The Effects of Integrated Vegetation Management on Richness of Native Compatible Flowering Plants and Abundance of Non-Compatible Tree Species on a Right-of-Way in Central Pennsylvania, USA

By Carolyn G. Mahan, Bradley D. Ross, and Richard T. Yahner

Abstract. We examined the effects of integrated vegetation management (IVM) and nonselective mechanical removal techniques (hand cutting and mowing) on the richness and abundance of native compatible flowering plants and noncompatible trees on an electric transmission line right-of-way in central Pennsylvania, USA. Our study focused on native flowering plants to help determine how different vegetation management techniques may affect native wildlife communities. We found no correlation between amount of herbicide applied and native flowering plant species richness or tree abundance. We found that the richness of native flowering plants did not differ between plots treated with an IVM herbicide approach and those that were mechanically treated ($t = 1.06$, df = 1, $p = 0.31$). However, mechanically treated plots had significantly higher abundance of trees than IVM plots ($t = 3.10$, df = 1, $p = 0.009$). We found that plots that were treated with herbicide mixtures that contained glyphosate in 2012 had lower native flowering plant species richness in 2016 than those treated with herbicide mixtures that did not contain glyphosate ($t = -2.44$, df = 1, $p = 0.04$). Our study indicates that long-term IVM approaches support native flowering plant species richness while limiting tree abundance under electric transmission line right-of-way. However, further study is needed to determine if the herbicide type and method (selective versus broadcast) of application affects species richness of native flowering plant communities.

Keywords. Early Successional Habitat; Forest Vegetation; Herbicide; Plant Species Richness.

INTRODUCTION

Electrical rights-of-way (ROW) vegetation management methods aim to keep vegetation away from transmission wires and, therefore, may promote early successional habitat that is compatible with a variety of native species and resistant to tree invasion (e.g., Mercier et al. 2001; Yahner et al. 2007; Komonen et al. 2013; Wagner et al. 2014). One way to develop this compatible vegetation cover is through Integrated Vegetation Management (IVM). IVM utilizes a variety of management approaches to achieve a desired vegetation community type. These approaches may include chemical (herbicide), manual, and mechanical techniques (e.g., McLoughlin 2002; Nowak and Ballard 2005; Lowe et al. 2007). The response of forest vegetation to IVM is important, because vegetation communities can change within 2 to 5 years due to natural plant succession processes. In general, the 2 phases of IVM along electrical ROW are: (1) use of an herbicidal spray and/or mechanical treatment to initially control the density of non-compatible trees (i.e., those that have the potential of growing to a height that is not compatible with safe ROW maintenance and electricity transmission); and (2) development of a tree-resistant plant cover type to reduce tree invasion of the ROW (Nowak and Ballard 2005). This vegetation management approach ideally produces a long-term reduction in treatment costs and herbicide use (Nowak and Ballard 2005; Turk 2015).

Previous studies—including many at this study site—have demonstrated that a taxonomically diverse array of early successional wildlife species is found using habitat under electric transmission lines managed by IVM. These wildlife include pollinators (bees, butterflies, moths, beetles, flies), reptiles, grassland and shrub land birds, and small mammals.
mixed-deciduous forest, and current plant and wildlife communities persist in response to decades of vegetation management. The objective of this study was to determine how herbicide or mechanical vegetation management approaches affect the number of trees and native compatible flowering plant species present on the ROW. This study focuses solely on native plant species that occur on the ROW.

