DISTRIBUTION AND DYNAMICS OF HAYSCENTED FERN FOLLOWING STAND HARVEST

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Abstract.—The distribution and dynamics of hayscented fern were examined as part of a large-scale study of oak regeneration in Pennsylvania. The study included 69 stands covering 3,333 acres in two physiographic provinces. Hayscented fern was more widely distributed and occurred at higher densities in the Allegheny Plateau physiographic provinces versus the Ridge and Valley region. After partial overstory removal, the density and distribution of fern increased in stands that were not treated with herbicide. Herbicide treatments successfully reduced fern densities and created a 'window of opportunity' about 4 years post-harvest for the establishment of regeneration.

INTRODUCTION

In the mixed hardwood forests of Pennsylvania, dense groundcover of hayscented fern (*Dennstaedtia punctilobula* (Michx.) Moore) and other herbaceous species interfere with the development of advance regeneration of oaks (Horsley and others 1992, Steiner and Joyce 1999). Regeneration of tree seedlings may be adversely affected due to hayscented fern's ability to influence the availability of light, nutrients, and water (Messier et al. 1989, Lyons and Sharpe 1996, George and Bazzaz 1999, Engelman and Nyland 2006). Hayscented fern has been classified as a competitor species because of its ability to respond aggressively to sudden resource availability by way of vegetation expansion of rhizomes and sexual reproduction through spore dispersal (Groninger and McCormick 1991, Hughes and Fahey 1991).

Hayscented fern's ability to occupy a variety of habitats makes it a dominant component of the understory in various regions throughout Pennsylvania. Small-scale studies have shown that hayscented fern is a large component of the groundcover in relatively productive oak stands (Allen and Bowersox 1989) and on poorly drained soils (Marquis 1979). There is limited information about the distribution of hayscented fern among other forest community types, however, previous studies have focused on only one or several stands and failed to look at landscape-level patterns of fern colonization. Yet in light of the oak regeneration problem facing forest managers in Pennsylvania, the distribution and dynamics of this competing species need to better understood (McWilliams and others 1995). This paper focuses on the distribution of hayscented fern at a landscape scale in Pennsylvania, and articulates its response to overstory removal and herbicide treatments.

STUDY AREA

The study area crosses the Allegheny Plateau and Ridge and Valley physiographic provinces of Pennsylvania (Fig. 1). Soils in both provinces in stands represented in this study are derived from sandstone, siltstone, and shale and are typically well drained and support moderately productive forests. Stand elevations range from 250 m above sea level in the Ridge and Valley province to 700 m on the Allegheny Plateau. Precipitation, temperature, and length of growing season vary with latitude and topography. Mean annual

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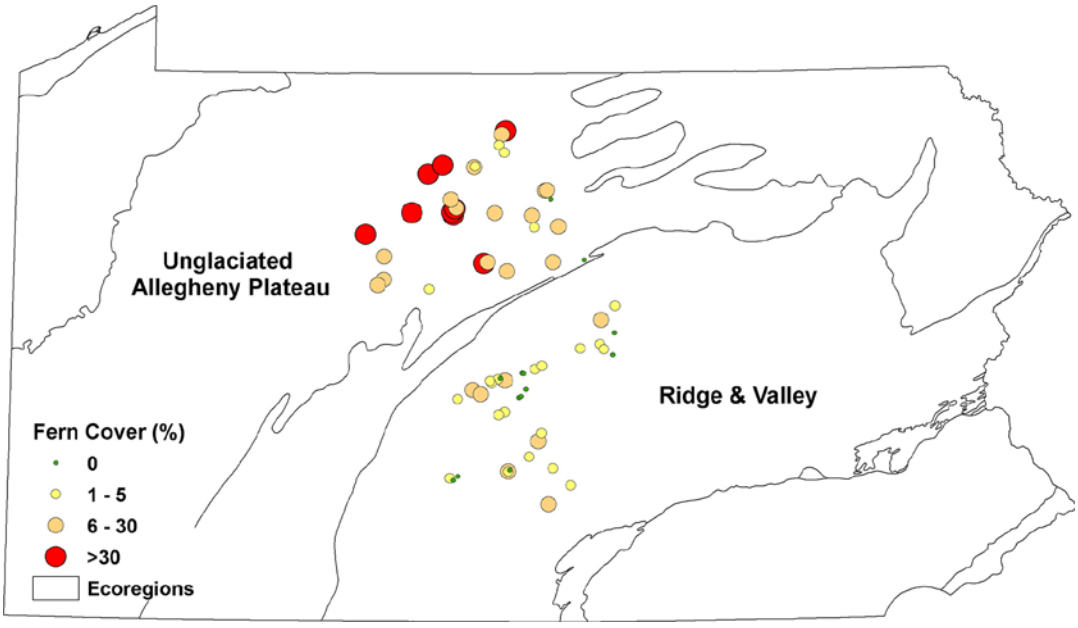

Figure 1.—Distribution of average hayscented fern cover in 69 Pennsylvania stands before harvest.

precipitation ranges from 960 to 1,070 mm and mean annual temperature ranges from 8 to 11 °C. The growing season ranges from 120 to 140 days in the northwest, and 140 to 180 days in the southeast.

