanical removal had similar effects as each treatment resulted in no significant difference in diversity measured by the Shannon-Weiner index (Dolan and Parker 2004).

In 1994, Hutchinson and colleagues (2005) began a research project to study the effects of prescribed fire on oak forests found on a part of the Allegheny Plateau that was never glaciated in southern Ohio. Their research goal was to evaluate the response of herbaceous plants to fire over a 5-year period. This project was initiated in response to an increase in shade-tolerant species such as red maple (*Acer rubrum*) in forests of the eastern United States attributed to fire suppression (Abrams 1998; Maurice et al. 2004; Saladyga 2006).

The four study sites shared similar characteristics such as elevation, soil, geology and topographic relief. Prescribed fires were carried out between late March and mid-April over a 5-year period. The results showed that prescribed fires did not significantly change the herbaceous understory of the mixed-oak forest. Areas that were burned exhibited greater small-scale species richness as compared to areas that were not burned, but differences were not statistically significant. Low intensity fires did not alter soil moisture, light availability, or soil nitrogen availability (Hutchinson et al. 2005).

To restore forest communities using prescribed fire, consideration should be given to the timing, frequency, and intensity of fire as this impacts the survival of individual plant species. Research presented previously suggests that a low intensity, dormant season fire could serve as a management tool to reduce invasive plants, and not disturb the distribution and success of native plants in an eastern deciduous forest (Saladyga 2006).

Research Objectives

The primary objective of this study was to document changes in understory structure and composition in response to one, dormant-season prescribed fire. Chester County Parks and Recreation wanted to evaluate the effectiveness of prescribed fire as a management tool to control invasive plants. More specifically, this research evaluated how invasive and native plant species respond to fire in a forest patch typical of the northeast Piedmont region. We anticipated that there were would be a notable loss of understory invasive species plant cover, and woody stem counts. Understory diversity was expected to increase following the initial burn treatment. The number of trees with vines was also expected to decrease.

Study Site Description

The study site is located in the Piedmont physiographic province of southeastern Pennsylvania, a landscape of gently rolling hills and stream valleys (N 40°1´40.15, W 75°50´29.00). The specific woodland under investigation is located within Hibernia County Park (HCP) in western Chester County (Figure 1).

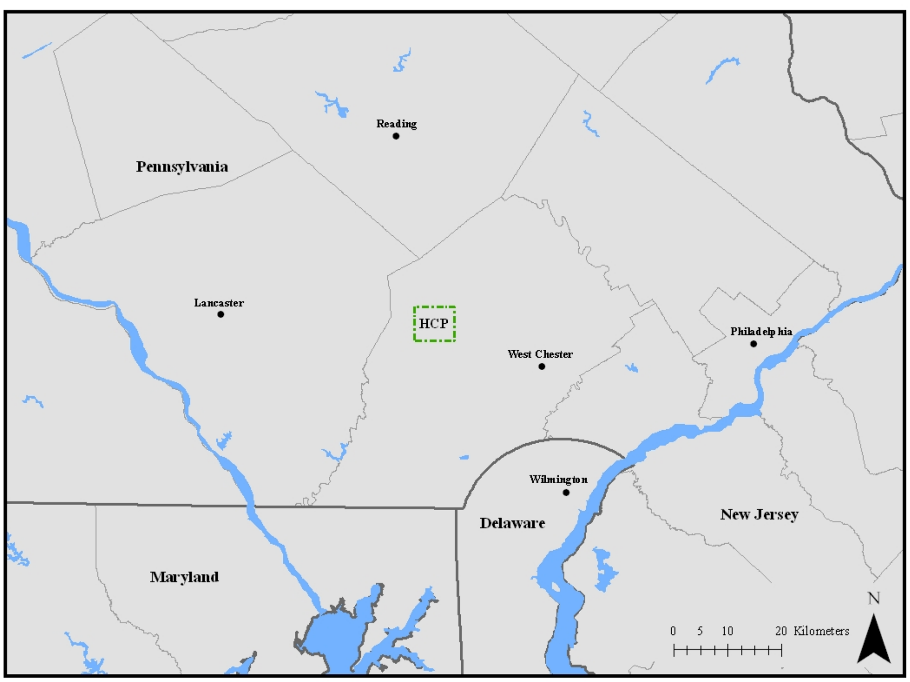

Figure 1. Hibernia County Park (HCP) highlighted by dashed box (Saladyga 2006).

