Natural Resource Network

Connecting Research, Teaching and Outreach

The 6th Eastern Old Growth Forest Conference

Moving Toward Sustainable Forestry: Lessons From Old Growth Forests

September 23-26, 2004
Geneva Point Center, Moultonborough, NH

Recommended Citation:
Bennett, Karen P., technical coordinator. 2005. Moving Toward Sustainable Forestry: Lessons from Old Growth Forests. University of New Hampshire Cooperative Extension Natural Resource Network Report

UNIVERSITY of NEW HAMPSHIRE
COOPERATIVE EXTENSION

UNH Cooperative Extension
131 Main Street, 214 Nesmith Hall, Durham, NH 03824

The 6th Eastern Old Growth Forest Conference

Moving Toward Sustainable Forestry: Lessons From Old Growth Forests

September 23-26, 2004

Geneva Point Center, Moultonborough, NH

2004 Event Sponsors

Adirondack Council
Appalachian Mountain Club
Audubon Society of NH
Bear-Paw Regional Greenways
Center for Woodland Education
Eastern Native Tree Society
Forest Stewardship Guild
Forest Watch
Friends of the Sandwich Range
Hancock Land Company
Lakes Region Conservation Trust
Manomet Bird Observatory
New England Forestry Foundation
New England Wildflower Society
New Hampshire Fish & Game
NH Division of Forest & Lands
NH Charitable Foundation
Northeast Wilderness Trust
Northern Woodlands Magazine
Society for the Protection of NH Forests
Society of American Foresters
The 500 Year Forest Foundation
The Nature Conservancy
The Sweet Water Trust
The Wildlands Project
The Wilderness Society
University of New Hampshire
UNH Office of Sustainability
UNH Cooperative Extension
USDA Forest Service- Northeastern Research Station
USDA Forest Service- Northeastern Area State & Private
White Mountain National Forest
Wonalancet Outdoor Club

September 2004 brought beautiful fall weather and 200 conservationists, land managers, and old growth enthusiasts to the shores of Lake Winnipesauke in Moultonborough NH for the 6th Eastern Old Growth Conference.

The conference was dedicated to furthering the scientific understanding and conservation of old growth forests in the eastern US and Canada and promoting sound forest management, informed by an understanding of old growth forest dynamics. The conference featured scientific research that emerged since the prior conference of 2000 and provided a forum for discussing the identification, protection and use of old growth forests on a working landscape. Specifically, conference objectives were: 1) to disseminate information to conservation groups and the forest products industry about old growth forests; 2) to explore the dynamics of old growth forest ecosystems in a way that can inform sustainable forestry practices; and 3) to provide a forum for discussing the ways in which the land conservation community can partner with the forest products industry in conserving forest lands.

These proceedings were prepared as a supplement to the conference. Papers submitted were not peer reviewed or edited. They were compiled by Karen P. Bennett, Extension Professor and Specialist in Forest Resources. Readers are encouraged to contact authors directly for more information or for clarifications. The papers appear in order of the conference schedule and a table of contents and the concurrent workshop schedule is included as an aid to finding papers of specific interest. Conference organizers are indebted to the authors.

Copies are available on the following website http://ceinfo.unh.edu/Forestry/Forestry.htm or for $5 each from UNH Cooperative Extension, 211 Nesmith Hall, Durham, NH 02824.

Conference Committee

Karen Bennett	**Jim DiStefano**
Kathie Fife	**Chris Kane**
Tom Lee, Ph.D.	**Bill Leak**
Evelyn MacKinnon	**Frank Mitchell**
Jim Northup	**Rick Van de Poll, Ph.D.**

Conference Advisors

Charles Cogbill	**Lee Frelich, Ph.D.**
Don Leopold, Ph.D	**Robert Leverett**
William Martin, Ph.D.	**David Stahle, Ph.D.**
Tom Wessels	

Table of Contents

Lobbying For Stewardship, Conservation and Old Growth, Opening Remarks

William H. Martin, University of Kentucky, Division of Natural Areas, Case Annex 105, Richmond, KY, 40475

Kentucky is one of the leading hardwood producers in the United States, and the forest products industries play a vital role in the state's economy. Forested acreage in the state is over 11 million acres (47% of total acres) with over 92 percent in private ownership.

Over the last 10 years, the state has advanced in forest stewardship and conservation. In 1994, dedicated funding was obtained for the Heritage Land Conservation Act. These funds have allowed the state natural resources agencies, local governments, and colleges and universities to acquire lands from willing sellers to conserve and preserve lands in their "natural state." Since creation of the Kentucky Heritage Conservation Fund, over 22,000 acres of land have been acquired. Most of this land is forested with purchases of old-growth bottomland hardwood forest in western Kentucky, the remaining tract of unique woodland-savannah in the central Bluegrass region, and a large tract of old-growth mixed mesophytic forest in the eastern mountains. In 1998, the Forest Conservation Act was passed, taking the first steps in state-wide forest stewardship. The act provides for a mandated Master Logger program and establishes Best Management Practices to guide harvesting operations.

These two stewardship and conservation initiatives required leadership by the two governors and support of the General Assembly. Their passage also required cooperation among several special interest groups including the forest industries and state conservation groups. Opposition came from groups favoring private property rights and environmental groups that wanted tougher regulation of harvesting practices and accountability.

Efforts to conserve forest land and promote sustainable forest in the eastern United Sates require the development of initiatives that are supported by a coalition of individuals and groups who are willing to lobby and work many hours and years toward common goals. In most states, natural resource issues have low visibility and limited, short-lived public awareness. The "forest coalition" will need to significantly elevate concern for and appreciation of the value of the goods and services provided by forests. Target audiences are the forest landowners (in particular!); the general public; members of the print and electronic media; local and state decision makers; and organizations who can become partners in this important conservation effort. Tomorrow's forests and people depend on a successful campaign.

Late-Successional Retention and Restoration on the Appalachian Mountain Club's Katahdin Iron Works Property in Maine, Opening Remarks

David A. Publicover, DF, Senior Staff Scientist, Appalachian Mountain Club, Gorham, NH

The AMC's Maine Woods Initiative is a long-term project that seeks to promote and integrate land protection, biological conservation, backcountry recreation, sustainable forest management, and local community economic development within the 100-Mile Wilderness region of central Maine. In 2003 the AMC took the first step in this project with the purchase of Little Lyford Pond Camps (a historic sporting camp) and the surrounding 37,000 acres of forestland from International Paper. The property lies between the towns of Greenville and Brownville and is bisected by the Barren-Chairback-Gulf Hagas section of the Appalachian Trail corridor. The property has a history of commercial timberland ownership and harvesting dating back to at least the 1870s.

A major goal of AMC's ownership is over time to encourage a more natural mature forest condition and an increased representation of late-successional structures and conditions. This will involve *retaining* these characteristics where they are currently present and *restoring* them where they are currently absent. While retention by its nature implies leaving things alone, restoration can take either a "hands off" approach (let nature take its course) or active management to promote the development of desired structures and conditions.