**MATERIALS AND METHODS**

During July to August 2012, 14 sections (20 m × 200 m) of the ROW at SGL 33 located directly under a 230-kV electric transmission line (area defined as the wire zone) were managed with either IVM, chemical (herbicide), or mechanical treatments (mowing or hand-cutting) to remove or limit tree growth (Table 1). Four of these sections were managed with non-selective mechanical treatments (e.g., all vegetation was cut to a height of 1 m with mowers or chain-saws), and ten were treated with herbicide applications that were either applied broadly or selectively depending on site conditions and IVM prescriptions (see Table 1 for specific commercial/chemical herbicides used). In 2016, we sampled native flowering plant vegetation in late July to correspond to maximum plant emergence at our study sites, realizing the plants with short growing and/or blooming seasons (e.g., spring ephemerals, fall asters) may be missed. We used sampling techniques developed for the research project (see Bramble et al. 1991) that were modified from vegetation sampling techniques developed by Braun and Blanquet (Moore 1962; Wagner et al. 2014). All trees at least 0.3 m in height were recorded within 3 permanent transects (each 20 m long × 2 m wide) in wire zones of each section. Only trees rooted in a transect were counted (i.e., trees rooted outside the transect with foliage extending into the transect were not counted). We then calculated the total number of trees in each treatment section and presented trees as a per hectare (ha) figure. Additionally, we determined the species richness of native flowering plants under 2 m in height that were compatible with ROW maintenance (e.g., forbs or plants with shrubby-growth form). These plant species were counted within a 5-m radius plot placed in the center of each transect. We also determined the dominant (> 50% of area) cover type along each transect. For species richness, native grasses (sedges Carex sp.) were included as one species. All other grasses were non-native and listed only as cover type. We calculated a Pearson...
RESULTS

We documented a total of 28 compatible native flowering plant species on our plots (Table 2). Not all species were present in each section. We also documented 7 different species of trees within our vegetation plots (Table 2). There was no correlation between herbicide application rate (liters of herbicide applied) and the number of both trees ($r = -0.30$, $n = 14$, $p = 0.29$) and native flowering plant species richness ($r = 0.21$, $n = 14$, $p = 0.46$). There also was no difference in compatible native flowering plant species richness between mechanically treated plots and herbicide-treated plots ($t = 1.06$, df = 1, $p = 0.31$; Table 1). However, when we compared herbicide treatments that contained

Table 1. Liters of herbicide applied/hectare (ha) in 2012 and number of trees/ha (< 0.3 m in height) in wire zones of 14 treatment sections on State Game Lands 33 Rights-of-Way Research and Demonstration Area, Centre County, PA, USA in 2016. Dominant (> 50% of area) cover type (forb, grass, or shrub) for wire zone is also presented.

<table>
<thead>
<tr>
<th>Liters of herbicide applied/ha (2012 treatment cycle)</th>
<th>Number of stems of trees/ha&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Native species richness of compatible flowering plant species&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Integrated vegetation management herbicide (H) versus mechanical (M) treatment</th>
<th>Herbicide application (selective [backpack spray] or nonselective [broadcast spray])</th>
<th>Cover type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1482</td>
<td>7</td>
<td>M (Mowing)</td>
<td>N/A</td>
<td>Shrub</td>
</tr>
<tr>
<td>0</td>
<td>2718</td>
<td>9</td>
<td>M (Mowing)</td>
<td>N/A</td>
<td>Forb</td>
</tr>
<tr>
<td>0</td>
<td>11,613</td>
<td>11</td>
<td>M (Handcutting)</td>
<td>N/A</td>
<td>Shrub</td>
</tr>
<tr>
<td>0</td>
<td>3459</td>
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<td>M (Handcutting)</td>
<td>N/A</td>
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</tr>
<tr>
<td>0.75</td>
<td>494</td>
<td>8</td>
<td>H (Glyphosate, Imazapyr)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Selective</td>
<td>Grass</td>
</tr>
<tr>
<td>0.75</td>
<td>741</td>
<td>8</td>
<td>H (Glyphosate, Imazapyr)</td>
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<td>Forb</td>
</tr>
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<td>0.75</td>
<td>494</td>
<td>6</td>
<td>H (Glyphosate, Imazapyr)</td>
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<td>Forb</td>
</tr>
<tr>
<td>6.27</td>
<td>247</td>
<td>7</td>
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<td>Selective</td>
<td>Grass</td>
</tr>
<tr>
<td>29.93</td>
<td>1729</td>
<td>15</td>
<td>H (Aminopyralid, Imazapyr, Triclopyr)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Broadcast</td>
<td>Forb</td>
</tr>
<tr>
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<tr>
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<td>19</td>
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<td>Forb</td>
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<tr>
<td>241.33</td>
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<td>10</td>
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<td>Shrub</td>
</tr>
<tr>
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<td>H (Aminopyralid, Glyphosate, Imazapyr, Picloram, Triclopyr)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Broadcast</td>
<td>Grass</td>
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<tr>
<td>436.82</td>
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<td>7</td>
<td>H (Aminopyralid, Glyphosate, Imazapyr, Picloram, Triclopyr)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Broadcast</td>
<td>Forb</td>
</tr>
</tbody>
</table>