The Park is located within a suburban area with large-lot residential properties interspersed with remnant, small-scale agriculture. Chester County Parks and Recreation identified five contiguous burn units for restoration efforts along a south-facing bank of the west branch of Brandywine Creek. Based on data collected for the long-term objective of monitoring oak regeneration, the forest within the study area can be characterized as a Tulip poplar/red maple (*Liriodendron tulipifera*/*Acer rubrum*) association. By frequency of occurrence, mid-canopy trees include red maple, American elm (*Ulmus americana*), black cherry (*Prunus serotina*), blackhaw (*Viburnum prunifolium*), bladdernut (*Staphylea trifolia*) and spicebush (*Lindera benzoin*) (Saladyga 2006).

METHODS

The initial prescribed burn was conducted in late April 2006 and included the approximately 5.9 hectares of a contiguous patch of woodland (Figure 2). The woodlands were bound by park roads in all directions except south, where they were bordered by the floodplain of the West Branch of Brandywine Creek.

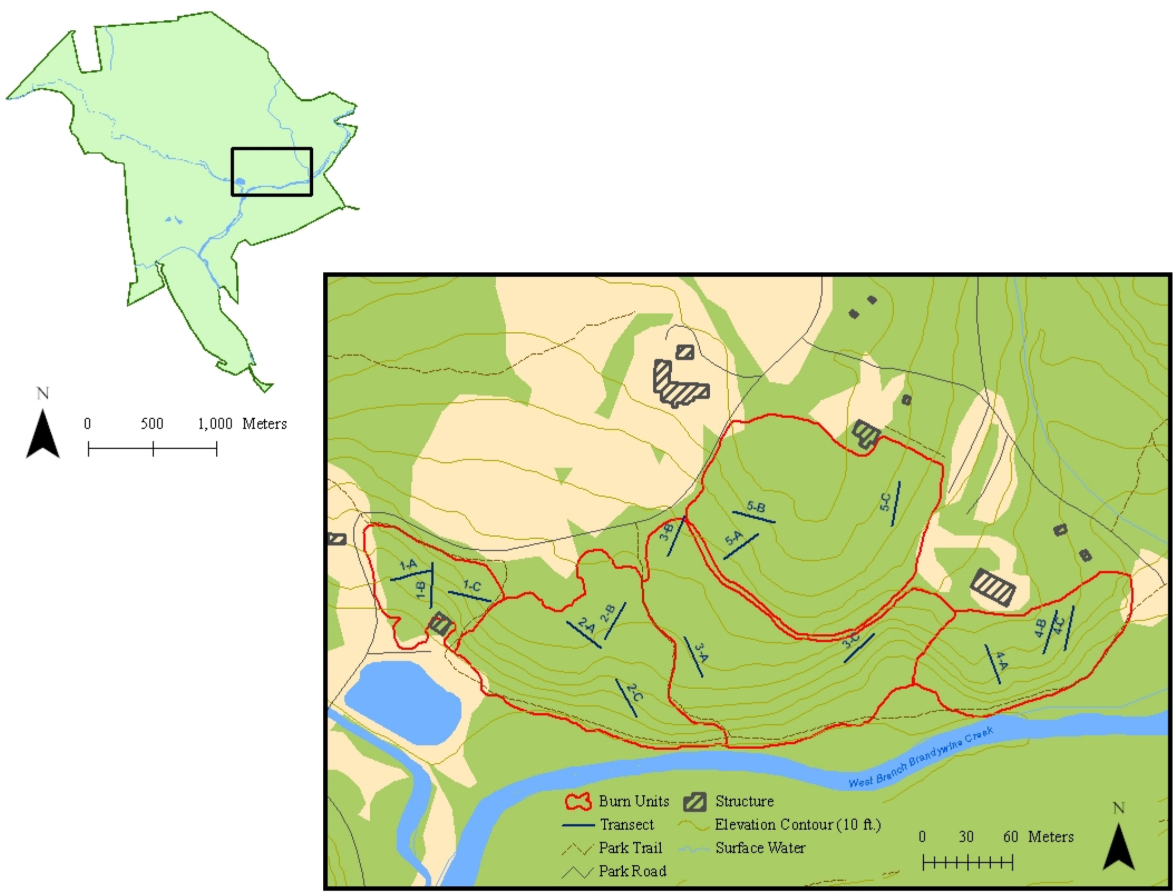

Figure 2. Hibernia County Park Burn unit and forest plot location map (Saladyga 2006).