Both retention and restoration must be considered across a range of scales:

- Individual trees within stands.
- Entire stands within compartments or watersheds.
- Entire watersheds within landscapes or large properties (small to midsized ecological reserves).
- Entire landscapes or properties within states or bioregions (large ecological reserves).

The AMC is currently developing a management plan for the property. A property-wide ecological survey was undertaken in the summer of 2004, a major goal of which was the identification of stands with significant late-successional characteristics. This information will be incorporated into plan decisions, including the designation of areas to be reserved from harvesting and decisions about harvesting standards and guidelines.

Examples of how our late-successional retention and restoration goals are being addressed in the plan at the range of scales describe above include:

Landscape level retention/restoration - 10,000 acres in the northern part of the property is being designated as an ecological reserve. This area encompasses much of the watershed of the West Branch of the Pleasant River upstream of Gulf Hagas. It was chosen primarily for its landscape context and diversity, rather than its current condition.

Individual or multi-stand retention/restoration - nine areas ranging in size from 9 to 535 acres have been identified as no-harvest "retention areas". While some of these areas were delineated based on non-ecological (recreational/aesthetic) factors, others were designated because they contain the most significant late-successional stands on the property ("incipient old growth") or contain mature stands with good potential for late-successional development over the long term. (In addition to these areas, inoperable lands and no-harvest riparian zones will also serve as sites for late-successional retention and restoration across the landscape.)

Within stand retention - Harvesting guidelines call for the retention of all trees over 18" DBH as well as cavity and wildlife trees. Guidelines of this type are fairly well-established and included in existing documents on sustainable forestry[1].

Within stand restoration - Many stands on the property have a history of heavy harvesting and are lacking late-successional characteristics. Harvesting guidelines will ensure the retention of sufficient overstory trees to provide a long-term supply of potential late-successional structures. For example, during the harvest of an extensive area of low-quality beech-dominated hardwoods in the summer of 2004, all yellow birch were retained from harvesting. This residual overstory (about 30 to 50 ft^2/acre of basal area in trees 8 to 14" DBH), though not appropriate from a purely silvicultural perspective, maintains a more natural multi-level canopy over the residual dense sapling understory. While some of these trees may be removed in future harvests, many will be permanently retained and will over time restore the large tree/coarse woody debris component that is currently absent.

Among the issues and questions raised by this approach are:

How "good" should a stand be to be worthy of retention? This will of course depend on the late-successional value of an area relative to the remainder of the property. The Late-Successional Index being developed by the Manomet Center for Conservation Sciences may serve as a valuable tool to help with this type of assessment.

Restoration through natural successional processes or active management? For example, one retention area consists of about 125 acres of even-aged red spruce about 80 years old. The stand lacks both late-successional structure and vertical and horizontal diversity. Though the stand will be reserved from harvesting, might it be more appropriate to promote the growth of larger trees and the development of structural diversity through harvesting?

Appropriate silvicultural strategies to promote late-successional restoration. While many groups (most notably The Nature Conservancy) are working to develop principles of "natural dynamics silviculture", this approach needs to be balanced against the appropriate silvicultural strategies based on existing stand conditions.

Incorporating late-successional retention and restoration into timber growth and harvesting models. *While consideration of retention and restoration at the stand level and above is relatively straightforward (areas are simply removed from harvest calculations), within-stand retention and restoration guidelines are not well considered by existing timber growth and harvest models.*

---

[1] For example, *Good Forestry in the Granite State: Recommended Voluntary Forest Management Practices for New Hampshire* and *Biodiversity in the Forests of Maine: Guidelines for Land Management*.

Balancing ecological and economic goals. The retention and restoration of late-successional conditions will incur a cost in foregone timber harvest revenue. The incorporation of these goals to the extent described here may be appropriate for public and non-profit ownerships but may prove unacceptable to commercial timberland owners. However, the general approach should be applicable, though the extent to which it is applied will vary based on the relative importance the landowner places on ecological goals versus economic return.

SEPTEMBER 24 CONCURRENT SESSIONS

	Meeting House Main Hall	**Meeting House Upper Room**	**Meeting House Room 3**	**The Chapel**	**Lakeview Lodge**	**Fireside Dining**
10-10:45	**Managing for Old Growth Forest Structure in Northern Hardwoods-** Bill Keeton, *University of Vermont*	**How Do We Manage Old Growth?-** Steve Fay, *USDA Forest Service*	**Does Age Matter? Evidence of Vigorously Growing Ancient Oaks-** Neil Pederson, *Columbia University*	**Designing Silvicultural Systems to Restore Eastern Old Growth Forest Communities-** Dylan Jenkins, *The Nature Conservancy*	**The Ancient Cross Timbers Consortium-** Dave Stahle, *University of Arkansas*	**Strategies for Finding Old Growth-** Bob Leverett, *Eastern Native Tree Society*
11-11:45	**European Earthworms as Ecosystem Engineers in North American Forests-** Lee Frelich, *University of Minnesota*	**The Disturbance History of Northern Maine Old Growth Forests-** Alan White, *University of Maine*	**Insect Biodiversity in Managed and Old Growth Forests-** Don Chandler, *University of New Hampshire*	**Ecological Forestry and Adaptive Management-** Ehrhard Frost, *Full Circle Forestry*	**Estimating the Capital Recovery Costs of Managing for Old Growth Forests-** Chris Ledoux, *USDA Forest Service*	**Does Size Matter?-** Mark Anderson, *The Nature Conservancy* & Ellen Snyder, *Biodiversity Consultant*
1:15-2	**The Role of Old Growth in Sustainable Forests in Regard to Wildlife-** John Hagan, *Manomet Center*, John Kanter, *NH Fish & Game*, Mariko Yamasaki, *USDA Forest Service*	**Nitrogen Retention in Eastern Old Growth Forests: Early Warning Signs of Nitrogen Saturation-** Christy Goodale, *Cornell University*	**Effects of Old Growth Riparian Forests on Adirondack Stream Systems-** Bill Keeton, *University of Vermont*	**Protecting Old Growth Using Forever Wild & Working Forest Easements-** Kathleen Fitzgerald, *Northeast Wilderness Trust* Charlie Niebling, *Society for the Protection of NH Forests* Nancy Smith, *Sweetwater Trust*	**Distribution, Composition, and Age Structure of Black Gum Swamps in New Hampshire-** Dan Sperduto, *NH Natural Heritage Bureau*	**Landowner Perspectives-** **Industry:** Gary Donovan, *International Paper* **State:** Bill Martin, *Eastern Kentucky University* **Private:** Ted Harris, *The 500 Year Forest Foundation*
2:15-3	**Empirical Dynamics: a Process Definition of Old Growth-** Charlie Cogbill, *Freelance Academic*	**Old Trees and the Value of Nature: How Our Philosophical Roots Affect the Way We View the Woods-**Rebecca Oreskes, *USDA Forest Service*	**Case Studies in Geobotany: Refining Our Understanding of the Influence of Substrate on Forest Plant Communities-** Scott Bailey, *USDA Forest Service*	**Identification & Conservation of Mt. Sunapee State Park's East Bowl Old Growth Forest-** Lionel Chute, *NH Natural Heritage*	**From Gravel Bars to Old Growth: Primary Succession in the Zoar Valley Canyon of Western New York-** Tom Diggins, *Youngstown State University*	**The Importance of Coarse Woody Material in Fostering Fungal Development-** Rick Van de Poll, *Ecosystem Management Consultants*
3:15-4	**Biodiversity Significance of Old Growth, Late Successional, and Economically Mature Forests-** John Hagan and Andrew Whitman, *Manomet Center*	**Bats and Small Mammals in Old Growth Habitats in the White Mountains-** Mariko Yamasaki, *USDA Forest Service*	**Using Remote Sensing to Identify and Map Old Growth-** Chris Kane & Pete Ingraham, *Society for the Protection of NH Forests* & Sam Stoddard, *UNH Cooperative Extension*	**A Comparison of Floristic Diversity in Old Growth Versus 100 Year Old Hardwood Forests of the White Mountains-** Leslie Adams, *Botanist*		**Ecological Economics and Long Term Investment in Forest Management-** Spencer Phillips, *The Wilderness Society*

