INDICATORS OF REGENERATIVE CAPACITY FOR EASTERN HARDWOOD FORESTS

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ABSTRACT. Hardwood forests of the eastern United States are characterized by a complex mix of species associations that make it difficult to construct useful indicators of long-term sustainability, in terms of future forest composition and stocking levels. The Pennsylvania Regeneration Study examines regeneration adequacy in the state. The study uses the Forest Service's Forest Inventory and Analysis (FIA) unit's systematic sample design and grid. Measurements of regeneration and related understory vegetation were added to the standard FIA sample protocols to obtain more detailed information on these forest components. The results indicate that only half of the samples in the study had adequate advance regeneration assuming high deer densities and a goal of re-establishing existing canopy dominants. Under moderate deer densities, results showed about 65 percent of the samples had adequate regeneration. These indicators could be a useful tool for evaluating prospective sustainability of the region's forest land.

KEYWORDS. Criteria; indicator; forest biodiversity; forest health; forest productivity; forest sustainability; forest understory; tree regeneration

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Introduction

Hardwood forests of the eastern United States are characterized by a complex mix of species associations that make it difficult to develop indicators of long-term sustainability. Criteria and indicators of sustainability for forests typically concentrate on existing overstory composition and structure. Such approaches address the forest overstory with no accounting for understory vegetation, thus are of limited use in eastern broadleaf deciduous forests. Future forest composition and stocking depends on existing regeneration and related factors. Silvicultural guidelines for hardwood forests require an assessment of existing advance tree-seedling regeneration to determine regenerative capacity, and hence, long-term sustainability of the existing forest overstory (Smith 1962, Marquis 1994). This limitation is exemplified by the Montreal Criteria and Indicators (Anonymous 1995). The only indicator of forest regeneration is "Criterion 6, Maintenance of Productive Capacity of Forest Ecosystems; Indicator 3, Area and growingstock in plantations." Forest planting is not common in eastern hardwood forests. As such, new indicators are needed to address regenerative capacity. Pennsylvania forests provide a useful case study because they are made up of *Quercus* spp. (mixed oak) and *Fagus-Betula-Acer* (northern hardwoods) systems that typify the challenges for constructing indicators of regeneration quality and abundance. A history of white-tailed deer overpopulation across much of the state adds to the difficulty of quantifying regeneration indicators.

Methods

Study Region

The Pennsylvania study region is predominantly between 39 and 41 degrees north latitude, is characterized by temperate climatic conditions, averages about 100 centimeters of precipitation annually, and encompasses a diverse mix of ecoregions and associated forest types. Total forest land is nearly 70,000 square kilometers, all but 5 percent of which is deciduous hardwood forest. The most common forest associations are mixed oak and northern hardwoods; however, these broad categories include a diverse mix of more specific forest associations. Forest ownership includes federal and state government, but is dominated by private owners. These owners, who control about 80 percent of the forest land, range from forest industry and corporate investment firms, to farmers and recreation clubs.

Sample Protocols

The Pennsylvania Regeneration Study examines regeneration adequacy in the state (McWilliams and others 1995). The study uses the USDA Forest Service Forest Inventory and Analysis (FIA) unit's systematic sample design and grid of plots laid across Pennsylvania. Each plot occupies a 2,400-hectare hexagon. A subset of one-fifth of the plots is measured annually during the leaf-on season, with all the sample plots measured every 5 years. Within each plot, are four 7.3-meter fixed-radius circular plots spaced 36.5 meters apart. Detailed measurements of tree regeneration are taken in a 2.0-meter circular microplot within each subplot.

At each microplot, all fully established seedlings (less than 2.5 centimeters in diameter) are tallied by species, source (seedling, stump sprout, or root sucker), and height class. For heavy-seeded species such as oak, root collar diameters are examined and classified as "established" (root-collar diameter at least 0.20 inch) and "competitive" (root-collar diameter greater than 0.75 inch). Percentage cover of associated understory nontree vegetation is tallied on the larger subplot.