The objectives of the prescribed fire management plan were to consume 75% of the leaf litter, top kill 75% of oak competitor saplings (i.e. *Liriodendron tulipifera*, *Fagus grandifolia*, and *Acer rubrum*), and top kill 75% of invasive species (i.e. *Rosa multiflora*, *Lonicera japonica*, and *Celastrus orbiculata*) (Vickers and Spencer 2006). The goal was to produce a low intensity fire to promote oak regeneration and restore native understory vegetation (Saladyga 2006).

Using the existing network of park trails and roads, researchers organized the study site into 5 burn units for fire management and control. Forest plots were randomly located by overlaying the UTM grid (NAD 83 zone 18) on the burn units with 3 plots per burn unit. Coordinates and aspect of possible plots (n = 15; 3 per unit) were selected using a random numbers generator. In February 2005, these 15 plots were located in the field (Saladyga 2006). The basic sampling unit was a 30 x 6 meter plot (Figure 3).

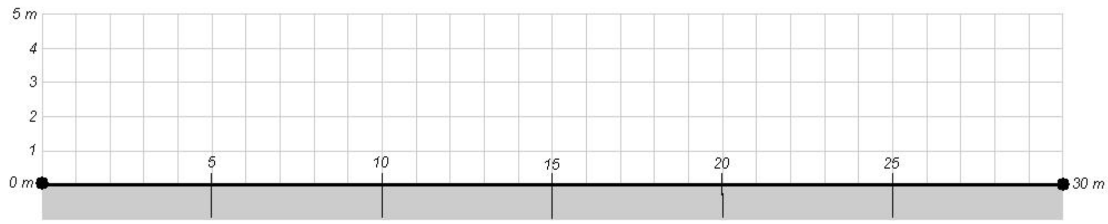

Figure 3. Forest Plot Diagram (Saladyga 2006).

To determine overstory structure and composition, all tree species greater than 2.5cm diameter at breast height (dbh) within a 30m x 5m section of the plot were mapped and tagged. Researchers noted presence and species of vines on the trunk or in the canopy of all trees. Within the remaining 30m x 1m area of the plot, stem counts of all tree (< 2.5cm dbh) and shrub species were recorded. For all forest plots, we randomly assigned the side in which overstory tree or stem data were recorded in relation to plot origin (0m). Additionally, the dividing transect functioned as a point-intercept line along which all species less than or equal to 1.5 meters in height were identified every 0.3m when contacted by a 0.635cm diameter height pole. Each species that touched the height pole was recorded at each point in order to obtain intercept counts (Saladyga 2006).

Baseline vegetation sampling took place in June 2005, which excluded some early spring and late summer ephemerals from the data. In May/June 2006, 2007, 2008, 2010 and 2011, post-burn vegetation data were collected to assess changes in understory species composition and structure in response to one prescribed fire.

Summary statistics were calculated to build a comparison between baseline and post-burn values and to create graphics to visually portray the changes from the baseline data and the post-burn years. To assess the changes between baseline and post-burn year 6 data, a paired samples t- test of difference between the means for the point, shrub, and tree data evaluates the change. In all cases, the test is one-tailed because we hypothesize that the point data average number per transect for invasive species will decrease after the fire, that species richness (number) and diversity will increase, shrub stems for invasive species will decline, shrub species richness (number) will increase, and number of trees with vines will decrease. Each baseline/post-burn test allowed for the assessment of response of native and invasive understory plants following one, dormant-season prescribed fire.

