Use of Monitoring and Adaptive Management to Promote Regeneration on the Allegheny National Forest

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Abstract—Forest regeneration in the Allegheny Plateau Region of Pennsylvania is a continual challenge due to an overabundance of white-tailed deer (*Odocoileus virginianus* Zimmerman) and the resulting density of interfering plants on the forest floor. Guidelines developed to establish regeneration on the Allegheny National Forest rely on the silvical characteristics of black cherry (*Prunus serotina Ehrh.*). Following these guidelines increased the regeneration success at the stand level, but led to less desirable outcomes at the Forest-level scale. Allegheny National Forest managers undertook a special inventory to verify this observation, based on early monitoring results, and then adopted an adaptive management strategy for each of the main forest types to change regeneration outcomes.

Introduction

The National Forest Management Act of 1976 requires that administrators of National Forests develop and implement a Forest Plan that outlines a vision of how and where sustainable forest management activities may occur. Monitoring data collected as part of the Allegheny National Forest's (ANF) Land and Resource Management Plan aided ANF silviculturists and Northeastern Research Station (NE) scientists in understanding the interactions between stand and forest scales. In this paper we report lessons learned in the last two decades from these interactions of two scales with respect to establishing diverse advance seedling regeneration.

Forest management and silviculture in the Allegheny Plateau Region of northwestern Pennsylvania occur against a backdrop of disturbance and ecological change. Today's forest is vastly different from the presettlement forest. The latter was removed during the railroad logging era that extended from the 1890s through the 1930s (Marquis 1975). The resulting transformation resembles the change observed in some stands subjected only to natural disturbances within the Tionesta Scenic and Research Natural Area on the ANF. Most notably, the proportion of shade-intolerant black cherry increased in Tionesta stands that were disturbed by 19th century tornadoes and other intensive wind events (C. Nowak, State University of New York, personal communication). Comparable changes in species composition occurred in Allegheny Plateau forests with the removal of the presettlement forest (table1) (Whitney 1990).

Concurrent with the removal of presettlement forest, and subsequent replacement with early successional forest, Pennsylvania's white-tailed deer herd rebounded after being nearly extirpated at the turn of the century. The deer population took advantage of subsequent optimal habitat conditions and limitations on hunting. The result was considerable damage to forest regeneration and shrub communities by the late 1920s. Figure 1 shows the white-tailed deer population of the Allegheny Plateau throughout this century along with the regional deer density goal set by the Pennsylvania Game Commission (Redding 1995).

Table 1—Change in species composition in the presettlement and second-growth Allegheny Plateau forests, in percent.

Species	Presettlement	Second-growth
Beech (*Fagus grandifolia* Ehrh.)	44	6
Hemlock (*Tsuga canadensis* (L.) Carr.)	20	6
Sugar maple (*Acer saccharum* Marsh.)	5	13
Red maple (*Acer rubrum* L.)	5	27
White pine (*Pinus strobus* L)	5	1
Black cherry	<1	23

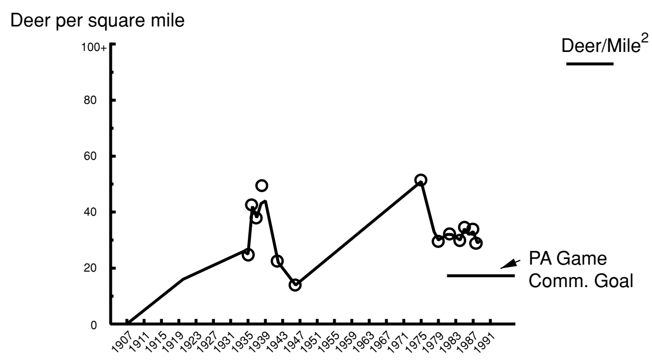

Figure 1—Change in deer density over time in four county region encompassing Allegheny National Forest (after Redding 1995).

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As the region's second-growth forests began to mature in the mid-1960s and early 1970s, deer densities were so high that more than 40 percent of the regeneration harvests were unsuccessful. Deer were responsible for nearly 90 percent of these failures (Marquis 1981). Where deer eliminated seedlings, less preferred or more resilient species filled the growing space. In time, hay-scented and New York ferns (*Dennstaedtia punctilobula* (Michx.) Moore and *Dryopteris noveboracensis* L.), grasses and sedges, striped maple (*Acer pennsylvanicum* L.), and root suckers of American beech created dense shade that interfered with the establishment of seedlings of more preferred tree and shrub species (Horsley 1991).

