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8th Central Hardwood Forest Conference

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The editors would like to acknowledge and thank all of the people who served as manuscript reviewers for the Proceedings. The quality of the Proceedings has been improved due to your efforts. We would also like to thank Dr. Mark J. Twery, David E. Fosbroke, Shirley I. Smith, and Mark A. Mitchell for their assistance in converting wordprocessing documents, proofreading, preparation of the table of contents, and layout assistance and Arlyn W. Perkey for providing the cover photograph.

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March 3-6, 1991

Edited by

Larry H. McCormick and Kurt W. Gottschalk

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FOREWORD

This conference is the eighth in a series of biennial meetings that began in 1976 at Southern Illinois University. Other conferences have been hosted by Purdue University, University of Missouri, University of Kentucky, University of Illinois, and University of Tennessee. The purpose of these conferences has remained the same: to provide a forum for the exchange of information concerning the central hardwoods and to engender coordination among forest scientists in the central hardwood region. This purpose is evidently well-served: the last several conferences have each attracted some 45 to 65 program contributions, and the audiences have been correspondingly large.

Previous organizers have refrained from drawing precise boundaries around the "central hardwood region." We prefer to continue that policy on the grounds that to do otherwise might preclude some very worthwhile participation. Thus, while the principal focus has remained on the oak resource for reasons that are obvious, the ecological scope has broadened from oak-hickory (in the early meetings) to Appalachian oak (Knoxville and State College) and mesophytic forests. With a few exceptions, the commercially significant species are similar for all these forest types, and advancements in knowledge are of general interest.

But the central hardwood region is not merely a collection of similar forest types. It also has historical, demographic, political, and economic characteristics that tend to distinguish it from other forest regions of the United States. For example, the population is heavily rural and agricultural, primary wood markets tend to be diffuse and unorganized, wilderness values and endangered species have generally not been overriding issues, and a relatively minor proportion of the forest land is controlled by public agencies or corporate ownerships. These and related conditions play critical roles in the practice of forestry in this region, and in the aggregate they emphasize its distinction from other regions; but no single one is necessarily unique to the central hardwoods. For these reasons, the characteristics of nonindustrial private forest land owners in Massachusetts might be just as relevant to the central hardwood region as regeneration methods for white oak in Indiana.

Since these proceedings are being published in advance, we have no way of judging the ultimate success of the upcoming Eighth Conference. Of course, our earnest hope is that this meeting shall sustain the excellent reputation of the series. We believe this hope is encouraged by the quality of the papers in these proceedings.

REVIEW PROCEDURES

Each manuscript published in these proceedings was critically reviewed by at least two scientists with expertise in disciplines closely aligned to the subject of the manuscript. Reviews were returned to the senior author, who revised the manuscript appropriately and resubmitted it in a diskette format suitable for printing by the Northeastern Forest Experiment Station, USDA Forest Service where they were edited to a uniform format and type style. Manuscript authors are responsible for the accuracy and style of their papers.

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POSTER SESSION

PISTILLATE FLOWER ABORTION IN THREE SPECIES OF OAK

Robert A. Cecich, Gary L. Brown, and Bart K. Piotter[1]

Abstract: Pistillate flower survival was monitored at weekly intervals in three species of oak (*Quercus rubra* L., *Q. velutina* Lam., and *Q. alba* L.) during the 1989 and 1990 growing seasons in central Missouri. Pollen was shed between late April and early May in both years. However, in 1989 only *Q. velutina* flowers had emerged by the time of pollen shed; in 1990 flowers of all three species were receptive. Tree-tree variation was observed in morphological development of the flowers, especially in peduncle length in *Q. rubra* and *Q. alba.*

Flower abortion was pronounced during the early part of both growing seasons. By the end of May 1989, 95 percent of the *Q. rubra* flowers had aborted; by early July of that year 98 percent of the *Q. alba* flowers were dead. In 1990 those values were about 65 and 75 percent, respectively, with 98 percent mortality observed in *Q. alba* acorns by the end of the growing season. Forty to fifty percent of the *Q. velutina* flowers aborted by early July in both years, with little mortality thereafter.

Weevils destroy a large portion of an acorn crop. But, most oak flowers abort before reaching the acorn stage. If we look at the potential crop as a function of the number of pistillate flowers at the time of pollination, it is apparent that weevils are not the primary causal agent of variable acorn crops. What happens to the flowers?

We are currently exploring the hypothesis that pistillate flowers are destroyed by insects, primarily those in the family Membracidae, the treehoppers. Adults of these true bugs or sucking insects are active in the crowns of *Q. alba* just after the flowers emerge. Adults were observed with their stylets inserted into the stigmas. The flowers turned from green to brown within a week and aborted. The most abundant species observed on *Q. alba* was *Atymna querci* (Fitch.). The adult is present from early May to early June when most of the pistillate flower abortion occurs.

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MEASUREMENT OF FOREST CONDITION AND RESPONSE ALONG THE PENNSYLVANIA ATMOSPHERIC DEPOSITION GRADIENT

D. D. Davis, J. M. Skelly, J. A. Lynch, L. H. McCormick, B. L. Nash, M. Simini, and E. A. Cameron[1], J. R. McClenahen and R. P. Long[2]

Abstract: Research in the oak-hickory forest of northcentral Pennsylvania is being conducted to detect anomalies in forest condition that may be due to atmospheric deposition, with the intent that such anomalies will be further studied to determine the role, if any, of atmospheric deposition. This paper presents the status of research along a 160-km gradient of sulfate/nitrate deposition across northern Pennsylvania begun in 1986 by a multidisciplinary group of researchers at Penn State University and Ohio State University. Four general objectives of the study are: (1) estimate atmospheric deposition loadings across the gradient and at the specific study sites, (2) locate ecologically analogous intensive study sites across the deposition gradient to minimize extraneous variability in forest response, (3) measure and relate forest responses to environmental factors, including atmospheric deposition, and, (4) estimate effects of ambient ozone concentrations on tree seedling growth along the deposition gradient by use of open-top chambers.