RESULTS

Point-intercept Count Data

Analysis of baseline vegetation data determined that Japanese honeysuckle (*Lonicera japonica*) and Multiflora rose (*Rosa multiflora*) are the two most prevalent invasive plants at the study site (Saladyga 2006). Figure 4 shows the total counts for all invasive species for the baseline data from 2005 and the post-burn year 6 (2011). Other invasives encountered included; garlic mustard (*Alliaria petiolata*), Oriental bittersweet (*Celastrus orbiculatus*), wineberry (*Rubus phoenicolasius*), Norway maple (*Acer platanoides*), Japanese knotweed (*Polygonum cuspidatum*), burning bush (*Euonymous alata*), and Tree of heaven (*Ailanthus altissima*). A post-burn assessment of invasive species count data added Woodland strawberry (*Fragaria vesca*), and Bush honeysuckle (*Lonicera maakii*). The count data for all invasive species declined precipitously after the fire in 2006, and then recovered slowly. Native species also declined and then recovered as depicted in Figure 5. The Shannon-Weiner diversity index (SWDI), an index sensitive to species richness and abundance of individuals, was calculated for each forest plot and then averaged (n=15). Baseline data analysis indicated a mean SWDI of 2.42 across the study area, and the average value for post-burn year 6 was 2.36. Both Species Richness (total number of species) and the Shannon-Weiner diversity index decreased after the fire and then recovered (see Figure 6). The t-test results for species richness and the Shannon-Weiner index were not significant at the p=0.05 level.

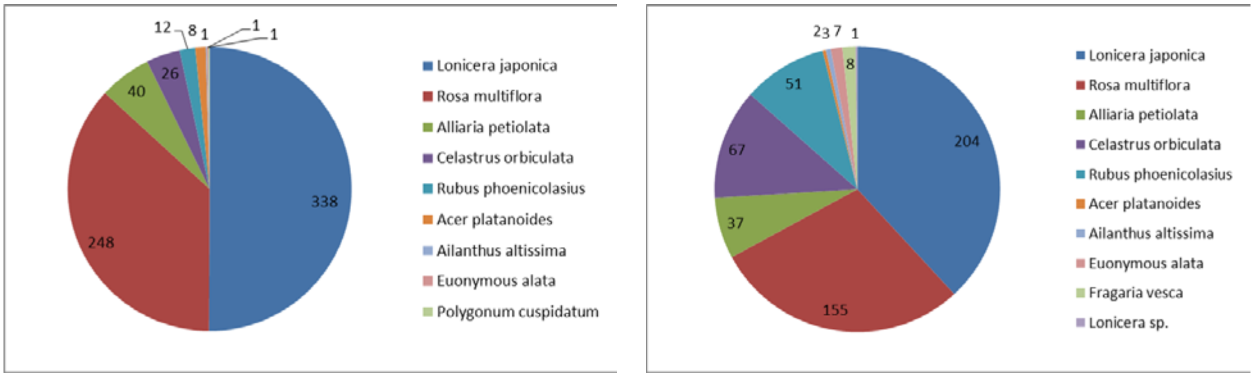

Figure 4. Total counts and proportions of invasive species for baseline 2005 (left) and post-burn year 6 (right).

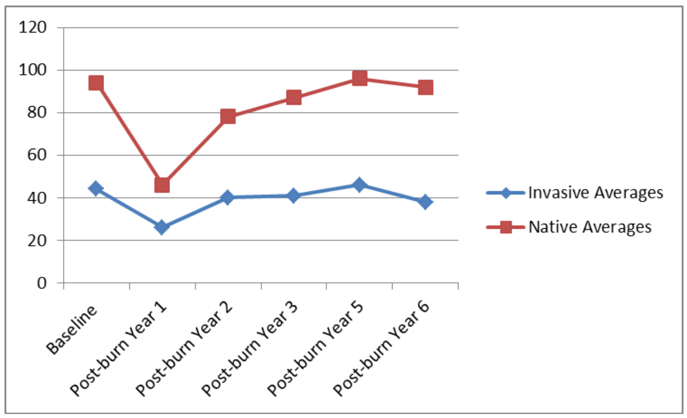

Figure 5. Average number of counts per transect (n=15) for invasive and native plants.