METHODS

Data Collection

Field measurements in 69 stands in Pennsylvania were performed on a total area of 3,333 acres of state land during 1996 - 2006. Thirty-one stands were located on the Allegheny Plateau and 38 stands in the Ridge and Valley physiographic provinces. All the stands were measured 1 year prior to silvicultural treatment, 52 stands were remeasured 1 year after treatment, 43 stands were remeasured 4 years after treatment, and 17 stands were remeasured 7 years after treatment. Depending on stand area, 15 to 30 twentieth-acre permanent plots (26.3 ft radius) were systematically installed in a square grid to represent the whole stand. Four permanent milacre subplots (3.72 ft radius), were also set up within each plot. On each subplot, percentage cover of hayscented fern was estimated. In total, we measured 7,481 subplots before treatment, and remeasured 5,163 subplots 1 year after treatment, 4,240 subplots 4 years after treatment, and 1,715 subplots 7 years after treatment.

Treatments

Treatments were based upon the forester's management objectives for each stand and were not experimentally controlled. The primary objective of the treatments was to establish and/or release desirable regeneration. Overstory treatments ranged from 20 to 80 percent basal area reduction at the stand level. Stands were treated with herbicide if hayscented fern densities appeared likely to inhibit regeneration as judged by the staff forester in charge. OUST® (sulfometuron methyl) or an ACCORD®/OUST® mix was applied to dense hayscented fern at various rates depending on fern density. Herbicide was applied before the first remeasurement in 22 of the 31 stands in the Allegheny Plateau and four of the 38 stands in the Ridge and Valley physiographic provinces.

Table 1.—Stand-level average of hayscented fern by physiographic provinces and time of assessment

	Time	Fern Cover (%)	Fern Freq.[1] (%)	Dense Fern Freq.[2] (%)
Ridge and Valley	1yr-pre (n=38)	3.0	11.6	4.2
	1yr-post (n=29)	2.8	27.1	3.7
	4yr-post (n=25)	4.8	46.1	5.5
	7yr-post (n=13)	9.6	55.5	13.6
Allegheny Plateau	1yr-pre (n=31)	19.6	52.0	28.3
	1yr-post (n=23)	7.8	46.1	9.5
	4yr-post (n=18)	7.4	57.1	9.7
	7yr-post (n=4)	11.2	62.4	14.0

[1]Percentage of subplots with hayscented fern cover.
[2]Percentage of subplots with heavy hayscented fern cover (>30 percent).

Data Analysis

For each stand, average fern cover, percentage of subplots with fern, and percentage of subplots with over 30 percent fern cover were calculated. Percentage cover by hayscented fern was divided into four classes—none, low (1 to 5 percent cover), moderate (6 to 30 percent), and heavy (over 30 percent). The heavy class reflects the level of competing vegetation that was considered problematic by Marquis (1994).

Fern cover class transition rates from before harvest to 1, 4, and 7 years after harvest were calculated. Transition rates were calculated as the percentage of plots in a given pretreatment cover class that fell into each cover class 1, 4, or 7 years after harvest. Consequently, transition rates sum to 100 percent for each pretreatment cover class. Subplots in the Ridge and Valley and Allegheny Plateau physiographic provinces were combined, but transition rates were calculated separately for herbicided and non-herbicided subplots.

RESULTS

Average hayscented fern cover percentage ranged before treatment for all 69 stands were plotted on the Pennsylvania physiographic provinces map (Fig. 1). Generally, stands on the Allegheny Plateau had a higher percentage of hayscented fern cover than stands in Ridge and Valley. However, there were two stands on the Allegheny Plateau that had no fern cover, and seven stands in the Ridge and Valley had moderate fern cover.