The study region lies within the southern portion of the Allegheny Plateau physiographic province, a strongly dissected, large unglaciated tableland with elevations of 500-700 m. Forest types within the region include oak-hickory, mixed deciduous, and northern hardwoods, depending on aspect, slope position, and other factors. Thirteen ecologically analogous stands, ranging from 7 to 58 ha, were selected for intensive measurement of forest response across the deposition gradient from an initial set of 53 candidate stands. Selection procedures included qualitative evaluations to ensure that minimum criteria were met, followed by statistical comparisons of soils and amounts of canopy species to establish similarity on the basis of factors unlikely to have been affected by atmospheric deposition (nonresponse variables). The stands were distributed approximately equally among four uniformly-spaced core areas across the 160-km gradient. They are ridgetop northern red oak-dominated stands, 70-80 years of age, with no evidence of intermediate cutting, severe defoliation or other major disturbance. Soils are course-textured, stony, acidic, and low in base saturation.

Bulk deposition estimates based on intensive deposition monitoring at ten sites across the gradient indicate that annual sulfate deposition (wet plus dry) averages 57 kg/ha at the western end and 38 kg/ha at the eastern end. A coincident gradient of nitrate and other ions also exists. The gradient monitoring also points out the large spatial variability and importance of intensive monitoring for accurate assessment of causal relationships. Surfacing

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techniques employing the Pennsylvania monitoring network data from 1982-1987 were used to estimate average deposition of various ions at the forest response study sites. These estimates are being used to study relationships between deposition and forest response.

Forest community response to sulfate/nitrate deposition is hypothesized to occur earliest within the herb stratum. Particular emphasis is therefore being placed on measures of herb-layer biomass, species richness, and elemental status of selected species in relation to forest overstory, soil and deposition factors. Numbers and size of woody species in other strata were also determined. Correlation/regression analysis of community parameters with deposition estimates and soil/site factors are being determined.

Soils were intensively sampled by horizon, and comparisons of chemical and physical properties in relation to deposition and other site/forest community parameters are underway. Forest floor mass and humus metals loadings are undergoing similar comparisons.

Tree growth relationships are being studied using standard dendroecological procedures to model red oak, white oak and tuliptree tree-ring width response to climate, site and deposition. Chronologies for host (oaks) and non-host (tuliptree) species will be compared to develop techniques for detecting and assessing past impacts of major oak insect defoliators. Red oak height growth for selected time periods based on stem analysis data is being used to model relationships with soil, site and deposition factors.

Forest health assessments include crown transparency and twig dieback surveys, as well as bole evaluations, within all study stands. Leaf symptoms are being identified and quantified on annual samples of over 14,000 leaves collected from these three species. Ancillary to the leaf assessment program, an expert computer system was developed as a training aid for symptom identification and rating. Crown and bole assessments for each of the 13 stands indicated no unusual tree health conditions. Certain foliar disorders (e.g., galls) appear to be related to deposition patterns.

A lichen survey revealed that lichen richness was comparatively greater on the low sulfate deposition portion of the gradient. Concentrations of Al, Fe, Cr, and Cu in *Hypogemnia physodes* thalli were greater on the high-deposition portion of the gradient. These findings are suggestive of an air pollution effect.

Red maple sap chemistry was monitored for 2 years at seven sites along the gradient to determine the usefulness of sap constituency as a biomonitor of soil and atmospheric deposition chemistry. Preliminary analyses indicate that elemental content of red maple sap may be a valuable tool to indicate biological effects of chronic atmospheric deposition along the gradient, but may not be useful in detecting short-term effects of artificially added sulfate.

Open-top chamber studies at three remote sites along the deposition gradient are underway to assess the foliar and growth impacts of ozone concentrations representing ambient, half-filtered, and full-filtered levels. Ozone levels in 1988 exceeded the standard of 120 ppb numerous times; the standard was not exceeded in 1989. An ozone gradient coincident with the sulfate/nitrate deposition gradient was found. Ambient ozone levels induced foliar

symptoms on black cherry and tuliptree (sensitive species), but slight to no symptoms on more tolerant red maple and red oak. Increasing basal diameter and height of black cherry during the growing season was negatively correlated with ozone dose. Ozone stimulated premature fall coloration and defoliation on black cherry.

IMPACT OF SMALL MAMMALS ON REGENERATION OF NORTHERN RED OAK

Colleen A. DeLong, and Richard H. Yahner[1]

Abstract: The impact of small mammals on regeneration of northern red oak (*Quercus rubra*) was studied from October 1989 to December 1990 in Huntingdon County, Pennsylvania. Acorns were planted in two replicates each of three silvicultural treatments: 20% shelterwood, 70% improvement, and untreated mature forest. Four hundred acorns were planted in a 0.8-ha study site in each replicate, giving a total of 2400 acorns in each of six trials (Nov-Dec, Mar-Jun). One-half of the total acorns were direct-seeded 2 cm below the soil surface, and one-half were surface-seeded in a shallow depression on the soil surface. Acorn loss was compared between autumn (Nov-Dec) and spring (Mar-Jun), among treatments and between acorn depths. Most acorn loss was attributed to white-footed mice (*Peromyscus leucopus*). Total acorn loss (direct-seeded, surface-seeded) in the 20% shelterwood ranged from 28% to 68% in autumn and from 96% to 100% in spring. Total loss in the 70% improvement ranged from 44% to 84% in autumn and from 94% to 100% in spring. Total loss in the untreated mature forest ranged from 67% to 88% in autumn and from 99% to 100% in spring. Loss of direct-seeded acorns ranged from 17% in the 20% shelterwood during autumn to 60% in the 70% improvement during autumn. Loss of surface-seeded acorns ranged from 40% in the 70% improvement during autumn to 83% in the 20% shelterwood during autumn. Preliminary evidence indicated that acorn loss was lower in autumn than in spring, and acorn loss in autumn was greater in untreated forest sites than in treated sites.