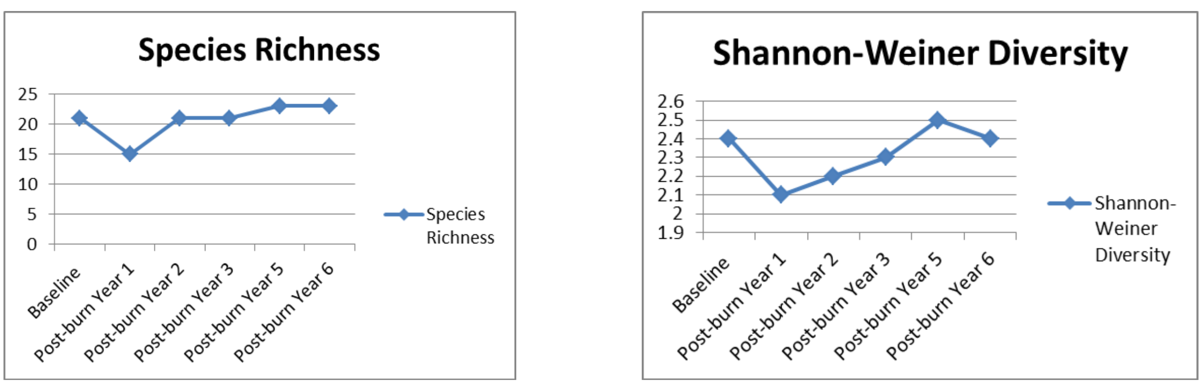

Figure 6. Average number of species (richness) and Shannon-Weiner Diversity Index per transect (n=15).

The paired samples t-test of difference of means for the average number of Japanese honeysuckle and multiflora rose between the baseline and post-burn year 6 data was significant (n=15, p=0.005 and 0.002 respectively) with a decrease over time (see Table 1).

Table 1. Mean values for point-intercept numbers of Japanese honeysuckle and Multiflora rose

Mean Points (n=15)	Baseline	Post-Burn Year 6
Lonicera japonica	**22.5**	**13.6**
Rosa multiflora	**16.5**	**10.3**

Understory Trees and Shrubs

Mean baseline stem counts for both invasive and native woody plants dropped after the fire, and then recovered considerably as shown in Figure 7. There is a statistically significant difference in the mean stem count (n=15) comparing the baseline to post-burn year 6 for native (p=0.002) and invasive (p=0.000) stems, but rather than the hypothesized decrease, there was an increase (see Table 2). Species richness for woody stems declined after the fire and then recovered (see Figure 8), and the paired samples t-test was significant (p=0.000) with an increase after the fire (Table 2).

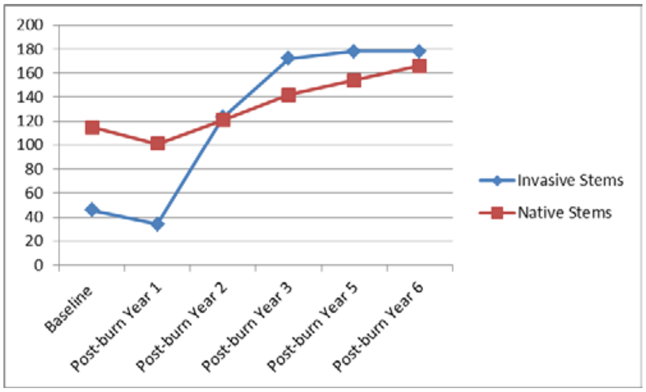

Figure 7. Average number of stems for invasive and native
species per transect (n=15).

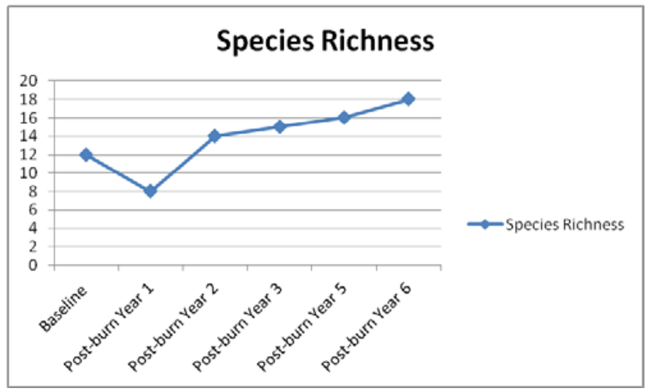

Figure 8. Average number of species (Richness) off woody stems per transect (n=15).