Indicators of Regenerative Capacity

Indicators of regenerative capacity were adapted for use from the work of Marquis (1994) and Sander and others (1976). The design of the indicators was complicated by several factors. First, the forests of Pennsylvania comprise a wide mix of species of differing shade tolerances. Second, harvest disturbance complicates the development of regeneration indicators because of differences in the degree of overstory removal, species selection, and the number of cuttings employed. Also, overstory-understory relationships are not well understood, making the predictions about future composition very difficult to make. Fourth, Pennsylvania currently supports a high deer population. In many areas, deer populations far exceed habitat goals for healthy forest understory development. Subsequently, new methods are needed for measuring and estimating degree of seedling establishment.

Finally, regeneration indicators are complicated by Pennsylvania forest landowners' varying objectives for owning and managing forest land. To address this issue, two species groupings were used for quantifying regeneration stocking. Canopy-based indicators were developed to address the need for replacing the existing forest canopy in the State. Canopy dominants were defined to include all species that currently account for at least two percent of the State's total

tree biomass and that typically form high forest canopy. Other species capable of achieving high canopy were included in an "other high canopy" category. All other tree species were lumped into an "other woody" category. As such, the indicators are cumulative because additional species are deemed acceptable in each of the latter two categories. The second species grouping is based on timber management objectives using existing silvicultural guidelines (Marquis 1994). Species were assigned to "desirable," "other commercial," and "other woody" categories. These indicators are also cumulative, and so, higher proportions of adequate advance tree-seedling and sapling regeneration (ATSSR) would be expected for the other commercial and the other woody categories, respectively, because these include a more species.

To overcome the difficulty of quantifying deer populations, regeneration indicators were developed for two levels: high and moderate. The high-deer guidelines represent the need for more established tree seedlings. The sample was screened to include only those samples that were in stands with sufficient light for seedling establishment, or from 40-75 percent stocked (Marquis 1994).

The tally of tree seedlings was used in conjunction with FIA's sample of saplings (trees from 1.0- to 4.9-inches in diameter) to develop indicators of ATSSR. Regeneration stocking guidelines from Marquis (1994) form the basis for indicators under high-deer conditions. Guidelines from Sander and others (1976) were adapted for moderate-deer conditions representative of the central hardwoods region where the guidelines were developed. The approach assigns a weight to each sample stem according to height class. For example, a 6-inch tall seedling is assigned a weight of one and a 5- to 10-foot seedling is assigned a weight of 50. The high-deer indicators require a minimum of 100 seedlings per microplot and the moderate deer indicators require at least 25 seedlings. If a seedling classified as "competitive" or a sapling is tallied on the microplot, the sample is deemed to have adequate ATSSR.

Results

The choice of regeneration indicator depends on one's perspective regarding regeneration needs. For example, one useful question to ask is: what proportion of stands in Pennsylvania would be expected to regenerate if current overstory replacement is the objective? The results indicate only half of the samples in the study had adequate ATSSR assuming high deer densities (Table 1). Under moderate deer density, 65 percent of the samples had adequate regeneration. The results are similar using timber management assumptions. The range of results for successful regeneration of commercial species was from 50 percent to 64 percent. These results indicate that remedial treatment is required to ensure adequate regeneration following harvest. Deer fencing is a common prescription.

Examining the results by ecoregion (Bailey 1995) reveals that little difference in regeneration across the state and poor regeneration is ubiquitous in Pennsylvania and not specific to a particular region, owner, or forest type. This approach likely underestimates the regenerative capacity of Pennsylvania's forests because stands with more than 75 percent stocking in the overstory would have even lower probabilities of successful regeneration when harvested. On private land, many of the heavier stocked stands are harvested. It is difficult to gauge these findings in relation to other states or regions because of a general dearth of this kind of information.