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HARDWOOD STUMPAGE PRICE TRENDS IN NEW ENGLAND

Donald F. Dennis and Paul E. Sendak[1]

Abstract: Stumpage price trends in New Hampshire and Vermont varied considerably among species and products. Real stumpage price trends, expressed in 1988 dollars using the Producer Price Index to remove the effect of inflation, are reported for selected species and products. Long-term (1964-1989) trends in average annual prices are reported for New Hampshire and short-term (1981-1989) trends in average quarterly prices are reported for Vermont.

Real prices for red oak stumpage increased at a remarkable rate. These prices have increased at an average annual rate of 11.3% in New Hampshire and 7.0% in Vermont, since 1981. These rates represent the average rate of price change that occured over and above inflation, which averaged 1.2% during the period. Real prices for white pine, another commercially valuable species, also outpaced inflation annually by 2.1% in New Hampshire and 2.0% in Vermont. Real sugar maple prices declined in Vermont at an average annual rate of -1.6% and declined slightly in New Hampshire since 1981.

Stumpage prices for hardwood pulp and fuelwood did not keep pace with inflation since 1981. It appears that the sharp upturn in fuelwood prices that occured in the late 70's and early 80's has ended. The average annual decline in real fuelwood prices was -6.7% in New Hampshire and -4.3% in Vermont. The inventory of low-quality hardwoods has increased substantially over the past few decades. Real prices for softwood pulp remained stable in Vermont and increased slightly in New Hampshire since 1981.

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PREDICTING TREE MORTALITY FOLLOWING GYPSY MOTH DEFOLIATION[1]

David E. Fosbroke, Ray R. Hicks, Jr., and Kurt W. Gottschalk[2]

Abstract: Appropriate application of gypsy moth control strategies requires an accurate prediction of the distribution and intensity of tree mortality prior to defoliation. This prior information is necessary to better target investments in control activities where they are needed. This poster lays the groundwork for developing hazard-rating systems for forests of the Appalachian Plateau (AP) and the Ridge and Valley (R&V) by comparing the impact of gypsy moth defoliation in these two provinces.

METHODS

Field plots were established in defoliated and undefoliated stands of both provinces from 1984-1986. Two hundred and twenty-seven 1/10-acre circular plots were located primarily on State Game Lands in Somerset County, Pennsylvania, and 158 plots were located at Green Ridge State Forest in Allegany County, Maryland. All plots were located along the leading edge of gypsy moth infestation and represented a range of site and stand conditions. On each plot, tree variables (e.g. species, height and d.b.h.) and site characteristics (e.g. site index, slope inclination and aspect) were measured. From 1984-1989, each tree was evaluated for defoliation and vigor annually. In 1989, all variables measured during plot establishment were remeasured. Z-tests were used to test for differences in initial stand conditions and in tree mortality between the two provinces.

RESULTS

Initial Stand Conditions

Pre-defoliation stand conditions were similar for the two provinces. On average, plots were located in fully stocked mixed-oak stands that had an average diameter of 8 inches. Initial stocking ranged from 72% to 91% and average basal area ranged from 101 to 109 square feet per acre. Stands in the R&V province contained a higher proportion of oak. Oaks in undefoliated stands of the R&V were evenly divided between northern red oak, black/scarlet oak, white oak and chestnut oak. In defoliated R&V stands, white oak and the black/scarlet oak group accounted for 81% of the total stand basal area. No non-host species accounted for a significant proportion of the R&V stands. In the AP, chestnut oak and northern red oak

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dominated the oak composition. Red maple was the most abundant of the non-host species present in the AP.

Defoliation History

Defoliation histories differed between the two provinces due to differences in land management philosophies. In the AP, lands managed by the Pennsylvania Game Commission were not treated following defoliation. Plot defoliation in the AP (weighted by d.b.h.) averaged nearly 60% in 1985 and 1986, 23% in 1987 and less than 10% in 1988 and 1989. The gypsy moth management strategy at Green Ridge State Forest was to limit defoliation by aerial application of Dimilin. The data suggest that our research areas were sprayed following a single year of heavy defoliation in 1985 (ave. defoliation = 55%). The following year, average defoliation had dropped to < 2%.

Tree Mortality

As expected from the differences in defoliation history, tree mortality was greater in the AP (34%) than in the R&V (16%) even though R&V stands contained more oak. In both provinces, as the amount of oak in stands increased, so did the amount of mortality. This increase was more noticeable in the AP than in the R&V due to the larger variability in species composition of AP stands.

Mortality also increased with the number and intensity of defoliations. Undefoliated stands had less than 10% basal area loss. A single defoliation increased mortality to between 16% (R&V) and 24% (AP); two, three and four defoliations resulted in 34, 45, and 77% mortality in the Appalachian Plateau. When the average annual defoliation over the five-year period was less than 20%, basal area loss was less than 20% in both provinces. In the R&V, which suffered one severe defoliation in five years (i.e. ave. annual defol. always < 20%), only one plot exceeded 25% mortality. In the AP, when average annual defoliation over the five-year period was greater than 25%, basal area loss exceeded 29%. When the average defoliation was greater than 40%, at least 56% of the stand basal area died.

