ASSESSING REGENERATION ADEQUACY IN PENNSYLVANIA'S FORESTS: A PILOT STUDY[1]

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Abstract—The USDA, Forest Service, Northeastern Research Station (NE), Forest Inventory and Analysis (FIA) unit began collecting forest inventory data on an annual basis in Pennsylvania starting this past field season. The forestry community of Pennsylvania has identified forest regeneration as a primary research issue for the inventory to address. New techniques for measuring and quantifying regeneration are needed because existing NE-FIA protocols and national FIA protocols will not provide the level of detail required. A pilot study is being conducted to determine a cost efficient method for measuring tree seedlings, shrubs, and competing vegetation. The study is expected to result in a recommended approach for full implementation next field season.

INTRODUCTION

Along with resource sustainability, forest regeneration has emerged as a critical research question in Pennsylvania due to the paucity of tree seedlings found in the typical forest understory (McWilliams and others 1995). The USDA, Forest Service, Northeastern Research Station (NE), Forest Inventory and Analysis (FIA) unit began collecting forest inventory data on an annual basis in Pennsylvania starting this past field season. The annual inventory provides an opportunity for landscape-level assessment of regeneration adequacy across the range of forested ecosystems common in the State. Regeneration assessment in Pennsylvania will require development of new inventory techniques because existing NE-FIA protocols (USDA Forest Service, 2000) and national FIA protocols (USDA Forest Service 2000) do not provide the level of detail needed to address regeneration adequacy.

The diversity of plant communities common across Pennsylvania's forested landscape, high white-tailed deer (*Odocoileus virginianus* Boddaert*)* populations, competing vegetation, and other factors make this a challenging and costly research problem to address. A consortium of interested groups within the State has agreed that a comprehensive system for evaluation and monitoring of forest understories is needed. Specific research questions associated with this goal are:

- What are the abundance, composition, and quality of advance regeneration?
- What are the abundance, composition, and quality of regeneration following major disturbance?
- What are the extent and composition of competing vegetation?
- What is the status of regeneration of oak and other key species?

Because of the importance and complexity of this issue, a pilot study to assess regeneration measurement protocols is being conducted during this year's field season.

PILOT STUDY

Goals and Objectives

The regeneration pilot study is intended to provide a field test of regeneration sampling design and measurements. Objectives of the study are:

- Determine the minimum (or optimal) set of sample plots required to quantify the character of tree regenerationand competing regeneration,
- Develop a scientifically credible and peer-reviewed set of measurement protocols that address the range of research questions,
- Test the analytical framework for assessing tree regeneration and competing regeneration, and
- Provide a cost model for full implementation of the regeneration assessment.

The findings of the pilot study will be used in the annual inventory design for Pennsylvania and as a tool for designing and implementing regeneration studies in other northeastern states.

Sample Design

The basic premise for designing the sample used in the pilot study was to collect as much data as possible within the footprint of the national sample design. For example, tree seedlings were tallied on four 6.8-foot microplots at each subplot, compared to one microplot that is used for the national sample design (fig. 1). The resulting dataset allows for analysis of standard errors associated with differing numbers of microplots. Data collection spanned the period between leaf-on and leaf-off conditions to allow a subjective evaluation of the field forester's ability to identify tree seedlings.

Regeneration and supporting data were collected at three levels: sample location, subplot, and microplot. Time data

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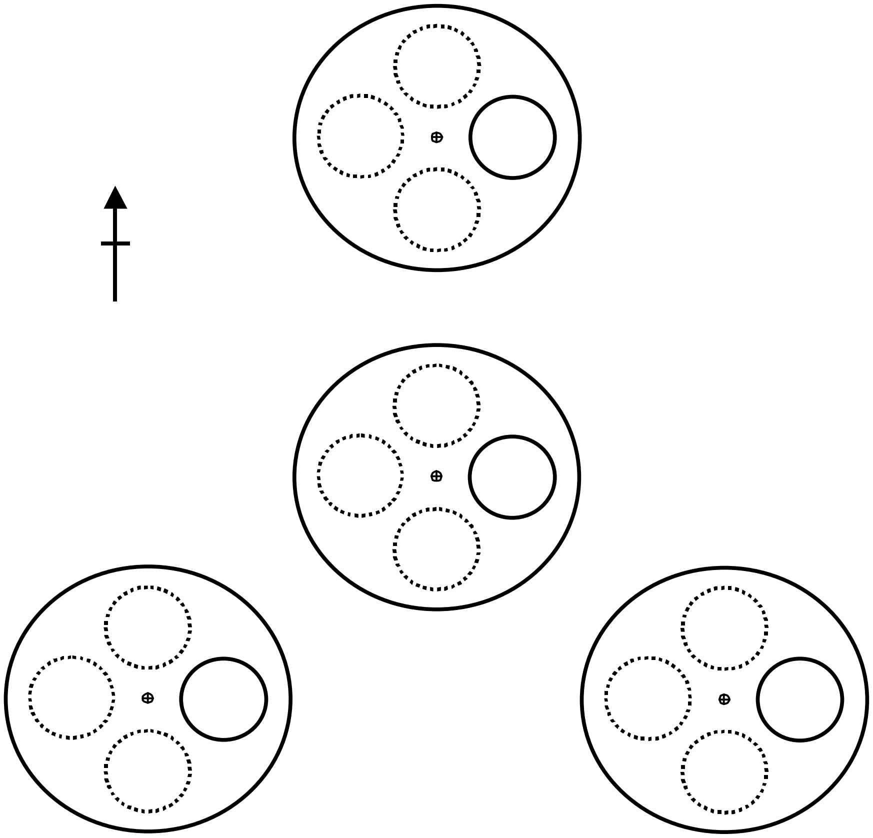

