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Habitat Diversity in Uneven-aged Northern Hardwood Stands: A Case Study

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Abstract

Habitat characteristics were quantified in an empirically balanced uneven-aged northern hardwood stand in central New York. Canopy structure, wildlife trees, downed woody material, low cover, and richness and abundance of understory vegetation were assessed. High vertical structural diversity and low horizontal patchiness were associated with the single-tree selection system. Downed logs and wildlife trees were spatially well distributed, and cavities at a range of heights and sizes were documented. Application of a selection cutting decreased total canopy closure, but maintained high vertical structural diversity and an even distribution of foliage among canopy strata. Cutting reduced the number of wildlife trees, but increased low cover, shade-intolerant understory vegetation, and the abundance and complexity of downed woody material. This study provides quantifiable evidence of the diversity of habitat characteristics associated with a balanced stand structure and uniform spatial arrangement of different sized trees in uneven-aged northern hardwood stands.

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Introduction

The objective of our research is to quantify habitat characteristics of uneven-aged northern hardwood stands. The structural complexity of uneven-aged communities has been a deterrent to habitat assessment in the past. Furthermore, the selection system is not often applied in northern hardwoods, making it difficult to locate potential research areas. Although irregular uneven-aged stands commonly result from different forms of partial cutting, "true" selection cutting resulting in empirically balanced stands is rare.

The selection system enables forest managers to sustain long-term growth and production in uneven-aged stands (Nyland 1996). A target structure is defined in terms of basal area, diameter distribution, and maximum diameter. Cuttings are then made on a fixed cycle to remove mature trees individually or in small groups, tend immature age classes, and regenerate a new cohort. Removals are prioritized within the limits of residual spacing, structure, and density goals. Noncommercial and disease-prone species, unacceptable growing stock (poor form, low vigor, defective, or low-quality trees), and trees beyond the maximum diameter are removed where possible. Marking diminishes structural excesses and makes provisions to rebuild deficit size classes. Adequate growing space is allocated to vigorous trees, and acceptable growing stock (trees with demonstrated potential for future growth) is released. Once a balanced condition has been attained, it is believed that managed stands will prove sustainable in terms of both structure and production (Nyland 1996).

The deliberate attempt to define, create, and maintain an empirically balanced uneven-aged condition differentiates selection system from other partial cuttings, which often have a disruptive effect on stand structural conditions (Nyland et al. 1993). For this reason, we describe the habitat characteristics of a balanced stand, to serve as an example of the type of conditions associated with selection cutting. This study is comprehensive, and we have presented only selected highlights of our findings here.

Materials and Methods

Study Area

The Cuyler Hill State Forest in Cortland County, New York, is a northern hardwood forest dominated by *Acer saccharum* Marsh. (60% of basal area) with representations of *Fraxinus americana* L. (12%), *Prunus serotina* Ehrh. (8%), *Fagus grandifolia* Ehrh. (7%), *Betula alleghaniensis* Britton (3%), *Tsuga canadensis* (L.) Carr. (3%), *Acer rubrum* L. (2%), *Tilia americana* L. (2%), *Ostrya virginiana* (Miller) K. Koch (1%), *Acer pensylvanicum* L. (1%), and miscellaneous (1%). Topography is hilly, and soils are well to somewhat poorly drained channery and medium-textured loams and silt loams (Nyland et al. 1976).

The stand was treated with single-tree selection cuttings in 1973 and 1993. These treatments removed the poorest trees and maintained a measurably uniform spatial distribution of growing stock. The harvesting operation was done by chainsaw felling and tree-length skidding with rubber-tired tractors. Directional felling was used to minimize residual stand damage, and logs were skidded on designated trails to a landing outside the stand. Residual structure closely resembled the Arbogast (1957) distribution both times (Fig. 1). This structure, proposed by Eyre and Zillgitt (1953) and presented as a management guide by Arbogast (1957), represents an empirically balanced distribution of trees by size class. Residual basal area in the Cuyler stand, computed for all trees 2.54 cm in diameter at breast height (d.b.h.) and larger, was 16.5 m^2/ha in 1973 and 16.6 m^2/ha in 1993.

Data Collection and Analyses

A 30.5-m systematic grid with a nested plot design was used to sample structure and vegetation in the 12-ha study stand before and after the 1993 cutting.