Before overstory removal, Ridge and Valley stands had lower fern cover, frequency of occurrence, and frequency of heavy hayscented fern than the Allegheny Plateau stands (Table 1). Average percentage of hayscented fern cover for the Ridge and Valley stands remained nearly unchanged from one year before treatment (3.0 percent) to 1 year after treatment (2.8 percent), but increased 4 and 7 years after treatment (4.8 and 9.6 percent, respectively). Average frequency of subplots with the presence of hayscented fern in the Ridge and Valley showed a pronounced monotonic increase during the survey period. One year before treatment, 11.6 percent of subplots had fern cover, increasing to 27.1 percent 1 year after treatment, to 46.1 percent 4 years after treatment, and to 55.5 percent 7 years after treatment. Changes in the percentage of plots with heavy fern cover occurred in a pattern similar to the average percentage of hayscented fern cover.

The Allegheny Plateau stands had an average of 19.6 percent fern cover 1 year before treatment. Fern cover dropped to 7.8 percent 1 year after treatment and 7.4 percent 4 years after treatment (Table 1). The

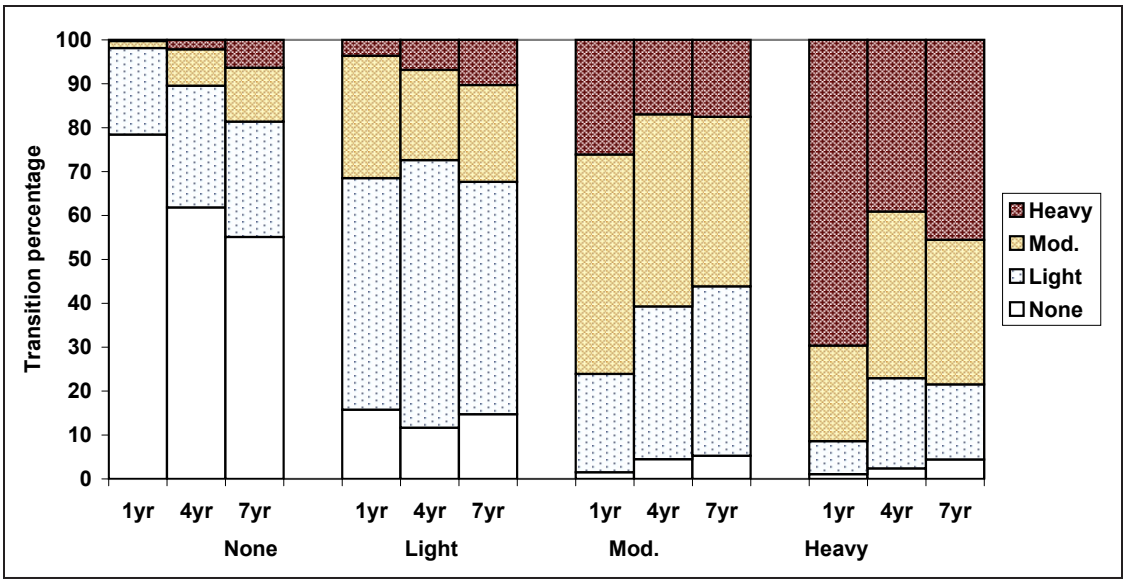

Figure 2.—Hayscented fern cover class transition percentages from 1 yr before harvest to 1, 4, and 7 yr after harvest without herbicide treatment (e.g. 78 percent of subplots classified as none cover class before harvest retained in the same cover class and 20 percent transited to the light cover class 1 yr after harvest).

decrease in fern cover was likely due to herbicide application as 58 percent of the stands were treated with herbicide after the first measurement. Fern cover recovered to 11.2 percent seven years after treatments. Percentage of plots with fern cover decreased slightly from 52.0 percent 1 year before treatment to 46.1 percent 1 year after treatment, but recovered and surpassed 4 and 7 years after treatment (57.1 and 62.4 percent, respectively). Changes in percentage of plots with heavy fern cover had a similar pattern to fern cover percentage.

Overstory removals without herbicide treatment resulted in an increase of fern after harvest throughout the survey period (Fig. 2). About 21.6 percent of subplots that had no fern cover before harvest moved into other fern cover classes 1 year after harvest. Four and 7 years after harvest, the percentage increased to 39.2 and 44.9, respectively. A considerable proportion of subplots that started in the light cover class moved into the moderate and heavy cover classes. Some reduction of fern cover density was observed on subplots that were classified as moderate or heavy fern cover classes. For subplots that had moderate fern cover before harvest, 23.9 percent fell into the light or no fern cover classes 1 year after harvest, and the percentage increased to 39.3 and 43.9 4 and 7 years after harvest, respectively. However, more than one-seventh of moderate fern cover subplots transitioned into heavy fern cover class throughout the post-harvest survey period. Less than 5 percent of the subplots that were classified in the heavy fern class fell into the no cover class after harvest. The overall trend is that stands without herbicide treatment after harvest had a spread of fern cover and increased density for subplots that had low or no fern cover before overstory removal.