Managing For Old-Growth Structure in Northern Hardwood Forests

William S. Keeton, Assistant Professor of Forest Ecology and Forestry, Rubenstein School of Environment and Natural Resources, University of Vermont, 343 Aiken Center, Burlington, VT 05405

Introduction

Recent research on sustainable forestry in the northern hardwood region of the United States and Canada has focused on "structure" (Keeton 2004) or "disturbance-based" (Seymour et al. 2002) silvicultural approaches. This includes managing for late-successional forests, which are vastly under-represented relative to the historic range of variability for this region (Mladenoff and Pastor 1993, Cogbill 2000, Lorimer 2001). An untested hypothesis is that silviculatural practices can accelerate rates of late-successional forest stand development (Franklin et al. 2002), promote desired structural characteristics, and enhance associated ecosystem functions more than conventional systems. I am testing this hypothesis using an approach, termed "Structural Complexity Enhancement (SCE), that promotes old-growth characteristics (Tyrrell and Crow 1994b, McGee et al. 1999) while also providing opportunities for timber harvest (Table 1). SCE is compared against two conventional uneven-aged systems advocated regionally for sustainable forestry (Mladenoff and Pastor 1993, Nyland 1998).

Table 1. Structural objectives and the corresponding silvicultural techniques used to promote those attributes in Structural Complexity Enhancement

Structural Objective	Silvicultural Technique
Multi-layered canopy	• Single tree selection using a target diameter distribution • Release advanced regeneration • Establish new cohort
Elevated large snag densities	• Girdling of selected medium to large sized, low vigor trees
Elevated downed woody debris densities and volume	• Felling and leaving, or • Pulling over and leaving
Variable horizontal density	• Harvest trees clustered around "release trees" • Variable density marking
Re-allocation of basal area to larger diameter classes	• Rotated sigmoid diameter distribution • High target basal area (34 m^2/ha.) • Maximum target tree size set at 90 cm dbh
Accelerated growth in largest trees	• Full and partial crown release of largest, healthiest trees

The objectives of SCE include multi-layered canopies, elevated large snag and downed coarse woody debris (CWD) densities, variable horizontal density, and re-allocation of basal area to larger diameter classes. The later objective is achieved, in part, using an unconventional marking guide based on a rotated sigmoid target diameter distribution. Rotated sigmoid diameter distributions have been widely discussed in the theoretical literature (O'Hara 1998), but their silvicultural utility has not been field tested. Sigmoidal form is one of several possible distributions in eastern old-growth forests (Leak 1996 and 2002, Goodburn and Lorimer 1999). These vary with disturbance history, species composition, and competitive dynamics. The distribution offers advantages for late-successional structural management because it allocates more growing space and basal area to larger trees. If the rotated sigmoid distribution proves sustainable in terms of recruitment, growth, and yield, it would suggest that silviculturalists have greater flexibility in managing stand structure, biodiversity, and other ecosystem functions in the northern forest region than previously recognized.

Methods

The study is replicated at two mature, multi-aged, northern hardwood forests in Vermont. There are three experimental manipulations. The first two are conventional uneven-aged systems (single-tree selection and group-selection) modified to increase post-harvest structural retention and to represent best available practices. Prescriptions are based on a target residual basal area of 18.4 m^2/ha, max. diameter of 60 cm, and q-factor of 1.3. Group-selection cutting patches are each approximately 0.05 ha in size. The third treatment is Structural Complexity Enhancement (SCE). The marking guide is based on a rotated sigmoid target diameter distribution applied as a non-constant q-factor. The marking guide is also derived from a target basal area (34 m^2/ha.) and maximum diameter at breast height (90 cm) indicative of old-growth structure. Accelerated growth in larger trees is promoted through full (4 or 3-sided) and partial (2-sided) crown release. Prescriptions for enhancing snag and downed woody debris volume and density are based on pre-harvest CWD volume and literature-derived targets. On one SCE unit at each of the two study area, downed logs are created by pulling trees over, rather than felling, to create pits and exposed root wads.

Each of the first two treatments (uneven-aged) is replicated twice; the third (SCE) is replicated four times. Two un-manipulated control units are located at each of the two study areas. Treatment units are 2 ha in size and separated by 50 meter (min.) buffers. Experimental manipulations (i.e. logging) were conducted on frozen ground in winter 2003. Sample data were collected from five 0.1 ha permanent sampling plots established in each treatment unit. Forest structure data, including leaf area index (LAI), detailed measurements of individual trees, and coarse woody debris (CWD) densities and volumes, have been collected over two years pretreatment and two years post-treatment. A before/after/control statistical approach was used to analyze sample data. Fifty year simulations of stand development were run in NE-TWIGS, comparing alternate treatments and no treatment scenarios.

Results

Residual stand structure

Post-harvest basal area, relative density, canopy closure, and LAI were significantly ($\alpha = 0.05$) higher under SCE. Canopy closure was most variable across group-selection units. There were significant differences ($P < 0.001$) in LAI responses among treatments. Single-tree and group selection cuts reduced LAI by 19.8 and 29.9% respectively. LAI reductions were lowest in SCE units (9.4%), indicating high retention of vertical complexity. LAI was significantly more spatially variable for both SCE ($P = 0.031$) and group-selection ($P = 0.010$) compared to single tree selection; within-treatment variance was not significantly different between SCE and group-selection units ($P = 0.296$). These results are indicative of the high degree of horizontal structural variability expected for both group-selection and SCE, achieved in the later through variable density marking and clustered harvesting around crown-release trees. SCE shifted residual diameter distributions to a form statistically indistinguishable from the target rotated sigmoid form. Continued reallocations of basal area and stem density into larger size classes, yielding a rotated sigmoid distribution spanning a full range of diameter classes, are thus likely over time.