Cavity trees, snags, and downed logs were measured on 8.03-m radius plots at 45 grid points (every other point on the grid). Cavity trees were defined as live trees and snags at least 2.0 m in height and 10 cm in d.b.h. with a nest cavity, den, or hollow that might shelter a hole-nesting species (Healy et al. 1989). No attempt was made to differentiate between inactive and active cavities, or between "natural cavities" (Evans and Conner 1979) and excavated holes. Potential cavity trees with decay but no actual hollow were not included in the sample. Diameter at breast height, species, cavity height, and size of the cavity entrance were recorded. Multiple cavities were recorded if present. Diameter and length were recorded for downed logs greater than 10 cm at the small end. Logs in decomposition class 5 (Maser et al. 1979) were not included in the sample.

Number of stems by species of all herbaceous and shrub vegetation regardless of size, and seedlings less than 0.3 m in height were recorded on 1.01-m^2 plots at all 87 grid points. Percentage of cover by species was also determined on these plots using the "cramming" method (Hays et al. 1981). Ranges, rather than absolute values, were used for estimating percentage of cover.

Canopy structure was quantified at 1.52-m intervals on four 9.14-m transects in cardinal directions at 45 grid points. A right angle penta-prism was used to determine presence or absence of foliage in each of three canopy strata: understory (1.5 to 5.0 m), midstory (5.0 to 12.0 m), and overstory (12.0 m and above). Total canopy closure (percentage of sample points with foliage in at least one canopy layer) was used as an index of within-stand *horizontal structural diversity*. *Vertical structural diversity*, or the degree of stratification, was the percentage of points with foliage in two or more strata simultaneously. *Vertical structural consistency*, or the degree to which foliage is evenly distributed through the three defined canopy layers, was determined by comparing closure in different strata.

Point samples of ground cover were also obtained every 1.52 m on the transects. Categories included downed woody material (including logging slash), litter, exposed organic soil, and exposed mineral soil. Additional measurements of understory vegetation were taken by dropping a plumb bob and recording all species intersected. The 24 samples of ground cover and canopy closure at each grid point were treated as subsamples for statistical analyses. Percentage of ground cover and canopy closure were determined using the mean number of observation points at which a given condition was present within each plot. Pre-cut and post-cut values were compared using a paired t-test for means (α= 0.05).

In addition to the above measurements, tops of 20 *A. saccharum* trees felled in 1993 were measured. Diameter at the base of the top, number of forks, and length and diameter of all bole and branch pieces were recorded down to a 10-cm minimum diameter.

Results

Cavity Trees and Snags

In the 1993 pre-cut stand, cavity trees (n= 25) occurred at a density of 27.45 ± 4.57/ha, with a mean of 1.04 ± 0.04 cavities/cavity tree. Mean d.b.h. of cavity trees was 38.8 ± 2.8 cm (range 12.5 to 61.4 cm). Cavities were unevenly distributed by tree species with a disproportionate number occurring in *F. grandifolia*, although d.b.h. ranges and means were similar among species. Of the measured cavities, 27 percent were smaller than 8 cm, 32 percent between 8 and 15 cm, and 41 percent larger than 15 cm. These were distributed at a range of heights, with 42 percent below 1.5 m, 19 percent between 1.5 and 5 m, and 38 percent between 5 and 12 m. No cavities were detected above 12 m.

Snags (n= 10) occurred at a density of 10.97 ± 3.83/ha in the 1993 pre-cut stand. Mean snag d.b.h. was 18.6 ± 3.9 cm, but both mean d.b.h. and range in diameter differed by species. Notably, *F. grandifolia* had a higher mean diameter (35.6 ± 11.7 cm) and a far greater range of values (19.1 to 52.0 cm) than those for other species, though a small sample size precluded meaningful statistical evaluation. Furthermore, even though 92 percent of cavity trees were live, 8 percent were dead *F. grandifolia*. This suggests a link to the beech bark disease, which is known to predispose trees to decay in the sawtimber classes of hardwood stands (Filip 1978; Houston and O'Brien 1983).

A projection of post-cut conditions from a tally of trees marked for removal suggests that the abundance of cavity trees and snags decreased and the distribution by size and tree species was altered. Large diameter *F. grandifolia*, for example, were heavily marked due to the beech bark disease.