To overcome an overabundant deer population, scientists emphasized the development of silvicultural techniques that rely on the regeneration characteristics of black cherry. A prolific seeder in this region, black cherry produces significant seed crops annually and bumper crops nearly every other year. Its seed remains viable in the forest floor for 3 to 5 years. Black cherry seedlings are of only moderate preference to white-tailed deer, grow rapidly in high light conditions, and respond dramatically to nitrogen/phosphorous fertilization (Marquis 1990).

Forest managers recognized that the shelterwood sequence was a means of establishing black cherry seedlings as advance regeneration in the northern hardwood, upland hardwood and Allegheny hardwood stands on the ANF (Marquis 1990). They used the herbicides glyphosate and sulfometuron methyl to eliminate interfering plants so that seedlings could become established (Horsley 1991). When abundant seedlings—usually black cherry—were established, overstory removal created light conditions that allowed seedlings to thrive and grow quickly out of the reach of deer. Fertilization and area fencing also were used to help stands regenerate.

The use of these techniques greatly improved the regeneration success rate, in other words, the rate at which fully stocked stands were established following regeneration harvests (USDA Forest Service 1998). They were implemented fully on the ANF beginning in 1980; however, regeneration treatments were concentrated in stands with abundant black cherry seed source.

By 1991, more than a decade after the adoption of the silvicultural guidelines, 10 years after the arrival of the beech bark disease complex, 7 years after the first wave of gypsy moth (*Lymantria dispar* L.) defoliation began, 6 years after a major tornado complex, and 5 years after approval of the ANF's Forest Plan, ANF personnel began to question the effectiveness of treatments and their impacts on stand development processes.

Monitoring

Monitoring and evaluation are important components of the Forest Plan. In cooperation with scientists with the Northeastern Research Station (NE), the ANF staff developed inventory and analysis methods that exceeded Regional standards. Specifically, ANF data included increased detail about species composition and relative heights of regeneration. Because these data were evaluated at both the individual stand and the forest level, ANF personnel were able to identify larger scale issues and concerns. For example, by aggregating results of annual stocking surveys for individual stands, we determined that black cherry seedlings were dominating the third-growth forest, nearly to the point of creating a monoculture. While this might be acceptable in an individual stand, it poses problems at the forest level.

Monitoring also drew managers' attention to another phenomenon. Because the guidelines were developed to overcome an overabundant deer herd and relied heavily on the regeneration characteristics of black cherry, managers were concentrating regeneration harvests in stands with a black cherry overstory basal area of at least 25 square feet. These stands regenerated black cherry successfully, but rarely regenerated the diversity of all the different overstories that included 25 square feet of black cherry. Monitoring helped managers recognize an important problem in its early stages, but they needed additional data to understand the underlying causes of the problem and its implications for projected Forest Plan outputs and outcomes. That is, monitoring results had implications for delivery of the volume and early successional wildlife habitat expectations included in the Forest Plan. The Forest Leadership Team decided that additional information, over and above what was available through established survey methods, was needed to provide consistent, accurate information on current forest conditions and to confirm the implications suggested by analysis of monitoring data

In 1992, with support from the NE's Forest Inventory and Analysis (FIA) unit, the ANF conducted an inventory based on a systematic sample of about 320,000 of the ANF's 513,000 acres. This survey spanned the acreage of Management Area 3.0 (MA 3). In this zone, management efforts focus on timber production primarily through the use of even-age management. The 6,000-plot survey was designed

Table 2—Distribution of understory vegetation in Management Area 3 on the Allegheny National Forest, 1992.

Condition	Percent of MA 3 affected
Adequate advanced regeneration	23
Inadequate advanced regeneration	77
Interfering plants	70
No interfering plants	30
Regeneration and interference	15
Regeneration but no interference	8

Table 3—Composition of understory interference in Management Area 3.0, Allegheny National Forest, 1992.

Interference	Percent of MA 3 affected
Fern	46
Grass	21
Woody	21
Laurel	1
Fern and/or grass	57
Any interference	70

Table 4—Overstory and understory species composition in MA 3, Allegheny National Forest, 1992.

Species	Overstory (basal area)	Understory (seedlings)
	- - - - - - - - - - *percent*	- - - - - - - - -
Black cherry	28	47
Red maple	25	16
Sugar maple	11	1
American beech	9	9
Eastern hemlock	7	<1

to provide current data on understory and overstory conditions.

6,000 Plot Survey Results

The survey data assessed a wide range of forest conditions and laid the ground work for many subsequent analyses. The following are some of the findings.