Crown release and vertical development

Marking guides were used to crown release 45 dominant trees per ha. on average in SCE units. When combined with the average pre-treatment number (20 per ha) of large trees (> 50 cm dbh), this exceeds our future target of 55 large trees per ha. The excess provides a "margin of safety" to accommodate canopy mortality. Crown release is likely to accelerate growth rates in the affected dominant trees by 50% or more based on previous modeling (e.g. Singer and Lorimer 1997). Crown release also resulted in spatial aggregations of harvested trees, creating canopy openings and variable tree densities. Elevated light availability associated with this effect is likely to promote vertical differentiation of the canopy through release and regeneration effects.

Coarse woody debris enhancement

SCE prescriptions resulted in substantially elevated densities of both downed coarse woody debris and standing snags. The structural complexity enhancement treatments increased coarse woody debris (> 30 cm dbh) densities, on average, by 10 boles/ha for snags and 12 boles/ha for downed logs. Snags were created primarily by girdling diseased, dying, or poorly formed trees. Pulling trees over was successful in most cases at creating large exposed root wads and pits. There were statistically significant differences ($P = 0.002$) between treatments with respect to downed CWD recruitment. Post-harvest CWD (logs > 10 cm diameter) volumes were 140% higher on average than pre-harvest levels in SCE units; mean CWD volume increased 30% in conventional uneven-aged units.

Projected stand development

Stand development projections suggest that total basal area under SCE will, on average, approach 34 m^2/ha after 50 years of development. This is >50 % higher than the mean for the conventional uneven-aged units. However, this difference is an artifact of the higher residual basal area left by SCE. The projections showed no significant differences in absolute growth rates between treatment scenarios. However, when projected development is normalized against the null scenario (development expected with no treatment), the simulations indicate that conventional systems increase cumulative basal area increment (CBAI) more, at least at the stand level. Both SCE ($P < 0.05$) and conventional treatments ($P < 0.01$) are projected to significantly accelerate tree growth rates above that expected with no treatment based on NE-TWIGS modeling. SCE is projected to significantly enhance rates of large tree recruitment over no treatment scenarios. There will be an average of 17 more large trees (> 50 cm dbh) per ha than there would have been without treatment after 50 years in SCE units. There will be 29 fewer large trees/ha on average in the conventional units than would have developed in the absence of timber harvesting.

Discussion

Silvicultural techniques can be used effectively to promote old-growth structural characteristics in northern hardwood and mixed northern hardwood-conifer forests. Both the uneven-aged and structural complexity enhancement (SCE) systems tested maintain high levels of post-harvest structure and canopy cover. However, SCE maintains, enhances, or accelerates develop of CWD, canopy layering, overstory biomass, large tree recruitment, and other structural attributes to a greater degree. The higher levels of structural retention associated with SCE are indicative of lower intensity, minimal impact forestry practices.

Both SCE and conventional uneven-aged treatments will result in accelerated tree growth rates according to NE-TWIGS projections. Since the conventional treatments had significantly lower residual basal areas, this result is consistent with previous research on growth responses to stocking density in northern hardwoods (Leak et al. 1987). However, an important effect of SCE is the promotion of large tree recruitment, whereas this process is impaired under conventional treatments that include maximum diameter limits. Projected basal area is also higher after 50 years of development under SCE due to greater post-harvest structural retention.

SCE resulted in significantly elevated CWD densities and volumes. However, it remains uncertain whether this effect will persist until natural recruitment rates increase, or, alternatively, whether CWD enhancement in mature stands has only transient or short-term management applications. Most of the newly added CWD is un-decayed. It is likely than decay class distributions will shift over time towards well-decayed material. As time passes, this will render silviculturally enhanced CWD increasing available as habitat and as a nutrient source (Gore and Patterson 1985, Tyrrell and Crow 1994a).

Table 2. Potential applications of SCE as an approach to incorporating old-growth structure into managed forests

Application	# Entries	Late-Successional Structural Development
Old-growth promotion	One or possibly two entries	High
Riparian management	Single or multiple	Moderate to high
Timber emphasis	Multiple	Low to moderate

SCE has a variety of useful applications, ranging from restoration to low intensity timber management. However, the degree of implementation and the number of stand entries will vary by application (Table 2). Forest managers have the flexibility to manage for a wide range of structural characteristics and associated ecosystem functions. Uneven-aged systems provide some but not all of these or provide them to a more limited extent. Maximum diameter limits significantly retard the potential for large tree (live and dead) recruitment based on the results. Stand development is thus continuously truncated by multiple uneven-aged cutting entries. The results show that SCE's marking guide can be used to successfully achieve a rotated sigmoid diameter distribution. Unconventional prescriptive diameter distributions, such as the rotated sigmoid, combined with higher levels of residual basal area, very large (or no) maximum diameters, and crown release are alternatives for retaining high levels of post-harvest structure and for promoting accelerated stand development.

Acknowledgements
This research was supported by grants from the USDA CSREES National Research Initiative, the Vermont Monitoring Cooperative, the Northeastern States Research Cooperative, and the USDA McIntire-Stennis Forest Research Program.

Literature Cited
Cogbill, C.V. 2000. Vegetation of the presettlement forests of northern New England and New York. Rhodora 102:250-276.

Franklin, J.F., T.A. Spies, R. Van Pelt, A. Carey, D. Thornburgh, D.R. Berg, D. Lindenmayer, M. Harmon, W.S. Keeton, D.C. Shaw, K. Bible, and J. Chen. 2002. Disturbances and the structural development of natural forest ecosystems with some implications for silviculture. Forest Ecology and Management 155:399-423.

Goodburn, J.M. and C.G. Lorimer 1999. Population structure in old-growth and managed northern hardwoods: an examination of the balanced diameter distribution concept. Forest Ecology and Management 118: 11-29.

Gore, J.A. and W.A. Patterson. 1985. Mass of downed wood in northern hardwood forests in New Hampshire: potential effects of forest management. Canadian Journal of Forest Research 16:335-339.

Keeton, W.S. 2004. Managing for old-growth structure in northern hardwood forests. In: C.E. Peterson (ed.). Balancing ecosystem values: innovative experiments for sustainable forestry. USDA Forest Service General Technical Report, Pacific Northwest Research Station (In Press).

Leak, W.B. 1996. Long-term structural change in uneven-aged northern hardwoods. Forest Science 42:160-165.

Leak, W.B. 2002. Origin of sigmoid diameter distributions. USDA Forest Service Research Paper NE-718.

Leak, W.B., D.S. Solomon, and P.S. DeBald. 1987. Silvicultural guide for northern hardwood types in the Northeast (revised). USDA Forest Service Research Paper NE-603. 36 pp.

Lorimer, C.G. 2001. Historical and ecological roles of disturbance in eastern North American forests: 9,000 years of change. Wildlife Society Bulletin 29:425-439.

McGee, G.G., D.J. Leopold, and R.D. Nyland. 1999. Structural characteristics of old-growth, maturing, and partially cut northern hardwood forests. Ecological Applications 9:1316-1329.