Figure 1—Sample location layout. The larger circles represent 24-foot radius subplots that are located 120 feet apart at azimuths 360, 120, and 240. The smaller circles represent 6.8-foot radius microplots that are located 12 feet from subplot center at azimuths 90, 180, 270, and 360. Microplots with solid lines are part of the national sample design. Microplots with dashed lines were added for the pilot study.

were recorded to provide estimates of the cost of collecting regeneration data and assist in determining the number of personnel needed to complete the measurements.

At the sample location level, a broad assessment of the impact of deer on understory vegetation was made. The assessment was based on general knowledge of local deer populations, the amount of available alternative food sources within one-square mile of the sample location (agricultural crops), and a list of understory species ranked by preference for browse by deer.

At the subplot level, a tally of vegetation that competes with tree seedling development was made. In the context of this study, competing vegetation is defined to include non-tree vegetation; such as shrubs, fern, grass, and other herbaceous vegetation that may inhibit the establishment and development of tree seedlings. Standard NE-FIA species codes were used for deciduous, evergreen, and dwarf shrubs and vines. Additional codes were needed for rhizomous ferns (Hayscented, New York, and Bracken), other ferns, grass, and other herbaceous vegetation. All competing vegetation data was tallied using 10-percent cover classes. The larger subplot was used to tally competing vegetation because of the patchy occurrence of these life forms (Marquis and others 1990).

Measurements of trees were collected on four 6.8-foot radius microplots located at cardinal directions within each subplot. The tree tally is intended to provide a sample representing future stand occupancy and composition. Conceptually, the size of the microplot represents the ground area occupied by a tree once it reaches a diameter of 5.0 inches, which represents a fully established tree of merchantable size (Marquis and others 1990). The sample of tree seedlings was limited to "established" seedlings. As such, seedlings that were less than 2.0-inches tall, had fewer than two normal sized leaves, or that bore cotyledons were not counted.

At each microplot, tree seedlings were tallied by species, seedling source (stump sprout and other), and eight height classes. A tally of saplings (trees from 1.0-inches to 4.9-inches in diameter) was made using a condensed set of the national FIA protocols that included diameter, crown ratio, and crown class. On microplots with trees 5.0-inches and larger, the species code of the most dominant large tree was recorded.

Complicating Factors

Design of an analytical framework for assessing regeneration adequacy in Pennsylvania is complicated by many factors. A diverse mix of forest communities and conflicting habitat uses make it difficult to set universal regeneration guidelines. Fike (1999) describes 54 forest and woodland communities. Very often, communities are not distinct but are in transition to other community types making it difficult to assess the ability of understory vegetation to perpetuate existing or potential overstory compositional traits. For example, a mature overstory comprised of oak (*Quercus* sp.) and ash (*Fraxinus* sp.) species may contain a well-stocked understory of red maple (*Acer rubrum* L.). The high economic value of oak, black cherry (*Prunus serotina* Ehrh.), sugar maple (*Acer sacharrum* Marsh.), ash (*Fraxinus* sp.), and other species in relation to less valuable species common in forest understories; as well as the importance of wildlife, aesthetic, and other recreational activities and their related habitat requirements further confuse the issue.

Any classification of regeneration must consider site occupancy requirements of individual species, degree of establishment, and seedling source. The suite of species common in Pennsylvania exhibit a wide range of site occupancy requirements that depend on numbers of stems and stem height. For example, the probability of survival of a six-foot seedling is quite different from a six-inch seedling. In addition, the degree of establishment can be challenging to measure, especially for small seedlings. New research has shown that root collar diameter is a better indicator of oak seedling establishment than seedling height (Personal communication. Dr. Patrick Brose. 2000. Research Forester, Northeastern Research Station, Old Route 6, Irvine, PA 16329–0267). Lastly, information on whether seedlings originate as stump sprouts or from other sources is useful for gauging the quality of the prospective future stand.