Slope inclination, aspect, and site quality also appear to influence tree mortality following gypsy moth defoliation. In the R&V, mortality was greatest (30%) on fair sites (NROSI=60-70) and lowest (11%) on the poorest sites (NROSI < 60). In the AP, mortality was greatest on the poor and fair sites (32 and 35% respectively) and lowest (9%) on the good sites (NROSI>70). In the AP, slopes greater than 20% had the greatest mortality (31-46%) while there was no relationship between slope inclination and tree mortality in the R&V. In the AP, mortality was greatest on southern and southeastern aspects (41 & 55%) and lowest on southwestern and eastern aspects (< 10%). In the R&V, mortality was greatest on northeastern through southeastern aspects (26, 20, 29%) and lowest on northern through western aspects (8, 13, 10%).

It is difficult to accurately predict tree mortality following defoliation because of the complex interaction of host vigor, insect populations, weather, secondary organism populations and site conditions. However, the results indicate that the proportion of oak and the level of

defoliation in a stand are the strongest foretellers of tree mortality. Several site conditions also appear to be related to mortality; however, these relationships may be driven by species composition. The testing of these interactions will need to be completed as part of the process of developing a gypsy moth hazard-rating system for Appalachian hardwood stands.

INVASION OF A PARTIALLY CUT OAK STAND BY HAYSCENTED FERN

John W. Groninger and Larry H. McCormick[1]

Abstract: Hardwood forests in Pennsylvania frequently develop a dense understory of hayscented fern (*Dennstaedtia punctilobula* (Michx.) Moore)) following partial overstory removal. Seedlings of desirable hardwood species are unable to develop in these understories. A study was conducted in a central Pennsylvania mixed oak stand to determine how hayscented fern becomes established following partial cutting.

Hayscented fern is capable of reproducing both sexually through the production of spores and asexually through the extension of a perennial rhizome. While rhizome extension and transportation by logging equipment have traditionally been considered the primary mechanisms of fern reproduction and invasion, these processes can also be the result of development from spores. Spores are disseminated throughout late summer and early fall and can emerge within days after release or during the following spring when soil conditions are favorable. Rhizomes grow and fronds are produced throughout the growing season. Individuals are capable of reproducing sexually three years after development from spores.

The study area is a 100-year-old stand dominated by northern red oak (*Quercus rubra* L.), black oak (*Quercus velutina* Lam.), yellow-poplar (*Liriodendron tulipifera* L.), and red maple (*Acer rubrum* L.) located on state forest lands 7 miles south of State College, PA. The site occupies a lower slope position and has a southeasterly aspect. Soils range from poorly to well drained. The stand received an improvement shelterwood cut during the spring of 1989 in which the basal area was reduced to 80 sq. ft. per acre. The stand contained a few isolated clumps of hayscented fern before logging. A previously partially cut stand adjacent to the study area contained dense fern understories.

Hayscented ferns arising from spores were observed in the study area during the spring one year after cutting. Both gametophytes and sporophytes were noted. These individuals are characterized by a dense clumping of small fronds generally less than 4 inches tall. A small rhizome (< 0.5 inches long) was usually present. These newly developing ferns appeared to be restricted to areas with high soil moisture usually growing from moss patches. Sexually

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reproduced ferns were most commonly associated with microsites produced by logging-related soil disturbance; where mineral soil was exposed through intensive log skidding and on the uphill banks of skid roads where high soil moisture is maintained by subsurface drainage. Ferns also grow frequently at the base of rocks or fallen logs where water runoff is concentrated and high soil moisture is maintained. We have occasionally observed spore origin ferns in microsites not associated with logging disturbance. These include soil mounds resulting from windthrown trees and wet areas associated with seeps. In contrast, new ferns have not been observed on well-drained mineral soil, areas with thick litter cover or on compacted skid roads. Dense shade does not appear to limit fern development under these conditions. Instead, shaded conditions may favor the growth of young ferns by maintaining high soil moisture.

Based on the findings of this study, sexual reproduction is the primary mode by which hayscented ferns invade previously fern free areas. Once these individuals become established, asexual reproduction through rhizome extension becomes the primary means of reproduction. Reducing the impact of log skidding on wet sites would also help prevent sexual reproduction of hayscented ferns. The herbicide sulfometuron (Oust®) effectively controlled hayscented fern spore emergence in a greenhouse study and may also prevent the development of spore origin ferns if applied following timber harvesting.

MICROCOPPICE: A NEW STRATEGY FOR RED OAK CLONAL PROPAGATION

Duane E. Harper and Brent H. McCown[1]

Abstract: The great demand for red oak (*Quercus rubra* L.) has forced plant propagators to consider viable methods of mass clonal propagation for the species. A process called 'microcoppicing' is presently being developed to help meet such needs. The advantage of this technique is that it proposes to work with oak's natural growth characteristics. The 'microcoppice' hypothesis capitalizes on the well-known ability of oak to form epicormic shoots. This concept should be capable of providing a large number of plants without being overly hampered by oak's episodic growth tendencies. This theory is being developed by utilizing seedlings, stump sprouts, and grafted scions from mature plants. Plant material will be disinfected, cultured on an agar-based media, and rooted *in vitro*. The plants will then be put through an *in vitro* coppicing phase, thus producing a multiplication effect. The derived microshoots will then be rooted *ex vitro*. After acclimation, it is believed that the plants could again go though a coppicing series for further multiplication. This process should be capable of producing a large quantity of plants from mature stock, a goal that has eluded plant propagators working with oak species.

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FIELD TESTING A SOIL SITE FIELD GUIDE FOR ALLEGHENY HARDWOODS

Stephen B. Jones[1]

Abstract: A site quality evaluation decision model, developed for Allegheny hardwoods on the non-glaciated Allegheny Plateau of Pennsylvania and New York, was field tested by International Paper (IP) foresters and the author, on sites within the region of derivation and on glaciated sites north and west of the Wisconsin drift line. Results from the field testing are presented along with the decision model as modified for both the glaciated and non-glaciated conditions.