Mladenoff, D.J. and J. Pastor. 1993. Sustainable forest ecosystems in the northern hardwood and conifer forest region: concepts and management. Pages 145-180 in: G.H. Aplet, N. Johnson, J.T. Olson, and V.A. Sample (eds.). Defining Sustainable Forestry. Island Press, Washington, DC 328 pp.

Nyland, R.D. 1998. Selection system in northern hardwoods. Journal of Forestry 96:18-21.

O'Hara, K.L. 1998. Silviculture for structural diversity: a new look at multi-aged systems. Journal of Forestry 96:4-10.

Seymour, R.S., A.S. White, and P.H. deMaynadier. 2002. Natural disturbance regimes in northeastern North America: evaluating silvicultural systems using natural scales and frequencies. Forest Ecology and Management 155:357-367.

Tyrrell, L.E. and T.R. Crow. 1994a. Dynamics of dead wood in old-growth hemlock-hardwood forests of northern Wisconsin and northern Michigan. Canadian Journal of Forest Research 24:1672-1683.

Tyrrell, L.E. and T.R. Crow. 1994b. Structural characteristics of old-growth hemlock-hardwood forests in relation to stand age. Ecology 75:370-386.

What Management Does Old Growth Need?

Stephen Fay, Forest Soil Scientist, White Mountain National Forest, 719 North Main Street, Laconia, NH 03246.

The purpose of this presentation is to share our current thinking on the management of old growth on the White Mountain National Forest (WMNF). As many know, we have a number of excellent examples of old growth northern hardwood and spruce-hemlock, including the Bowl Research Natural Area (RNA), which was established in the 1930's. The goal here is to talk about old growth management in its broadest sense, not just the details of dealing with existing, well known areas.

The conversation continues as to what is the definition of old growth. While this is not the topic at hand, it is valuable to know our existing definition as a starting point. We like to think of good examples of old growth as being unevenaged (three or more age classes), northern hardwood or spruce-hemlock, reasonably steady (though dynamic) age distribution, structure, tree species composition and biomass with natural disturbance cycles typical of the forest type over time. In addition to an absence of human disturbance, areas should be fairly large, 40-acres for hardwoods and 160-acres for spruce-hemlock, and have good representation of trees 250-300 years old, or more.

We have three principles in mind to guide our broadest thinking about old growth management—1/ Keep a weather eye for more good examples; 2/ These areas need not be monuments; and, 3/ Pay attention to the big picture.

Keep a weather eye

There might be a temptation to think that with all the past and present uses of the White Mountain National Forest, no more larger examples of old growth might be found. After all, there has been a long history including timber harvest, agriculture, fire, recreation use and towns. However, experience suggests otherwise. Shingle Pond Candidate Research Natural Area was identified and documented about five years ago. Here is a location with a hiking trail through it that has been used for years. It is very close to North Conway, N.H. There is a sawmill nearby, and the area is relatively low in elevation (1700') and readily accessible. Despite this, there is northern hardwood with no evidence of human use that includes trees 250-300 years old, and spruce-hemlock with red spruce up to 29" in diameter and 260 years old, and hemlock up to 40" in diameter and 270 years old. A similar spruce-hemlock site was recently found near Rattle River along the Appalachian Trail. The point is that places like this still exist, and we need to be thinking that such finds are still possibility.

These Places are not Monuments

There might be a sense that good old growth areas should be preserved and protected from any form of human use. However, careful human use can reap advancement of our knowledge and understanding of forest ecology, and help in the broader environmental discussion. While there are many possible examples, here are a few to underscore this benefit of old growth.

Debate is taking place about atmospheric deposition, including deposition of nitrogen. Part of this discussion, including the potential effects of such deposition on water quality, relates to how forests with different land use histories cycle nitrogen. In particular, it is believed that old growth forest may contribute more nitrogen to streams than younger forest because they are less demanding of available nitrogen. Research at the Bowl Research Natural Area in the 1970's was some of the first evidence that this was the case. More recent research, using the Bowl and other old growth sites on the WMNF as reference sites, is now comparing nitrogen cycling at these sites to locations where there was intense timber harvest and fire at the turn of the century. In addition to these examples, there has been substantial work on forest succession trends and forest stand structure that was incorporated into northern hardwood silvicultural guides. With care, therefore, these larger areas of old growth can not only provide their aesthetic values, but also contribute to broader scientific progress.

Pay attention to the "big picture"
Discussion continues about making sure that we have some landscape-wide representation of old growth. This not only means incorporating a variety of forest types, but also thinking about landscape position. The WMNF was part of an eastern U.S. analysis of forest communities, evaluating gaps in natural communities that we should consider for conservation. While there will always be discussion about how much is enough, northern hardwood and spruce-hemlock were forests identified for the WMNF. These appear with the Research Natural Areas, or candidate Research Natural Areas, in the existing and proposed Land and Resource Management Plans (Forest Plan).

There is an interest that we seek out more old growth locations at lower elevations. While we already have some excellent examples at "lower" elevations, such as Mountain Pond candidate RNA, the last two discoveries at Shingle Pond and Rattle River are both at lower elevations, about 1700' and 1200'. With time, more low elevation examples may arise, though from our perspective we should be diligent to find more old growth examples no matter what the elevation.

Does Age Matter? Evidence of Vigorously Growing, Ancient Oaks in the Eastern U.S.

Neil Pederson, Ed Cook, H. Myvonwynnn Hopton, Gordon Jacoby, Tree-Ring Laboratory, Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY 10964

Introduction

Most ecological, forestry and carbon sequestration models are built upon the premise that trees lose vigor as they age. Previous studies of old trees at latitudinal and altitudinal treeline suggest that this premise may not be true (e.g. Jacoby et al. 1996 – Fig. 1a; Esper et al., 2002 – Fig 2c). Temperate forests are thought to be an important part of the 'missing carbon sink' in the global carbon cycle (IPCC, 2001). Eastern North American forests provide goods and services to millions of people making it important to determine if similar changes in growth of old trees has occurred in this region. Here we examine the growth trends of more than 800 oak trees from a dataset composed of white oak (*Quercus alba* L.) and chestnut oak (*Q. prinus* L.) distributed from Alabama to Michigan and New York State. We compare these results with smaller networks of yellow-poplar (Liriodendron tulipifera L.) and Atlantic white-cedar (*Chamaecyparis thyoides* (L.) B.S. P.)), species with considerably different life history traits.

Methods

Increment cores were collected from at least 14 canopy trees growing in a range of forest conditions including uncut to old, previously logged forests. All samples were cross-dated and measured using standard dendrochronological techniques (Cook and Kairiukstis, 1990). Some of the oak and yellow-poplar data here is available from the International Tree-Ring Database (ITRDB). Of the oak populations from the ITRDB all have at least one tree >300 years of age while the ITRDB yellow-poplar populations have at least one tree >200 years old. The number of trees (populations) for each species is 838 (39), 153 (11) and 229 (14) for oak, yellow-poplar and Atlantic white-cedar (AWC) respectively.