Conclusions

Timber species, such as oak, maple, black cherry (*Prunus serotina* Ehrh.), and ash (*Fraxinus* spp.) command high prices and support a large timber market. Recreation competes on nearly equal footing with timber; hunting is popular, as are camping, fishing, hiking, and other activities. In addition to the loss of value to humans, the prospective loss of oak and other heavy-seeded species reduces or eliminates food sources for many faunal species that depend on hard mast (Healy 1997).

The proposed indicators of regenerative capacity fill a void in national and international systems for addressing forest land sustainability. Hardwood forests dominate most of the eastern United States making these indicators a useful tool for evaluating prospective sustainability of the region's forestland. Although some modifications would be necessary for use outside the Pennsylvania study region, stocking requirements could be adapted from regional silvicultural guides.

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Table 1. Percentage of regeneration samples satisfying advance tree-seedling and sapling regeneration (ATSSR) criteria by regeneration measure, ecoregion, and stocking guideline under conditions where existing stocking levels are sufficient for seedling establishment (40-75 percent), Pennsylvania, 2002.

Measure/ Stocking Guideline	State	Ecoregion			
		Western Broadleaf	Plateau	Central Appalachians	Eastern Broadleaf
Canopy Dominance:					
High-deer:					
Canopy dominant	44.2	46.0	40.5	45.0	54.5
Other high canopy	50.3	52.7	42.6	54.1	54.5
Other woody	56.5	61.9	46.8	59.4	63.6
Moderate-deer:					
Canopy dominant	60.2	59.3	63.3	58.1	68.2
Other high canopy	65.3	65.0	65.0	65.6	68.2
Other woody	71.4	73.5	68.8	71.9	72.7
Timber Management:					
High-deer:					
Desirable	36.4	44.2	27.8	37.2	36.5
Other commercial	50.1	51.3	43.5	53.8	54.5
Other woody	56.6	61.1	47.7	59.7	63.6
Moderate-deer:					
Desirable	51.9	57.5	49.4	49.7	54.5
Other commercial	63.6	62.8	62.4	64.7	68.2
Other woody	70.6	72.6	67.1	71.6	72.7
Standard error	1.7	3.1	3.2	2.8	10.7

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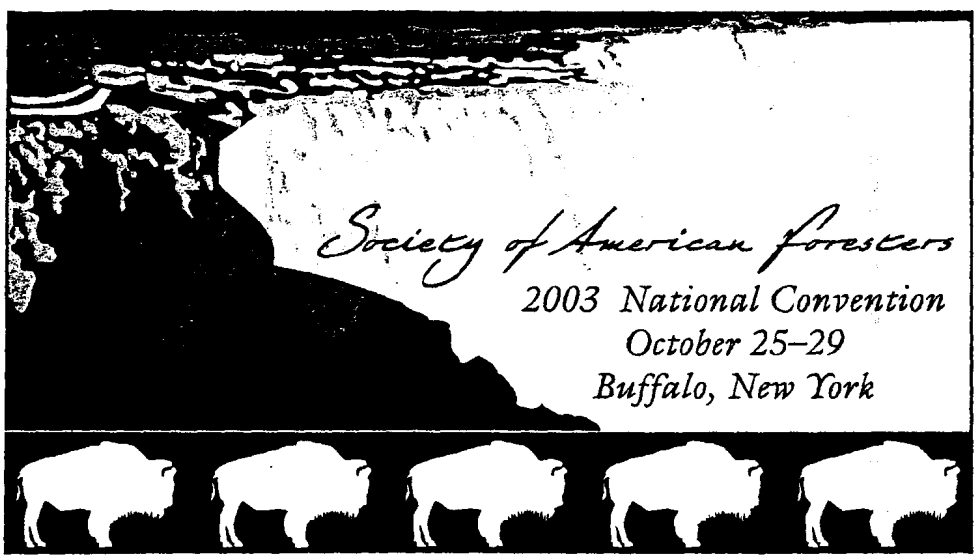

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