Within the region of derivation on the non-glaciated Allegheny Plateau, field testing warranted only a minor modification of the slope criteria for discriminating between the four topographic classes. North and west of that region, lesser topographic variability seems to obviate the need for four distinct sets of site quality decision criteria.

The models serve as practical field guides for foresters, and rely on field determinable decision criteria, including: soil texture, soil stoniness, aspect, shade angle, slope shape, and effective rooting depth. IP foresters and management have adopted the field guide as a principal criterion for forestry investment decisions. A documentation of site potential using the field guide is requisite to budget authorization for individual land management actions.

Suggestions are offered for developing similar field guides elsewhere in the Central and Eastern Hardwood Regions.

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COMPARISON OF NORTHERN GOSHAWK NESTING HABITAT IN APPALACHIAN OAK AND NORTHERN HARDWOOD FORESTS OF PENNSYLVANIA

J. Timothy Kimmel and Richard H. Yahner[1]

Abstract: The Northern Goshawk (*Accipiter gentilis*) is a rare to uncommon woodland raptor in Pennsylvania. Although it is primarily a boreal species, the goshawk nests in Northern Hardwoods and Appalachian oak forests along the southern margin of its range in Pennsylvania. This study compared the nesting habitat of goshawks in Appalachian oak and Northern Hardwoods forests in Pennsylvania during the 1989-90 field seasons.

Vegetative and physiographic habitat variables were quantified at both the nest site (microhabitat) and landscape (macrohabitat) levels. Preliminary results indicate that conifers may be more important for goshawks nesting in Appalachian oak forests. We suggest that microclimatic factors associated with conifer stands in oak forests may create a more favorable nesting environment for this northern raptor. Results of this study will be important in developing management strategies for maintaining critical nesting habitat for the goshawk in Pennsylvania.

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RESPONSE OF CHESTNUT OAK AND RED OAK TO DROUGHT AND FERTILIZATION: GROWTH AND PHYSIOLOGY

Karl W. Kleiner, Marc D. Abrams, and Jack C. Schultz[1]

Abstract: Chestnut oak (*Quercus prinus* L.) and red oak (*Quercus rubra* L.) seedlings were grown for two seasons under two nutrient regimes: **fertilizer** + (NPK) and **fertilizer** - (No NPK). Beginning two weeks after budbreak, water was withheld for 10 weeks during the second growing season. Leaf water potentials, gas exchange measurements and growth measurements were made on a subset of plants on alternate weeks (5 sample weeks).

Red and chestnut oak growth was positively influenced by the **fertilizer** + treatment. Over the ten week treatment period, seedling diameter, height, and shoot weight were all significantly greater in the **fertilizer** + treatment, with the greatest differences measured during weeks 8 and 10. Red oak shoot and root weights were significantly greater in the **water** + treatment. Budbreak of red and chestnut oaks in the **fertilizer** + treatment was on average, 3 days earlier than for individuals in the **fertilizer** - treatment. Based on growth over the ten weeks, the treatment rankings for both red and chestnut oak were: $H_20+/NPK+ > H_20-/NPK+ > H_20+/NPK- > H_20-/NPK-$.

Over the 10 week treatment period, measures of red and chestnut oak carbon gain rates, stomatal conductance, transpiration rates and water use efficiency were all significantly reduced by the **water** - treatment. The greatest reduction in carbon gain rates occurred during weeks 8 and 10. By week 10 chestnut oak carbon gain rates were significantly reduced in the **water** - treatment (27% reduction) as compared to the **water** + treatment. Although red oak exhibited a greater reduction in carbon gain rates than chestnut oak (37% reduction), this was not significant due to the greater variation among the seedlings.

For chestnut oak, significant reductions in carbon gain rates occurred before significant reductions in leaf water potentials occurred. Although predawn leaf water potentials and mean diurnal leaf water potentials in the **water** - treatment were not significantly lower until week 10, carbon gain rates, water use efficiency, stomatal conductance and transpiration rates were all significantly reduced by week 8 in the **water** - treatment.

The **fertilizer** + treatment did not ameliorate carbon gain rates for seedlings of red or chestnut oak in the **water** - treatment. In both the **water** + and the **water** - treatments, unfertilized seedlings had significantly greater carbon gain rates, stomatal conductance, transpiration rates, predawn and diurnal leaf water potential than fertilized seedlings. Based on

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the measures of carbon gain rates during the final week of drought, the treatment rankings for red oak were: H_2O+/NPK- > H_2O+/NPK+ > H_2O-/NPK- > H_2O-/NPK+ and the treatment rankings for chestnut oak were: H_2O-/NPK- > H_2O+/NPK+ > H_2O+/NPK- > H_2O-/NPK+.

PHYSIOLOGICAL AND STRUCTURAL FOLIAR CHARACTERISTICS OF FOUR CENTRAL PENNSYLVANIA BARRENS SPECIES IN CONTRASTING LIGHT REGIMES

Brian D. Kloeppel, Mark E. Kubiske, and Marc D. Abrams[1]