Oaks were divided into groups of 50 year time periods (1851-1900, 1801-1850, … pre-1651) to reduce the potential for bias caused by young trees. Each grouping contained only those trees with an inner ring date from that period. These are conservative groupings because they are uncorrected for missed piths and time to reach coring height; some trees may be older than the group in which they are placed. Because of smaller sample sizes and younger age distributions, yellow-poplar and AWC were grouped into 70 and 30 year age classes, respectively, with 70 years as the minimum tree age.

All available cores per tree were averaged to create an idealized radius per tree. Trees for each grouping were standardized using a straight-line fit to remove differences in tree and population-level productivity, averaged and then rescaled using average ring width to create an of index raw ring-width. No growth trends were removed. Bootstrap confidence limits (95% level) were calculated to determine when growth was significantly different from the long-term mean. Using allometric equations, chronologies of carbon increment were created for oaks and yellow-poplar. The white oak equation was used to represent the oaks.

Results
Results show that growth does not always decline as trees age. In all classes, oaks have shown increased ring widths over the past 150 years. Ring widths have been significantly wider than average since the late-1800s and throughout most of the 20th century. Remarkably, this phenomenon is observed in the oldest known white oak (1519-1983). This tree experienced increasing ring widths from 1811-1982 when it was 292 to 463 years old. Likewise, the oldest known chestnut oak responded vigorously to a reduction in competition at 410 years of age, *following* one century of increased growth rates. The oldest yellow-poplar trees have experienced increased ring widths similar to oak. AWC displays a different timeframe for its growth trend, with increasing ring widths since the 1920s. Over the last 200 years the rate of carbon increment in the oldest trees increased steadily with the strongest increases in the late-1800s and 1990s.

Summary
Many of the trees in this dataset experienced accelerated growth at 200, 300 and even 400 years of age. Because carbon allocation to stem growth occurs after root and shoot requirements are met (Waring and Pitman, 1985), it is clear that the oldest trees have experienced vigorous growth over the last century.

These results lead to questions such as: “What is senescence?”; “Should the term overmature be considered dead?” and “Is senescence related to genetics, bad luck, or a combination of the prior, with site quality and climate?” It was argued 84 years ago that age may not be the primary factor of long-term productivity (Marshall, 1920). In fact, growth declines leading to mortality of midwestern oaks are often correlated to drought (Pedersen, 1998).

It is hard to discern the exact mechanisms driving the long-term growth trends, especially given changes in atmospheric composition and climate. We can say with confidence that the increased growth of AWC is related to its temperature sensitivity and regional warming (Hopton and Pederson, in press; Pederson, et al., in press). Isotopic tree-ring analysis may help determine factors driving growth.

Initial suppression was a frequent feature of old oaks of this dataset, indicating that it does not limit productivity. As oak growth does not seem to be limited by age or suppression, long-term management seems feasible if judiciously based on natural disturbance regimes.

Our results also indicate that old oak forests may be active carbon sinks to help reduce the buildup of anthropogenic carbon. Evidence of trees representing three species ≥1/2 maximum known age with accelerated growth lends justification for conservation of the many old, second-growth forests in the eastern US landscape. From this data it would appear that growth of 120+ year-old trees will slow only if environmental conditions deteriorate significantly.

References

Cook, E.R. and L.A. Kairiukstis, (eds), 1990. Methods of Dendrochronology. Kluwer Academic Publications, Hingham, MA: 408 pp.

Intergovernmental Panel on Climate Change. 2001. Third Assessment Report - Climate Change 2001. The Third Assessment Report Of The Intergovernmental Panel On Climate Change, IPCC/WMO/UNEP.

Esper, J., E.R. Cook, and F.H. Schweingruber. 2002. Low-frequency signals in long tree-ring chronologies for reconstructing past temperature variability. Science 295: 2250-2253.

Hopton H.M. and N. Pederson. In press. Climate sensitivity of Atlantic white cedar at its northern range limit. Proceedings of the Atlantic White Cedar Management and Restoration Ecology Symposium - "Uniting Forces for Action." June 2nd-4th, 2003. Millersville, MD.

Jacoby, G.C., R.D. D'Arrigo, Ts. Davaajamts, 1996. Mongolian tree rings and 20th-century warming. Science, 273, 771-773.

Marshall, R. 1927. Influence of precipitation cycles on forestry. J. For. 25: 415-429.

Pedersen, B.S. 1998. The role of stress in the mortality of midwestern oaks as indicated by growth prior to death. Ecol. 79: 79-93.

Pederson, N., E.R. Cook, G.C. Jacoby, D.M. Peteet, and K.L. Griffin. In press. The influence of winter temperatures on the annual radial growth of six northern-range-margin tree species. Dendrochronologia.

Waring, R.H. and G.B. Pitman. 1985. Modifying lodgepole pine stands to change susceptibility to mountain pine-beetle attack. Ecology 66: 889-897.

The Ancient Cross Timbers Consortium

David W. Stahle and R. Daniel Griffin, Tree-Ring Laboratory, Department of Geosciences, Ozark Hall 113, University of Arkansas, Fayetteville, AR 72701
479-575-3703 dstahle@uark.edu

The Cross Timbers form the frontier between the eastern deciduous forest and the grasslands of the southern Great Plains, and may have covered some 17.9 million acres (Kuchler 1964; and see Figure 1). This great ecotone preserves some of the most extensive tracts of ancient forest left in the eastern United States, and offers exceptional public and private conservation opportunities. These rugged old-growth woodlands were not commercially important, but have high ecological integrity and preserve vital components of our eroding biodiversity. They form a key link in the oak archipelago that extends from Central America into southeastern Canada, and provide essential habitat for many species, including neotropical migratory birds. The Ancient Cross Timbers Consortium was established in 2003 to unite educational institutions, government agencies, conservation organizations, and individuals around the research, educational, and conservation opportunities presented by the extensive old-growth forest remnants in this ecosystem (web site = http://www.uark.edu/xtimber). The Consortium is organizing a cooperative network of research natural areas in ancient Cross Timbers remnants extending 700 miles from southeastern Kansas to southern Texas. Recent Consortium-related research has mapped the distribution of ancient woodlands in the Cross Timbers of eastern Oklahoma (Bayard 2003), the Western Cross Timbers of northcentral Texas (2004), and on a preliminary basis in southeastern Kansas (Griffin 2003). Together, these estimates suggest that as much as 0.9 million acres of old-growth forest might still survive in the Cross Timbers ecosystem (Figure 1). Clark (2003) has documented the age structure, composition, and fire history of the Keystone Ancient Forest Preserve near Tulsa, which was recently purchased by the State of Oklahoma and is being managed by The Nature Conservancy. Long tree-ring chronologies derived from old forests of the Cross Timbers have also been used to reconstruct past drought (Cook et al., 2004) and explore its socioeconomic impacts in the southcentral United States.