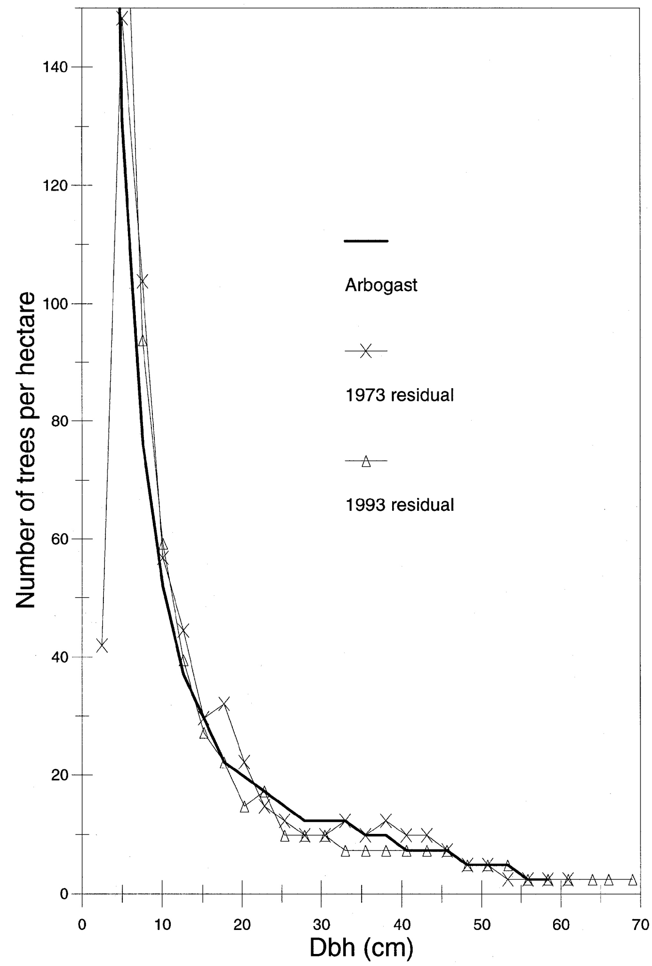

Figure 1.—Diameter distribution of an empirically balanced uneven-aged stand on the Cuyler Hill State Forest, in relationship to the Arbogast (1957) guide.

Canopy Structure

Horizontal structural diversity, vertical structural diversity, and vertical structural consistency were all high in the pre-cut stand (Table 1). These structural characteristics are indicative of the widespread intermingling of trees of different sizes and ages that is related to a balanced diameter distribution and even spacing (Kenefic and Nyland 1996). The link between diameter distribution and canopy structure is further strengthened by a study of tree and crown characteristics in this stand, that established significant relationships between tree diameter and height, crown length, and crown projection area (Kenefic 1995; Kenefic and Nyland 1999).

Although foliage in the residual stand remained distributed evenly between the midstory and overstory, percentage of canopy closure in all categories decreased significantly (Table 1). Lower percentage of closure in the understory (and thus lower occurrence of all three strata simultaneously) is most likely the result of sapling losses during logging rather than silvicultural treatment because few understory trees were of merchantable size.

Table 1.—Canopy closure percentages and stratification in an empirically balanced selection stand on the Cuyler Hill State Forest, 1993 (Kenefic and Nyland 1996). Results of paired t-tests for means (α = 0.05) are shown

Canopy stratification	Pre-cut (n = 45)	Post-cut (n = 45)	Paired t-test (p-values)
Canopy - *foliage in any stratum*	97 ± 0.7	85 ± 2	< 0.0001
Understory - *foliage 1.5 to 5.0 m*	67 ± 3	37 ± 3	< 0.0001
Midstory - *foliage 5.0 to 12.0 m*	68 ± 3	59 ± 3	0.0050
Overstory - *foliage above 12.0 m*	76 ± 3	59 ± 3	< 0.0001
Both understory and midstory - *foliage 1.5 to 5.0 m and 5.0 to 12.0 m*	46 ± 3	27 ± 3	< 0.0001
Both midstory and overstory - *foliage 5.0 to 12.0 m and over 12.0 m*	50 ± 2	38 ± 3	< 0.0001
All three strata simultaneously - *foliage 1.5 to 5.0 m, 5.0 to 12.0 m, and above 12.0 m*	35 ± 2	18 ± 3	< 0.0001