- Understory composition is dominated by species that interfere with the development and establishment of tree seedlings (tables 2 and 3). Seedlings sufficient in number to count as "adequate advance regeneration" (Marquis and others 1992) are found on only 23 percent of MA 3. Some kind of understory interference is found across 70 percent of MA 3. The understory is dominated by vegetation such as fern, grass, beech suckers and striped maple.
- Species diversity is limited on plots where advance regeneration is adequate. Black cherry seedlings comprise the advance regeneration on 91 percent of the acres on which it was adequate.
- There were significant differences between overstory and understory species composition (table 4).
- Differences between overstory and understory species composition are even more apparent when examined by forest type.
- There is a disproportionate amount of seedling regeneration within the Allegheny hardwood forest type (Allegheny hardwoods account for 29 percent of the acreage, and have 53 percent of the advanced regeneration).

Application of Survey Results

Results of the 6,000 plot survey were first used to support a 1995 analysis of timber harvest capability on the ANF (USDA Forest Service 1995). ANF personnel identified 13 management issues related to natural or anthropogenic disturbance such as a complex of tornadoes in 1985, beech-bark disease, and gypsy moth impacts; the cumulative effects observed through our monitoring; and errors made during analysis for the Forest Plan. Each issue had the potential to change the level of goods and services projected in the Forest Plan. The survey data supported the following conclusions:

- Changes in forest type are likely over time if there are no changes in regeneration practices.
- A better understanding of regeneration requirements for species other than black cherry is needed so that the acreage for potential regeneration harvests can be increased.

A Timber Harvest Capability Report (THCR) incorporated these conclusions in estimates of anticipated harvest levels between 1995 and 2005. The harvest capability was reduced to 53.2 million board feet per year, although the Allowable Sale Quantity of 94 million board feet per year was not changed. This reduction in harvest level acknowledged management limitations in forest types with lower proportions of black cherry. Managers undertook a program of new research and adaptive management to increase harvest capability by gaining a better understanding of regeneration requirements of all species found on the Allegheny Plateau region of northwestern Pennsylvania.

Adaptive Management

The production estimates in the THCR include volume to be produced from stands that will be regenerated using adaptive management. In developing an adaptive management strategy the ANF's objectives were to obtain full stocking of advance regeneration of a variety of species, appropriate to the forest type of the existing stand, and to make final harvests or selection harvests in stands with adequate stocking of advance regeneration, and achieve full stocking and establishment of a variety of species. On the basis of previous research, the ANF developed separate work plans for the upland hardwood, northern hardwood and oak forest types.

Upland Hardwoods

Following an extensive review of research on Allegheny hardwoods, several modifications to shelterwood sequences were identified for upland hardwood stands, i.e. those in which black cherry is associated with shade-intermediate species. The data suggested that intermediate species, most frequently red maple, but also cucumbertree *(Magnolia acuminata* L.*)* and black and yellow birch *(Betula lenta* L. and *alleghaniensis* Britt.*)*, established successfully as advance regeneration where both deer browsing and low shade were controlled for 3 to 5 years. The most effective silvicultural technique is a non-commercial shelterwood seed cut to remove shade-tolerant saplings and poles, inside fences where deer damage is severe These treatments will be followed in 3 to 5 years with a more conventional commercial shelterwood seed cut to add shade-intolerant species to the advance regeneration. A final removal cut will be scheduled 1 to 2 years after the second seed cut. Post-harvest stocking surveys will be needed to monitor the development of seedlings in the third-growth stand. Release treatments that target desirable seedlings might be necessary.

Northern Hardwoods

In other parts of the Northeast, uneven-age silvicultural systems are well matched to the northern hardwood forest type (Nyland 1996; Leak and others 1987). The ANF had attempted to implement uneven-age prescriptions in a variety of northern hardwood stands from 1988 through 1994. During the summer of 1996, overstory and understory data were collected in these stands to assess the effectiveness of treatments and to determine whether modifications in the use of uneven-age management were needed. Working with NE scientists, ANF foresters learned that the required new age class of seedlings had not developed in most stands. However, where target objectives in stand structure were achieved, particularly by removing sufficient numbers of pole-sized stems, the seedling regeneration was successful (DeMarco and others, in preparation).

On the basis of these results, ANF foresters developed prescription guidelines to limit the application of uneven-age silviculture to situations with a maximum probability of regeneration success, and initiated an administrative study to determine whether the removal of interfering plants in connection with group-selection prescriptions would enhance regeneration.