Table 2. Mean values for Number of Stems and Species Richness for stems

Means (n=15)	Baseline	Post-burn Year 6
Native stems	**114.8**	**165.7**
Invasive stems	**45.7**	**178**
Species Richness	**11.6**	**17.5**

Vine Growth on Trees

The mean number of trees per plot declined over the study period. The mean number of trees with vines dropped after the fire, and then recovered. There was no statistically significant difference at the p=0.05 level between the baseline (4.7) and post-burn year 6 (5.4) for the average number of trees with vines.

DISCUSSION & CONCLUSIONS

This study has shown that fragmentation of the forest landscape has promoted establishment of invasive species associated with disturbed edge habitat (e.g. Japanese honeysuckle and multiflora rose) (Saladyga 2006). Vegetation response to fire varied spatially following the initial burn treatment and influenced the results of the research. Burn unit 1 at the western end of the study area had numerous seeps and springs running throughout that created wet conditions. Fire intensity was extremely low and there was low consumption of leaf litter and poor top kill of invasive species. As this burn unit sits on the edge of the study area, the edge effect was also pronounced with extensive patches of multiflora rose which were not killed in the prescribed burn. This contributed to higher than expected numbers of invasive plant stems after post-burn recovery from the fire.

The location of plot 3B was also problematic in that it was close to a popular trail head and the edge of the woodlands. There was also a small wetlands area included in the plot as indicated by the presence of skunk cabbage (*Symplocarpus foetidus*) that reduced the intensity of the fire. In short, plots in Unit 1 and 3B did not burn well and should be considered for other management strategies other than fire. The invasive woody stem counts were higher than expected after the fire, and these plots may have contributed to this outcome.

As expected, there was a significant reduction in understory species richness and Shannon-Weiner diversity for the first post-fire year (Wang and Kemball 2005; Saladyga 2006). Both measures of species diversity recovered to pre-burn levels for the point-intercept data, and were significantly higher for the woody stem data. Weather conditions varied throughout the study period and may have influenced spring vegetation vigor. In particular, the years immediately following the fire were drier than normal until the winter of 2009-2010 during which we received higher than average snowfall. The spring flora in post-burn year 5 was notably more vigorous.

Mean point-intercept counts of Japanese honeysuckle were significantly reduced by the prescribed fire. Japanese honeysuckle exhibits a number of characteristics such as plasticity in leaf phenology and morphology that contribute to its success across a range of habitats (Schierenbeck 2004). In a woodland habitat, its ability to climb up into the canopy combined with its semi-evergreen character adds to its competitive advantage (Carter and Teramura 1988). Japanese honeysuckle creates an open, thick mat that suppresses native herbs, shrubs, and tree saplings (Schierenbeck 2004; Saladyga 2006). The research results support the use of frequent fire treatments to prevent and suppress the spread of Japanese honeysuckle vine at this site. As the native plant community recovered sufficiently within 5 years after the initial burn, carrying out a prescribed burn every 5 years could serve to effectively manage Japanese honeysuckle without harming the native plant community.

The prescribed burn resulted in a significant reduction in the point-intercept presence of multiflora rose across the study area except as noted for burn unit 1 and plot 3B. As a species found in more open habitats, multiflora rose responds to greater light availability, but where there is also woody structure for bird perch sites. Invasion of rose seedlings occurs frequently under bird perch sites because there is better germination of seeds after passing through the digestive tract of birds (Schery 1977; Saladyga 2006). The results of this research suggest that prescribed fire would be an effective management tool for control and suppression of multiflora rose in a woodland habitat, and that a five-year burn schedule would not adversely impact the native plant understory.

Low-intensity fire was effective at killing vines on trees without killing the tree itself. While vines did return to grow on trees in the study area, they were reduced in vigor and height. Establishing a prescribed fire management plan for the woodlands at Hibernia County Park would serve to reduce invasive plants in the areas where fire intensity can be maintained. In areas of the woodlands that are too wet too burn well, other management strategies should be considered.

The goal of restoration at woodland sites similar to Hibernia County Park should be to maximize the relatively stable environment of the forest interior and reduce edge area and the disturbances that create it (Saladyga 2006). A prescribed fire plan on a five year rotation in combination with mechanical removal in areas that do not burn well would serve to effectively manage and suppress dominant invasive species at this site without disrupting the native plant community. Additional research on the response of these plant communities to fire in a fragmented suburban landscape would advance our understanding of vegetation dynamics in woodland communities.

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