Abstract: Four central Pennsylvania barrens species, black oak (*Quercus velutina*), chestnut oak (*Quercus prinus*), red maple (*Acer rubrum*), and sassafras (*Sassafras albidum*), in the sapling size range were tagged and monitored in juxtaposed understory and full sunlight conditions. Five times during the 1990 growing season diurnal gas exchange measurements were collected along with stomatal and tissue leaf structure on all species in both light regimes. Concurrently, tissue pressure-volume (P-V) analysis and soil moisture analysis were conducted to compare inter-site and inter-species water relations parameters. One sampling date was conducted at the end of a mild drought period to determine if adjustments had occured in water relations parameters. Leaf structure data indicated that guard cell length and stomatal density were fixed over the growing season, but differences existed between the contrasting light regimes. Also, the full sunlight treatment leaves were relatively thicker than the understory leaves. Species diurnal gas exchanges measurements were similar within light regimes, but differences in species diurnal patterns existed. Sassafras usually peaked soon after full sunlight conditions existed and then tailed-off markedly; whereas all three other species reached a plateau in mid-morning and maintained moderate levels of net photosynthesis during the afternoon. Soil moisture did not decrease to drought conditions at anytime during the growing season. However, the fourth diurnal measurement on August 3, 1990 showed a 50% decrease in soil moisture to 6%. This decrease in soil moisture did not significantly affect pre-dawn leaf water potentials or the calculated parameters from the P-V analysis. However, the P-V analysis did show the high capacitence and relatively high wilting point exibited by sassafras compared to the other three species.

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EFFECT OF STAND AGE AND SOILS ON FOREST COMPOSITION AT SPOTSYLVANIA BATTLEFIELD, VIRGINIA

David A. Orwig and Marc D. Abrams[1]

Abstract: Woody vegetation was surveyed in 28 forest stands at the Spotsylvania Battlefield, Virginia to examine forest composition and structure in relation to stand age and edaphic features. Pioneer stands consisted primarily of *Pinus virginiana*, which represented 50% of the overstory importance value total, whereas mid-successional stands contained a mixture of pine and hardwood species including *Quercus alba*, *Liriodendron tulipifera*, and *Liquidambar styraciflua*. Late successional stands were dominated by *Quercus* and *Carya* species, as well as *Cornus florida* and *Nyssa sylvatica*. Although *Q. alba* was the leading dominant in presettlement forest data and in half of the surveyed stands, lack of oak reproduction in the oldest stands casts doubt as to the future dominance of the species, possibly due to fire exclusion. Pine stands were found on deep, well-drained eroded soils while hardwood stands were found on both well-drained and poorly-drained soils. Radial growth analysis indicated that all stands were initiated within the last 150 years. Many stands were even-aged and appeared to be in a prolonged stem exclusion stage, with little or no recruitment of species into the tree size category. Stand age, past land use, and edaphic characteristics were the primary factors in determining the present vegetative composition and structure within Spotsylvania Battlefield.

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FIELD RESPONSE OF RED OAK, PIN CHERRY AND BLACK CHERRY SEEDLINGS TO A LIGHT GRADIENT

Mark R. Roberts[1]

Abstract: The objective of this study is to determine the relationship between light conditions and the growth of natural seedlings of red oak (*Quercus rubra* L.), pin cherry (*Prunus pensylvanica* L.) and black cherry (*P. serotina* Ehrh.) growing under a range of canopy densities in northwestern Pennsylvania. Annual height growth, total height and photosynthetically active radiation (PAR) are being monitored for two growing seasons (1990-1991) on 1-year-old natural seedlings. Experimental plots were located in mature oak stands where understory trees (<5.3" dbh) were removed and the remaining overstory trees represented 100%, 60% and 40% residual relative densities. The areas also were fenced to exclude deer and eliminate the impact of browsing on seedling growth rates. The plots were variable in size up to a 50 foot radius, and contained at least six healthy seedlings of one of the target species. Ten plots that represented a range of canopy densities from complete canopy cover to large openings were established for each species. The plots were stratified into three canopy density levels: large openings, partial canopy, and complete canopy. In each plot, the six tallest 1-year-old seedlings of each species were selected for measurements. Only seedlings that were free of physical damage and that were free-to-grow (not overtopped by surrounding vegetation) were selected. Total integrated PAR was measured over a 24-hour period at least once in each plot in September, 1990, using six Li-Cor quantum sensors attached to a Li-Cor LI-500 integrator. Each sensor was placed on a platform directly above one of the six seedlings. All radiation values will be expressed as a percent of full sunlight received in the open. At the end of the 1990 growing season, the second year of seedling growth, stem elongation in the first and second year were measured on each seedling. Total seedling height was also measured. For red oak seedlings, the number of flushes in each year was recorded. These measurements will be continued during the 1991 growing season.

Preliminary results dealing with total seedling height as related to canopy density class are presented in this poster. Average total height was similar for the three species under the complete canopy, but differences among species became more pronounced as canopy density decreased. The height of red oak seedlings increased only slightly from the complete canopy to the large openings (0.7 ft. to 1.1 ft.), with no significant differences among canopy density classes ($p>0.05$). The mean heights of black cherry were 0.9, 2.7, and 5.9 ft. for the complete, partial and open canopy classes, and the heights of pin cherry were 1.2, 4.4, and 9.8 ft. for the three canopy density classes, respectively. For both pin cherry and black cherry, the

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differences among canopy density classes were significant ($p<0.05$). These results indicate that heavy cutting does not stimulate height growth of red oak seedlings, but does stimulate growth of the competing cherry species. The dramatic increase in height growth of pin cherry and black cherry under the partial and open canopy conditions creates intense competition for red oak seedlings. Under the full canopy, red oak seedlings would not be suppressed by pin cherry and black cherry, but seedling vigor is low and may result in poor long-term survival. If natural red oak regeneration is desired, limited overstory removal combined with control of competing vegetation will probably be required. The detailed measurements of PAR, when complete, will help define more precisely the light and canopy conditions that will favor the growth of red oak regeneration.