Herbicide treatments in conjunction with overstory removals successfully reduced the cover of hayscented fern to non-problematic levels across all density classes (Fig. 3). One year after treatment, fern cover was absent or light on 86.9 percent of the subplots that started with heavy fern cover. Among all of the pretreatment cover classes, fern cover was light or absent in over 80 percent of the subplots. Four years after treatment, the recovery of hayscented fern from the herbicide treatment was evident. Furthermore, the pretreatment cover class influenced the level to which fern abundance recovered. More than one-tenth of the subplots that had heavy fern cover before harvest returned to that class 4 years after harvest.

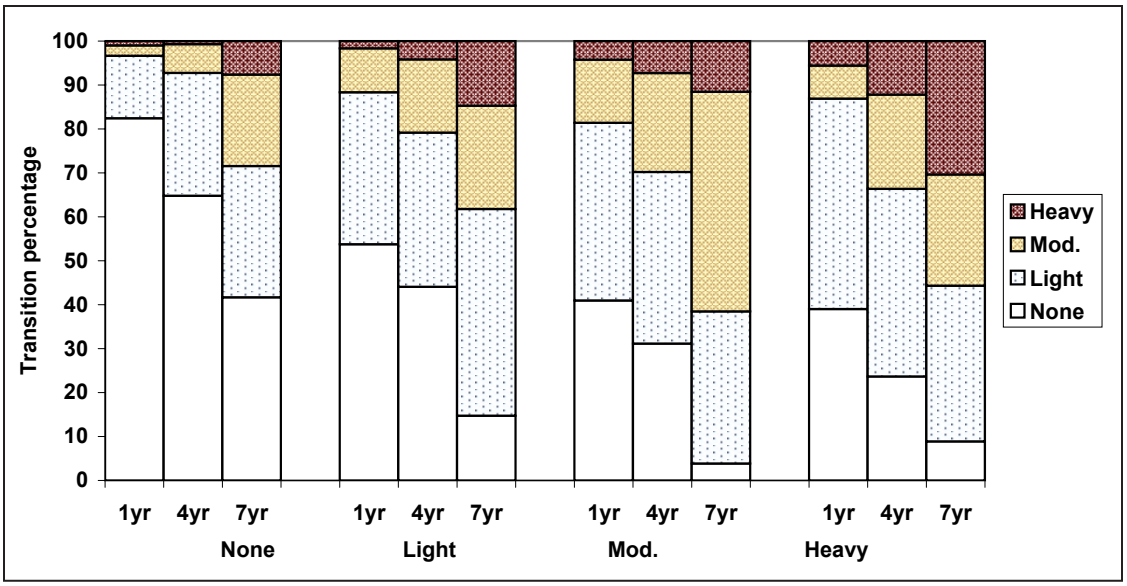

Figure 3.—Hayscented fern cover class transition percentages from 1 yr before harvest to 1, 4, and 7 yr after harvest with herbicide treatment (e.g. of all subplots classified as heavy cover class before harvest, 39 percent, 24 percent, and 9 percent transited to the none cover class 1, 4, and 7 yr after harvest, respectively).

An additional 7.3 percent of the subplots that had moderate pretreatment fern cover reached heavy fern cover by 4 years after harvest. The recovery of hayscented fern from herbicide treatment was even more pronounced 7 years after harvest. Over three-fifths of the subplots that had moderate fern cover before harvest returned to the moderate class or increased to the heavy class, and over one-half of the subplots that had heavy fern cover before harvest recovered to the moderate or heavy class 7 years after harvest.

DISCUSSION

Competition between tree seedlings and hayscented fern has been identified as a factor contributing to the oak regeneration problem in Pennsylvania (McWilliams and others 1995). Our results indicate that hayscented fern is more prevalent on the Allegheny Plateau than in the Ridge and Valley.

Without herbicide treatments, hayscented fern became more widely distributed and increased in density following partial overstory removal. Most of the stands in the Ridge and Valley were not treated with herbicide because hayscented fern was either absent or did not occur at problematic levels before harvest. After harvest, both the distribution and density of hayscented fern increased as a result of stand disturbance associated with overstory removal. However, hayscented fern did not reach problematic densities after 7 years in the Ridge and Valley because initial densities were low. In contrast, the distribution of fern in this region increased dramatically. It is uncertain whether this increase in distribution is a precursor to a greater fern problem in the future, or a short-lived phenomenon associated with overstory disturbance. The expansion of fern has the greatest potential to become a problem in stands that fail to regenerate quickly.