<sup>a</sup>Mechanical treatments versus herbicide treatments differed significantly ($t = 3.10$, df = 1, $p = 0.009$); mechanical treatments versus glyphosate herbicide treatments differed slightly ($t = 2.18$, df = 1, $p = 0.06$); mechanical treatments versus non-glyphosate herbicide treatments differed slightly ($t = 2.03$, df = 1, $p = 0.08$); glyphosate versus non-glyphosate herbicide treatments did not differ ($t = -0.74$, df = 1, $p = 0.481$).

<sup>b</sup>Mechanical treatments versus herbicide treatments did not differ ($t = 1.06$, df = 1, $p = 0.31$); mechanical treatments versus glyphosate herbicide treatments differed slightly ($t = 1.81$, df = 1, $p = 0.09$); mechanical treatments versus non-glyphosate herbicide treatments did not differ ($t = 0.19$, df = 1, $p = 0.86$); glyphosate versus non-glyphosate herbicide treatments differed significantly ($t = -2.44$, df = 1, $p = 0.04$).

<sup>c</sup>Accord concentrate (glyphosate) 7% + Arsenal (imazapyr) 1%

<sup>d</sup>Garlon 3A (triclopyr) 5 pints/100 gal (2 L/380 L) + Milestone (aminopyralid) 7 oz/100 gal (210 ml/380 L) + Arsenal (imazapyr) 1%

<sup>e</sup>Milestone (aminopyralid) 5 oz/100 gal (150 ml/380 L) + Arsenal (imazapyr) 4 oz/100 gal (120 ml/380 L)

<sup>f</sup>Milestone (aminopyralid) 7 oz/100 gal (210 ml/380 L) + Rodeo (glyphosate) 1% + Arsenal (imazapyr) 1% + Tordon K (picloram) 4% + Garlon 3A (triclopyr) 5 pints/100 gal (2 L/380 L)

correlation coefficient ($r$) to determine if there was a relationship between herbicide application rate in 2012 and stems of tree species and/or compatible native flowering plant species richness measured in 2016. We also used a two-tailed $t$-test ($\alpha = 0.05$) for unequal sample sizes (and unequal variances) to determine if mechanical or chemical treatment influenced tree species abundance or the species richness of compatible native flowering plants at our plots. We also compared the effects of herbicide type on plant response; in particular, we examined the effects of herbicide mixes that contained glyphosate with those that did not. All statistical analyses were performed using Minitab® 17 (2010).
glyphosate versus those that did not, we found that glysophate-treated plots had significantly lower native flowering plant species richness than those treated with herbicide mixtures that did not contain glyphosate ($t = -2.44$, df = 1, $p = 0.04$; Table 1). Regardless of type of herbicide used, mechanically treated plots had significantly higher numbers of tree species than chemically treated plots ($t = 3.10$, df = 1, $p = 0.009$; Table 1).