Bayard, A.R., 2003. Quantifying spatial distribution of ancient oaks with predictive modeling. M.A. Thesis, University of Arkansas, Fayetteville. 68 pp.

Clark, S.L., 2003. Stand dynamics of an old-growth oak forest in the Cross Timbers of Oklahoma. Ph.D. dissertation, Oklahoma State University, Stillwater. 192 pp.

Cook, E.R., C.A. Woodhouse, C.M. Eakin, D.M. Meko, and D.W. Stahle, 2004. Long-term aridity changes in the western United States. *Science* 306:1015-1018.

Duck, L.G. and J.B. Fletcher, 1945. A survey of the game and fur bearing animals of Oklahoma. *Oklahoma Game and Fish Commission Bulletin No. 3,* 144 pp.

Dyksterhuis, E.J., 1948. The vegetation of the Western Cross Timbers. *Ecological Monographs* 18:325-376.

Griffin, R.D., 2003. An ancient forest model for the Cross Timbers ecotone in southeastern Kansas. Unpublished manuscript, Tree-Ring Laboratory, University of Arkansas, Fayetteville. 19 pp.

Kuchler, A.W., 1964. *Potential Natural Vegetation of the Coterminous United States*. Special Publication 36. American Geographical Society, New York.

Kuchler, A.W., 1974. A new vegetation map of Kansas. *Ecology* 55:587-604.

Peppers, K.C., 2004. Old-growth forests in the Western Cross Timbers of Texas. Ph.D. Dissertation, University of Arkansas, Fayetteville. 170 pp.

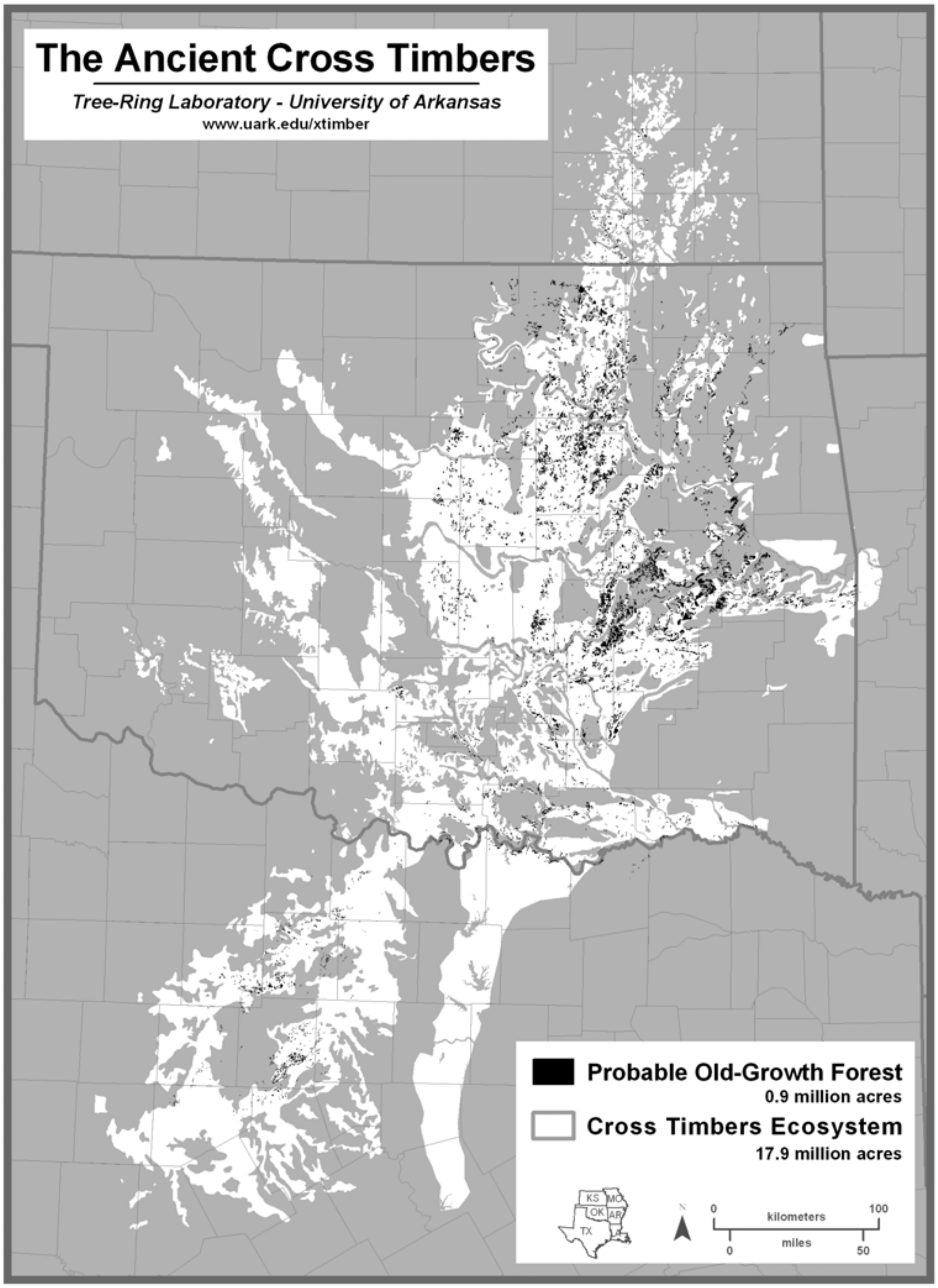


Figure 1. The potential natural distribution of the Cross Timbers ecosystem (in white, after Duck and Fletcher 1945; Dyksterhuis 1948; Kuchler 1964, 1974) and the possible distribution of old-growth forest remnants (in black, after Bayard 2003, Griffin 2003, and Peppers 2004).

Strategies for Locating New Stands of Old Growth Forest

Robert T. Leverett, Eastern Native Tree Society, Holyoke, MA 01040

The late 1980s and all through the 1990s saw an explosion in the identification of old growth forest sites in the eastern United States. These were discoveries that weren't supposed to happen. Given the long history of human land use and the over 700 scientific papers submitted on the well-known eastern old growth remnants, the operative assumption by land managers, forestry professionals, scientists and naturalists, and grassroots forest activists was that all old growth in the East had been thoroughly documented. However, that turned out not to be the case for a variety of reasons, not the least of which was a stereotypical view of old growth that didn't match the forested landscape to include its embedded patches of surviving old growth. The wide ranging search of the 1990s changed the reigning paradigm of a landscape "swept clean" of its primary forest cover down to a few well-known surviving patches to one of a landscape left with lots of small, previously unrecognized old growth holes and a few patches of larger size.