PIONEER MOTHERS' MEMORIAL FOREST REVISITED

Richard C. Schlesinger, David T. Funk, Paul L. Roth, and Charles C. Myers[1]

Abstract: The area now known as Pioneer Mothers' Memorial Forest was acquired by Joseph Cox in 1816 from the public domain. In 1944, a portion of that property, including the area referred to as Cox Woods, was established as a National Forest Research Natural Area. This beech-maple forest, located in the Knobs area of southern Indiana, is considered to be one of the few remaining remnants of the original forests in the region. Although there is no known record of cutting trees in the stand, portions of it were pastured prior to it's acquistion by the Forest Service in 1941. Also, a tornado in 1897 blew down most of the larger trees in a strip about 160 m wide through a portion of the stand. Otherwise, the forest appears essentially undisturbed.

Following the 1978 growing season, permanent plots were established in the stand on a 50 m by 50 m grid. All trees 15 cm dbh and larger were measured and mapped on a 0.1 ha circular plot, and trees between 5 cm and 15 cm were measured and mapped on a 0.01 ha circular plot in the center of the main plot. These plots were remeasured following the 1989 growing season. Two of the 153 plots were located in a pine planting, 15 plots were bordered by private lands (open pasture and harvested forest), and 15 plots were in old pasture areas. Thus, the following descriptions are based on the data from the 121 remaining plots, representing 30.25 ha.

The total number of trees has declined from 620 per ha in 1978 to 522 in 1989. The basal area (sq. m per ha) increased slightly from 27.1 to 27.8, while the overall stocking percent went from 95 to 93. Seventy-six trees per ha grew passed the 5 cm minimum dbh threshold, and 175 trees per ha died during the 11 year period between measurements. A total of 32 species were represented by at least one individual in the 1978 sample; in 1989, there were 33 species.

Sugar maple (*Acer saccharum* Marsh.) was by far the most prevalent species in both 1978 (48 percent of the trees) and 1989 (55 percent). Dogwoods (*Cornus florida* L.) were a distant second at 8 percent in 1978. In 1989, the second most numerous species was beech (*Fagus grandifolia* Ehrh.) at 8 percent. In terms of basal area, sugar maple was 25 percent and 27 percent, respectively, in 1978 and 1989, followed by beech at 15 percent in 1978 and yellow poplar (*Liriodendron tulipifera* L.) at 16 percent in 1989.

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Fifty-two percent of the ingrowth trees were sugar maples. Of the 12 other species that were represented by ingrowth, dogwood was the next most numerous at 14 percent. However, more stems of these two species died than of any others. Sugar maple was 26 percent of the mortality, while dogwood was 16 percent.

The visually-dominant portion of this old growth stand, those trees at least 51 cm dbh and larger, increased from 31 trees per ha in 1978 to 34 trees in 1989. Basal area per ha increased from 11 sq m to 12 sq m, representing 41 percent of the total basal area in 1978 and 44 percent in 1989. Of the 19 species composing this portion of the stand, beech was most numerous in 1978 (24 percent of the total number), followed by yellow poplar at 13 percent. Sugar maple was the sixth most numerous at eight percent. In terms of basal area, the pattern was similar. Beech was 28 percent of the total, followed by yellow poplar at 13 percent, and sugar maple was seventh at seven percent.

During the 11 year study period, mortality of these large trees amounted to 5.5 trees per ha and 2 sq m of basal area. Fifty-two percent of the trees lost were beeches (60 percent of the basal area). Black walnuts (*Juglans nigra* L.) and sugar maples were 11 percent each.

By 1989, yellow poplars were the most numerous large trees (19 percent of the total number), with beeches now second at 15 percent. The basal area represented by these two species was nearly equal (18 percent and 17.5 percent respectively). Sugar maples were still sixth in number (eight percent) and moved to sixth in basal area (six percent).

The most notable change from 1978 to 1989 is the loss of the large beech trees. Thirty-eight percent of the large beech trees that were present in 1978 died. During the same period, ingrowth into the large tree size class was sufficient to replace only 12 percent of the mortality. The largest of the dying beeches was 104 cm dbh, while several others were over 80 cm. Thus, several large gaps in the canopy were created.

Another important change in the overstory is the increase in number of yellow poplar trees. Overall, eight new trees per ha grew passed the 51 cm threshold. Thirty-two percent of these were yellow poplars. The next most numerous recuits were black oaks (*Quercus velutina* Lam.) at 13 percent, followed by white oaks (*Q. alba* L.) and northern red oaks (*Q. rubra* L.) at 11 and 10 percent, respectively. Sugar maples were the fifth most numerous recuits at eight percent.

During this relatively short study period of 11 years, there have been several significant changes in what was thought to be a relatively stable community. The total number of live trees dropped by 16 percent, while the basal area and stocking percent remained relatively constant. The number of large trees increased by eight percent, while at the same time the most numerous large tree species in 1978, beech, was represented by 34 percent fewer trees. If such stands are to be used as benchmarks representing the original forests, it will be necessary to describe not only the composition and structure at a particular point in time, but also the expected amount and type of variation over time.

SURVIVAL AND GROWTH OF DIRECT-SEEDED AND NATURAL NORTHERN RED OAK AFTER CLEARCUTTING A MATURE RED PINE PLANTATION

R.D. Shipman and D.B. Dimarcello[1]

Abstract: Initiated in 1985, a study was designed to evaluate the effects of site preparation (rototilling) and logging slash on 5-year survival and growth of natural and direct-seeded northern red oak (*Quercus rubra* L.) after clearcutting a mature, 45-year-old red pine (*Pinus resinosa* Ait.) plantation in central Pennsylvania. The study area, approximately 2.2 ha in size, is flanked on the northeast and southeast by dense stands of Norway spruce (*Picea abies* (L.) Karst.) and on the southwest by 60-70 year-old mixed oak stands. Soils supporting the red pine plantation are mainly well-drained, moderately acid (pH 4.5-5.6) silty clay loams, derived from weathered shale and shaly limestone.