**DISCUSSION**

Our research supports past results from this study area (e.g., Yahner and Hutnik 2005) and from other ROW (De Blois et al. 2004; Yahner et al. 2008; Wagner et al. 2014) that demonstrate selective herbicide use as part of an IVM plan is an effective approach to limiting tree species on ROW while maintaining native plants species richness (Clarke et al. 2006; Wagner et al. 2014). Although our study took place under transmission lines within an eastern forest landscape, studies from a variety of forest areas indicate that selective use of herbicides does not significantly reduce native plant diversity and may cause less disturbance to native ecosystems than mechanical removal approaches. Menges and Gordon (2010) found that mechanical-only vegetation management treatments increased soil compaction and disturbance, while treatments that used mechanical vegetation removal in conjunction with targeted herbicide application were best at reducing hardwood abundance and maintaining native species in Florida upland habitats. Furthermore, Fortier and Messier (2006) found that manual brush cutting (similar to hand-cutting) was the least effective vegetation management approach at reducing competing deciduous trees and shrubs in forests in Canada. However, they also found that non-selective (broadcast) application of herbicides can decrease plant species richness and abundance over time. In boreal forests, native plant species abundance was reduced following severe mechanical site preparation but was maintained with targeted herbicide application to competing non-native plants (Swift and Bell 2011).

Our research indicates that the type of herbicide mixture applied (as well as application method) may affect species richness of native flowering plants—a topic that is receiving more attention. For example, Isbister (2016) found that herbicide mixtures that contained imazapyr caused more damage to non-target plant species than triclopyr in boreal forests. However, Lowe et al. (2007) found that herbicide mixtures that contained both imazapyr and triclopyr effectively controlled non-native invasive plants and permitted restoration of native plant communities in central Indiana. Glyphosate has been an important tool in the removal of invasive, non-native vegetation in forest communities, and a systemic review of the use of glyphosate in forest environments indicates no significant risk to wildlife and plant communities (Rolando et al. 2017). Furthermore, recent research in central Pennsylvania demonstrated the resilience and recovery of native plant communities when invasive, non-native plants were controlled through selective and careful application of glyphosate (Maynard-Bean and Kaye 2019). However, the potential negative effects of glyphosate on forest soil microbial and earthworm communities indicate caution for long-term application, especially in northern ecosystems (see Helander et al. 2012 for review; Gaupp-Berghausen et al. 2015; Aristilde et al. 2017). Therefore, we urge further study into the effects of specific herbicide mixtures on native non-target plant and soil communities, especially in forest (versus agricultural) settings.

Our research is unique due to the long-term nature of IVM management at the study site. However, our research is hampered by this feature as well. Over the 50+ years of treatment, herbicide mixtures, amounts, and application approaches have changed, but the basic research objective of understanding IVM as compared to mechanical approaches to ROW management have remained consistent. Our research focuses on measuring response of wildlife and plants to the treatments and, in general, our study supports the findings of other researchers that non-selective mechanical treatments (e.g., mowing, hand-cutting) facilitated the invasion and abundance of trees in transmission line ROW (Mercier et al. 2001; De Blois et al. 2004). Integrated vegetation management on ROW, which includes selective herbicide treatment, provides opportunities for maintaining native plant species richness while limiting the invasion of tree species. We note that our vegetation sampling in mid-summer may miss the effects of IVM on plants with short emergence (e.g., spring ephemerals), but we do note the presence of native plant communities dominated by Eracaceae and Asteraceae that dominate ROW in other northeastern studies (Wagner et al. 2019). Other common native plant species found along the ROW corridor in our study, such as *Rubus* and *Solidago*,
ecological importance in terms of ecosystem function in food webs. *Solidago* (goldenrods) play a central role in supplying late-season nectar and pollen for flower visitors (Wagner et al. 2014). In addition, the vegetation structure and native plant species richness maintained under transmission lines, in part, determines what subsets of vertebrates will forage, nest, or shelter along a right-of-way.

**LITERATURE CITED**


Ibister K. 2016. Early responses of northern boreal vegetation to power line right-of-way management techniques including the acute toxicity of imazapyr and triclopyr to non-target plants [master’s thesis]. Saskatoon (Saskatchewan, Canada): University of Saskatchewan. 138 p.


Minitab 17 Statistical Software. 2010. State College (PA, USA): Minitab, Inc. www.minitab.com


Swift KI, Bell FW. 2011. What are the environmental consequences of using silviculturally effective forest vegetation management treatments? *Forestry Chronicle*. 87:201-216.


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