Oak

Maintaining the oak (*Quercus* spp.) forest type was an issue highlighted in the the Forest Plan. There was little previous regeneration success due to mortality in much of the oak type from successive years of gypsy moth defoliation and severe drought. As a result, there was little basis for developing adaptive management strategies. In 1996, ANF personnel initiated extensive monitoring of the current condition of oak regeneration in stands that were regenerated over the past 20 to 30 years to determine the conditions in which oak seedlings had become established. In addition, historical records were searched to establish a reasonably accurate sketch of preharvest conditions and the sequence of harvest activities. The following was observed in stands with oak seedlings:

- Oak seedlings were found in some areas that experienced major catastrophic disturbance, e.g. tornado and/ or tree mortality associated with insect defoliation or wildfire.
- There were varying degrees of success in oak retention as the young stands developed from seedling to sapling size.
- Site factors (slope, aspect, and soil properties) seem to play a greater role in seedling establishment and development in the oak forest type than in Allegheny upland, or northern hardwoods.
- Quality as well as quantity of light plays an important role in the development of seedlings.
- Artificial regeneration can be used to supplement oak stocking, though protection from deer is critical in achieving planting success.
- Frequent post-harvest surveys are needed to determine whether seedling release is necessary.
- Oak stump sprouts are less important in oak regeneration at Allegheny Plateau deer densities than they are in other parts of the oak-hickory forest.

There were several outcomes of this investigation. Along with NE scientists at Parsons, West Virginia, ANF foresters continued an administrative study on artificial regeneration and tree shelters. Also, with NE personnel at Morgantown, West Virginia, they initiated a study of release treatments in sapling-size stands, and of prescribed burning as a site-preparation technique. Some stands have been identified for shelterwood and release treatments.

Summary and Conclusions

Silviculturists have always been adaptive managers. We observe the outcomes of our treatments and adapt our practices to reflect what we've learned. On the ANF, integrating the formal component of Forest Plan monitoring into this process has improved our silviculture and allowed us to scale up to the forest level in our understanding. We monitored both natural and anthropogenic treatments—silviculture, defoliation and mortality, tornado damage—and learned from each. Because we collected detailed information about variation in pre-treatment conditions and post-treatment outcomes—not just "regeneration success" but *what species, in what relative abundance*, for example—we could recognize cumulative effects and adapt our silvicultural prescriptions accordingly. We saw that landscape scale implementation of stand-level guidelines was leading to a forest-wide change in species composition and changed both our monitoring and our practice. We subdivided our monitoring efforts according to forest type, and tried to learn what conditions and treatments resulted in diversity in the emerging regeneration. We are just starting to use the new practices, and to monitor their results. We expect to continue to learn from our experiences through the Forest Plan Monitoring process.

References

DeMarco, Lois; Stout, Susan L.; Ristau, Todd. [In preparation]. An assessment of the application of uneven-age management prescriptions on the Allegheny National Forest, 1988–1994.

Horsley, Stephen B. 1991. Using Roundup and Oust to control interfering understories in Allegheny hardwood stands. In: McCormick, Larry H.; Gottschalk, Kurt W. eds. Proceedings 8th central hardwood forest conference; 1991 March 4–6; University Park, PA. Gen. Tech. Rep. NE-GTR-148. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 281–290.

Leak, W. B.; Solomon, D. S.; DeBald, P. S. 1987. Silvicultural guide for northern hardwood types in the Northeast (revised). Res. Paper. NE-RP-603. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 36 p.

Marquis, D. A. 1975. The Allegheny hardwood forests of Pennsylvania. Gen. Tech. Rep. NE-GTR-15. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 32 p.

Marquis, D. A. 1981. The effect of deer browsing on timber production in Allegheny hardwood forests of northwestern Pennsylvania. Res. Paper. NE-RP-475. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 10 p.

Marquis, David A 1990. *Prunus serotina* Ehrh. Black cherry. In: Burns, Russell M.; Honkala, Barbara H., tech. coords. Silvics of North America. Vol. 2, hardwoods. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture, Forest Service: 594–604.

Nyland, Ralph D. 1996. Silviculture: concepts and applications. New York: McGraw-Hill. 633 p.

Redding, Jim. 1995. History of deer population trends and forest cutting on the Allegheny National Forest. In: Gottschalk, Kurt W.; Fosbroke, Sandra L. C. eds. Proceedings, 10th central hardwoods forest conference; 1995 March 5–8; Morgantown, WV. Gen. Tech. Rep. NE-GTR-197. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 214–224.

U.S. Department of Agriculture, Forest Service. 1986. Land and resource management plan for the Allegheny National Forest. Milwaukee, WI: U.S. Department of Agriculture, Forest Service, Eastern Region. 346 p.

U.S. Department of Agriculture, Forest Service. 1995. Analysis of timber harvest program capability 1995 through 2005. Warren, PA: U.S. Department of Agriculture, Forest Service, Allegheny National Forest. 52 p.

U.S. Department of Agriculture, Forest Service. 1998. Monitoring and evaluation report: Allegheny National Forest FY 1997. Warren, PA: U.S. Department of Agriculture, Forest Service, Allegheny National Forest. 91 p.

Whitney, G. G. 1990. The history and status of the hemlock-hardwood forests of the Allegheny Plateau. Journal of Ecology. 78: 443–458.