Herbicide treatments created a “window of opportunity” for the establishment of seedlings following partial overstory removals. One year after treatment, fern cover was reduced to non-problematic levels on most of the subplots with initially heavy fern cover. After 7 years, fern cover had partially recovered from the herbicide treatments, but less than one-third of the initially heavy fern cover plots had returned to that condition. Given that oaks are expected to produce large acorn crops every 4 to 6 years, the

window of opportunity provides a chance to capture a regeneration cohort. A heavy mast year shortly after the herbicide treatment, or initially high levels of advance regeneration, should result in the successful establishment of oak regeneration (Johnson and others 1989). The rate of fern recovery between two consecutive surveys accelerated after treatments and a complete recovery is likely (Horsley and others 1992). If a mast year does not occur in the several years following the herbicide treatment, the window of opportunity will likely close as fern recovery accelerates.

Caution is needed when applying the findings to forest management practices. In our stands, we have different intensities of overstory removal, ranging from 20 to 80 percent. Although over 70 percent of the stands had at least 50 percent of their overstory removed, there might be a relationship between the rate or extent of fern spread after cutting, and the cutting intensity. Other factors such as forest community types might also influence the findings. Additional analyses of those factors may be needed in future studies.

CONCLUSIONS

- Hayscented fern is more prevalent on the Allegheny Plateau than in the Ridge and Valley physiographic provinces of Pennsylvania.
- Hayscented fern became more widely distributed and increased in density after overstory removal in stands that were not treated with herbicide.
- Herbicide treatments created a window of opportunity for the establishment of regeneration. After 4 years, fern recovery was accelerated and the opportunity to establish regeneration appeared to decline.

LITERATURE CITED

Allen, D.; Bowersox, T.W. 1989. **Regeneration in oak stands following gypsy moth defoliations.** In: Rink G.; Budelsky, C.A. eds. Proceedings, 7th Central Hardwood Forest Conference; 1989 March 5-8; Carbondale, IL. Gen. Tech. Rep. NC-132. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 67-73.

Engelman, H.M.; Nyland, R.D. 2006. **Interference to hardwood regeneration in northeastern North America: assessing and countering ferns in northern hardwood forests.** Northern Journal of Applied Forestry. 23: 166-175.

George, L.O.; Bazzaz, F.A. 1999. **The fern understory as an ecological filter: emergence and establishment of canopy-tree seedlings.** Ecology. 80: 833-845.

Groninger, J.W.; McCormick, L.H. 1991. **Invasion of a partially cut oak stand by hayscented fern.** In: McCormick, L.H.; Gottschalk, K.W. eds. Proceedings, 8th Central Hardwood Forest Conference; 1991 March 4-6; University Park, PA. Gen. Tech. Rep. NE-148. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 585-586.

Horsley, S.B.; McCormick, L.H.; Groninger, J.W. 1992. **Effects of timing of oust application on survival of hardwood seedlings.** Northern Journal of Applied Forestry. 9: 22-27.

Hughes, J.F.; Fahey, T.J. 1991. **Colonization dynamics of herbs and shrubs in disturbed northern hardwood forest.** Journal of Ecology. 79: 605-616.

Johnson, P.S.; Jacobs, R.D.; Martin, A.J.; Gobel, E.D. 1989. **Regenerating northern red oak: three successful case histories.** Northern Journal of Applied Forestry. 6: 174-178.

Marquis, D.A. 1979. **Shelterwood cutting in Allegheny hardwoods.** Journal of Forestry. 77: 140-144.

Marquis, D.A. 1994. **Quantitative silviculture for hardwood forests of the Alleghenies.** Gen. Tech. Rep. NE-183. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 129-246.

McWilliams, W.H.; Stout, S.L.; Bowersox, T.W.; McCormick, L.H. 1995. **Adequacy of advance tree-seedling regeneration in Pennsylvania's forests.** Northern Journal of Applied Forestry. 12: 187-191.

Messier, C.T.; Honer, T.W.; Kimmins, J.P. 1989. **Photosynthetic photon flux density, red:far -red ratio, and minimum requirement for survival of Gaultheria shallon in western red cedar-western hemlock stands in coastal British Columbia.** Canadian Journal of Forest Research. 19: 1470-1477.

Steiner, K.C.; Joyce, B.J. 1999. **Survival and growth of a *Quercus* rubra regeneration cohort during five years following masting.** In: Stringer, J.W.; Loftis, D.L., eds. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 255-57.