A 100 percent, before and after harvest inventory of all naturally occurring economically important tree seedlings, noncommercial shrubs and herbaceous species was conducted during September, 1984 and April, 1985 respectively. Following inventory, all natural (advanced) red oak seedlings beneath the red pine overstory were hand-sheered back to the groundline to facilitate later identification of direct-seeded red oak seedlings. An uncut "control" block was inventoried, but received no additional pre-harvest treatments.

Four duplicate site preparation treatments, each approximately .04 ha in size were established on the study area: (1) Rototill-no slash (2) Rototill-slash (3) No rototill-no slash and (4) No rototill-slash. In preparation for oak seeding, one-half of the treatments received a mechanical pre-harvest scarification of the forest floor and surface soil layers with a 4 h.p. gasoline engine rototiller between 8-foot spaced red pine tree rows. On the remaining blocks, "fresh" slash (tops and branches) 0.5 to 1.2 m thick, was left undisturbed on the forest floor after removal of the merchantable pine logs. Previously stratified red oak acorns, collected from five trees of the same seed source were planted on April 6, 1985. Acorns were sown in each treatment between consecutive red pine "stump" rows, 1.8 m apart. Within each row, acorns were spaced .45 m apart at a depth of 2.5 to 5.0 cm using a metal "V"-tipped planting pole, creating holes in the mineral soil. Two acorns were sown in each hole, covered by soil and surface litter, and tramped over by foot. Shoot emergence of the germinating seed first occurred in mid-May, 1985.

Variation in survival and growth of direct-seeded and naturally occurring northern red oak seedlings was evaluated after the first and fifth growing seasons. Chi-square analysis and pairwise comparisons were used to test significant differences among and between site preparation treatments. After the first growing season, survival of both direct-seeded and

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naturally occurring red oak seedlings with the rototill/slash and no rototill/slash treatments were significantly higher (P=0.05) than the rototill/no slash and no rototill/no slash treatments. However after five growing seasons, scarifying with a rototiller, in combination with intact logging slash, showed significantly greater total numbers of seedlings/ha than the remaining treatments. Mean 5-year height growth of acorns sown on slash-covered areas with or without rototilling were both significantly superior to seedlings grown on plots without logging slash (Fig. 1). Germination and early survival of direct-seeded acorns was most pronounced on rototilled blocks. Although the presence of slash also enhanced germination and survival, an added benefit of slash cover was to protect young red oak seedlings from browse damage.

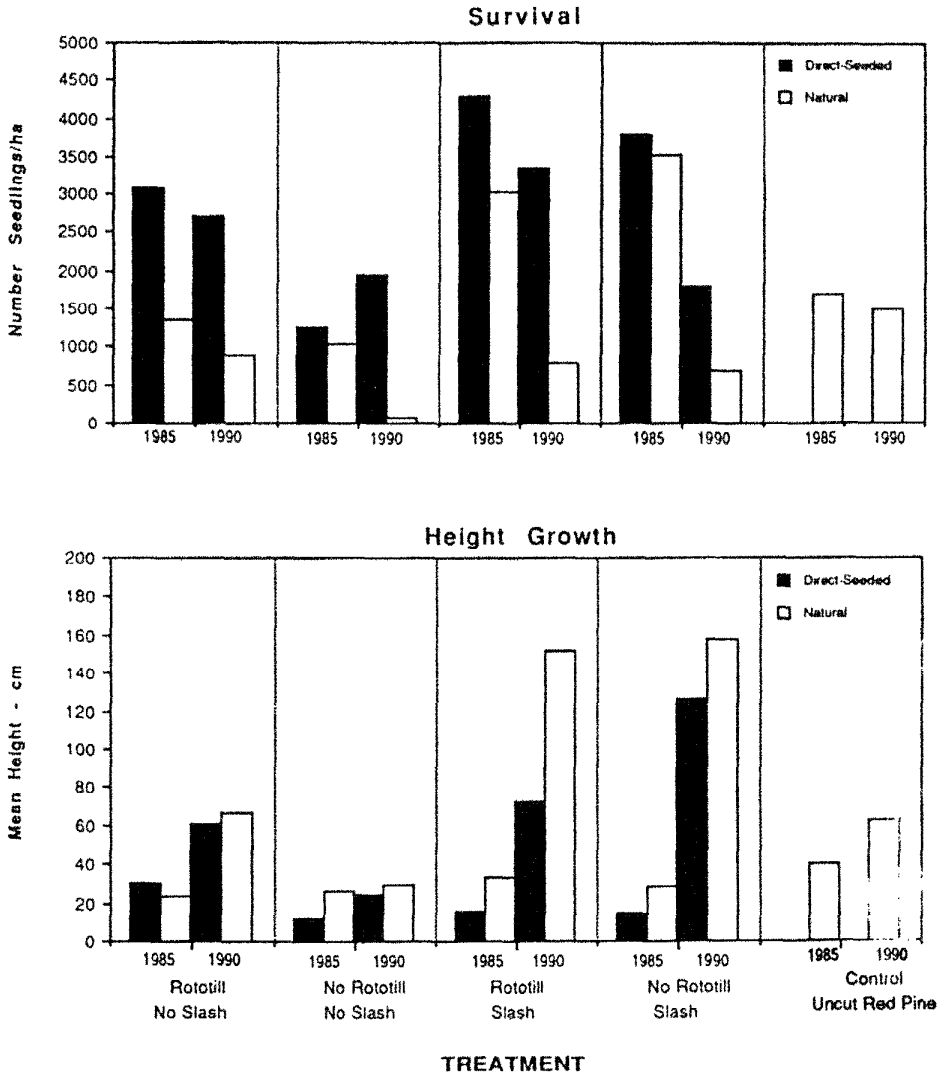

Figure 1. Effects of site preparation on northern red oak seedlings after clearcutting red pine.