Low Structure

Downed logs greater than 10 cm in diameter at the small end (n= 128) occurred in the pre-cut stand at a density of 140.35 ± 16.43/ha. These had a mean length of 5.82 ± 0.30 m and 7 percent forked at least once. Selection cutting resulted in an influx of downed woody material. Logging slash in the form of hardwood tops, in particular, greatly increased the complexity of low structure. The *A. saccharum* tops sampled following the 1993 entry were highly complex, with a mean of 3.72 ± 0.80 forks/top and a mean accumulated branch length (sum of all branch and bole pieces in a given top) of 20.53 ± 4.36 m. Percentage of ground cover by woody slash increased significantly (p= 0.0001) from 3 percent to 11 percent post-cut, and foliage on branches and tops from felled trees covered 20 percent of the post-cut ground surface. This represents a potentially important but temporary source of woody material and browse.

Understory Vegetation

Thirty-eight plant species were detected in the understory sample of the study stand. Herbaceous vegetation contributed the most in terms of ground cover (23%), followed by shrubs (10%) and seedlings (8%). Importance values based on percentage of cover, stem density, and frequency show that the five most important species were: *A. saccharum*, *Viburnum alnifolium* Marshall, *Dryopteris* spp., *Viola papilionacea* Willd., and *Arisaema triphyllum* (L.) Schott. Overall, the understory community consisted primarily of shade-tolerant species, with minimal components of early successional, light-demanding species. Percentage of cover of herbaceous, shrub, and seedling vegetation decreased significantly following logging, while exposed mineral soil, organic matter, and logging slash increased significantly (Table 2). Although time since cutting was insufficient to detect changes in species composition, sampling in another selection stand suggests that a short-term increase in the component of shade-intolerant understory vegetation will occur in response to lower residual canopy closure (Kenefic 1995).

Conclusions

These measurements of stand structural diversity and species composition represent the first attempt at comprehensive habitat quantification in a managed uneven-aged stand. The findings clearly demonstrate the diversity of features associated with the selection system in northern hardwoods, and should serve as a source of baseline data for future research on this and similar sites.

The diversity of habitat characteristics associated with an empirically balanced structure provides a noncommodity incentive to practice the selection system. High canopy closure, predominance of shade-tolerant understory vegetation, and a wide range of cavity heights and sizes were documented in our study and may prove characteristic of uneven-aged stands. Most notably, the stand had a high vertical structural diversity and an even distribution of foliage among canopy strata both before and after selection cutting. This consistency of structure is evidence of the previously unquantified link between habitat diversity and maintenance of a balanced stand structure and uniform spatial arrangement of different-sized trees in uneven-aged northern hardwood stands managed under the selection system.

Table 2.—Ground cover percentages in an empirically balanced selection stand on the Cuyler Hill State Forest, 1993. Results of paired t-tests for means ($\alpha = 0.05$) are shown

Ground cover	Pre-cut (n = 45)	Post-cut (n = 45)	Paired t-test (p-values)
Herbaceous vegetation	25 ± 2	14 ± 1	0.0001
Shrubs	11 ± 2	7 ± 2	0.0143
Seedlings	21 ± 2	12 ± 1	0.0001
Litter	95 ± 0.8	77 ± 3	0.0001
Exposed mineral soil	1 ± 0.5	13 ± 1	0.0001
Exposed organic soil	0 ± 0	5 ± 3	n/a
Logging slash	3 ± 0.6	11 ± 2	0.0001

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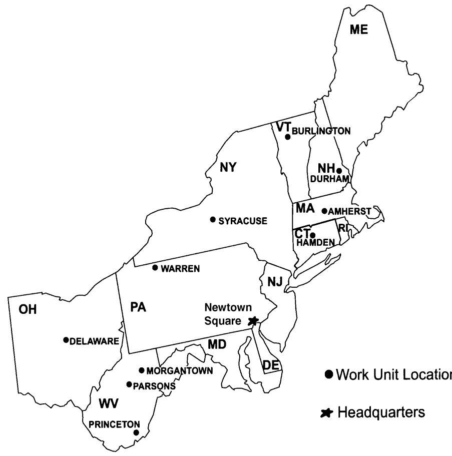

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