The regeneration assessment should also perform well under a variety of stand conditions, from older closed canopy stands to heavily disturbed stands with a need for new stand establishment. This will allow analysis of both advance regeneration levels and post-disturbance regeneration success.

Competing vegetation in forest understories is another complicating factor. The regeneration assessment should include an estimate of the degree that competing vegetation interferes with the establishment and growth of tree seedlings. So far, the study objectives do not call for remeasurement of percent cover; however, it is likely that remeasurement will emerge as an objective in future discussions with clients for this information. Any remeasurement design will need to consider the work of van Hees and Mead (2000) who noted some limitations of remeasuring percent cover estimates over time.

Perhaps the most significant factor influencing regeneration in Pennsylvania is the large deer population in the State. Population data indicate that relative deer densities exceed thresholds for adequate seedling development across most of the State (Pennsylvania Game Commission. 2000. Unpublished deer population data available from the author).

Analytical Features

The analysis will focus on classifying regeneration adequacy of forest conditions encountered at each sample location and estimation of numbers of tree seedlings per acre. The number and placement of microplots will be determined using standard errors. Standard errors will be examined for individual species and species groups for different numbers and placement of microplots. The configuration(s) that provides the smallest acceptable standard errors will be considered for implementation. Quality assurance methods will be developed following the choice of sampling protocols. Lastly, cost estimates will be developed using the time data.

There are a number of existing guidelines for evaluating regeneration and silvicultural research will likely provide improved measures over time. Because of this, the approach for classifying regeneration adequacy needs to be flexible enough to consider different schemes for evaluating the stocking of seedlings by height class. It is also useful to be able to examine a range of regeneration guidelines, rather than assuming a single metric will fit all needs. As a starting point, the data will be compiled using the framework from a previous study of regeneration using NE-FIA data (McWilliams and others 1995). The approach considers three species groups, two levels of acceptable seedling density, and a set of weights to be applied to height classes. Individual tree species are assigned to desirable, commercial, and woody groups using commonly accepted timber conventions. The two levels of acceptable seedling density, 25 (low) and 100 (high) seedlings per acre, cover the range of regeneration guidelines found in the literature (Leak 1980, Sander and others 1976, Marquis and Bjorkbonm 1982). To account for different seedling survival rates by height class, each seedling was weighted as follows:

Height Class	Weight
2 to 6 inches	1
6 inches to 1 foot	1
1 to 2 feet	2
2 to 3 feet	2
3 to 5 feet	20
5 to 10 feet	50
10 to 15 feet	50
Greater than 15 feet	50

Any combination of weighted stems that meets or exceeds the minimum number required was considered adequately stocked. For example, a microplot is considered to meet the high-density requirement if it contains a minimum of two stems at least five feet tall for the species group of interest. Similarly, a microplot is stocked at the low-density level if twenty 6-inch and three 2-foot stems are encountered. Any forested condition at the sample location is considered adequately regenerated if at least 70 percent of the microplots are adequately stocked.

The species groups, acceptable seedling densities, and height-class weights can all be adjusted to fit differing viewpoints regarding what constitutes adequate regeneration. It may also turn out that different height-class weights will be needed for individual species or species groups. For example, one viewpoint may hold that American beech (*Fagus grandifolia*) is not a commercial species. The prevalence of beech in Pennsylvania's forest understories would likely have a significant impact on the population estimates of commercial-species regeneration adequacy.

Analysis of competing vegetation is relatively straightforward. Estimates of percent cover for shrubs, fern, grass, and other herbaceous vegetation will be used to support and explain regeneration stocking and composition.

The suite of regeneration indicators will be used to classify the overall status of regeneration across Pennsylvania and for important sub-regions, such as ecoregions, forest-type groups, and geographical units. The measurements should also provide sufficient data for developing relationships between overstory and understory composition. This will facilitate predictions of prospective composition of future forest communities in the State.

NEXT STEPS

The data collection phase of the study has been completed. The immediate next step will be to complete the analysis of study data to address the specific objectives of the pilot study described above. Once a final set of measurement protocols is determined, the protocols and associated analytical framework will be circulated for peer review and final adjustments will be made. Full implementation of the regeneration measurements will proceed during this coming field season. Another opportunity for research is to explore auxiliary data sources for correlation of regeneration findings with other variables, such as soils, physiography, deer populations, and acid deposition.

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