What were those of us making the old growth discoveries seeing that others weren't? What triggered in us the notion that there was more old growth in the East to be found? For the most part, the discoveries of the 1990s were made by a few individuals who had remained relatively shielded from the reigning notions about original forest, what it looked liked, and how it had all but been eliminated except for a few well-known spots like Hearts Content in Pennsylvania, the Porcupine Mountains in Michigan, and the Great Smoky Mountains in Tennessee and North Carolina. In a sense, our ignorance, if not arrogance, was bliss. We didn't trust authority. Our breakthroughs came as we simply absorbed the 'look and feel' of old growth in the known spots and then applied the lessons we learned to inaccessible areas of mountainous regions or swamps where commonsense dictated to us that logging would have been minimal - if at all. We collected tree ages in candidate sites to verify individual and collective antiquity. If actual advanced tree ages were verified in sufficient number or percent of total stems in the canopy, other physical characteristics of old growth were present, and there were no signs of major direct human disturbance, then a site was usually declared as old growth or at least as a viable old growth candidate. Consulting opinions were almost always sought that included those of top research forest ecologists. Subsequent historical searches might be conducted to determine the original settlement period, plus whatever anecdotal evidence could be gathered that might cast light on possible human uses of a potential site. However, the overriding criterion was tree age and the lack of direct evidence of past human disturbance such as alien species, rock walls, cellar holes, wolf trees, and valuable timber species missing that should have been present, etc.

From our free wheeling searches of the late 1980s and throughout the 1990s, we developed a number of ad hoc guidelines for hunting for old growth remnants. The first and foremost requirement was and is a thorough familiarization with old growth characteristics across the forest types indigenous to a geographical region. One does not compare northern tundra to southern swamp forests. As one gains experience, the two reigning rules are: (1) if it doesn't look like old growth, it probably isn't, and (2) if it looks like old growth, it may be.

To get to the place where one can make these calls in confidence requires visitation to a hundred sites or more, preferably many more. There are now guidebooks to old growth sites that can be legally visited. Having and using such a book is a given for anyone starting out to hunt new old growth. The operative assumption is that repeated exposure to old growth characteristics across multiple sites representing multiple forest types allows the development of the necessary sensitivity to spot likely candidates elsewhere. But beyond a highly general prescription, how does one go about efficiently gaining the experience? Is there a shopping list of old growth characteristics and an order they should be studied?

One begins with the most manageable task - identifying characteristics of age in individual tree species and the predominant conditions of growth, e.g. in open or closed canopy conditions. Every tree cannot be cored, so learning to age trees by eye is an important first step in qualifying old growth candidates. One then looks for other signs of forest maturation such as tip up mounds, abundant coarse woody debris in varying stages of decay for the type forest, canopy gaps of varying sizes, heterogeneous plant colony development consistent with the habitat niches present, etc. What one does not do is become wedded to numerical parameters to prove or disprove old growth. Assemblage of data by the USFS by old growth researchers shows that old growth indicators such as the volume of coarse woody debris have wide numerical ranges. It becomes difficult to validly exclude a site on the basis of an old growth indicator falling outside of a range. For a bounded area, it is difficult to pronounce the area as old growth, if it has no conspicuously old trees. However, if one happens to be standing in the aftermath of a blow down and just by expanding the size of the area would introduce an abundance of old trees, one must accept a role for commonsense. In fact the commonsense rule can be extended to all areas of investigation.

It is axiomatic that a good historical search of land use history can reveal patterns of use that would cast doubt on the old growth status of a site. However, land use records seldom conclusively prove that an entire property was logged especially if there are areas of extreme terrain. If it looks like it was logged, it probably was and vice versa.

What has been described here is what we might call the gestalt approach to old growth identification. The more time one spends in sharpening one’s interpretive skills, the better one becomes. While that seems like commonsense, a truism that hardly needs to be stated, academics sometimes discount the need for experience, believing that their experimental design will yield numeric data that will prove or disprove an old growth hypothesis.

So what can be said in summary? The best strategy for locating old growth on one’s own is to begin by developing sensitivity to the most visible old growth characteristics, sensitivity that is fine-tuned to individual forest type. The most visible characteristic is age in individual tree species. Each species of tree shows its age just as humans do, if one knows what to look for. But one takes a very systematic approach to age dating by eye. What are the most conspicuous indicators of age at each stage of growth? How does a tree grow if in intense competition with other trees, if growing in the open? Does overall form change with age? As sensitivity to tree age is being acquired, one begins developing sensitivity to other old growth indicators to include what species to expect for the forest type, patterns of vegetative colonization at ground level, the abundance and distribution of pits and mounds, the abundance, size, and distribution of canopy gaps, the amount of coarse woody debris in varying stages of decomposition, possible past human directed disturbances that indicate intentional forest manipulation such as the harvesting of a single species, leaving too few mature members of the species. While sensitization to tree age and other old growth indicators is proceeding, one visits the broadest range of old growth sites as possible in the company of an expert who can point out quintessential old growth features for each represented forest type. One gradually acquires a 'gestalt sense' of old growth that allows one to see how all the pieces tend to fit together and to be able to distinguish a mature second growth forest from its old growth counterpart. Then it is a case of constant practice analogous to the mastery of any sport. What one avoids is the expectation that numeric evaluations of old growth characteristics, found in the research literature, will provide the silver bullet to reveal hitherto disguised old growth. Students can spend a full year staring into the green mantle and never perceive all the subtle changes a forest goes through on its way to becoming certifiable old growth. Along the way, one learns not to equate tree size and age and to be sensitive to uniformity of age that suggests a past large-scale disturbance event. One becomes quickly attuned to invasive species and other signs of human intervention. One continually compares sites to gain a sense of the proportions.

There are what we might call macro old growth indicators such as canopy texture, but guides to becoming an old growth sleuth cannot be written in summary form. The most important ingredient is time on site.

Earthworms as Ecosystem Engineers in North American Forests

Lee E. Frelich, Cindy M. Hale, Andy Holdsworth, and Peter B. Reich
University of Minnesota, Department of Forest Resources, 1530 Cleveland Ave. N., St. Paul, Minnesota 55108, USA. Freli001@umn.edu

Invasion by non-native earthworms into previously earthworm-free forest ecosystems has only recently received substantial attention from ecologists. Such ecosystems occur in the temperate and boreal forests of North America at latitudes of 45-60 degrees N. Earthworms native to North America were unknown in this region prior to the introduction of European earthworm species (*Lumbricidae*). Earthworms are keystone detritivores that partly control the composition of the plant community by changing seedbed conditions, soil characteristics, flow of water, nutrients and carbon in the ecosystem, and the relationship between plants and herbivores. Earthworms consume the forest floor and incorporate Carbon from litterfall into the A horizon of the mineral soil (Bohlen et al. 2004 a,c), and increase the bulk density of the upper mineral soil horizons by cementing soil particles together (Hale et al. 2004). This affects the whole soil food web, including the mycorrhizal community that is essential for many forest tree and plant species, and the above ground plant community (Bohlen et al. 2004b).

Seedbed conditions for plants are changed when earthworms invade, and tree species such as red oak and sugar maple and herbs in the genera *Aralia, Botrychium, Osmorhiza, Trillium, Uvularia*, and *Viola* that germinate well in thick litter are no longer favored. The standing crop of tree seedlings and herbs may also be eliminated when the earthworms invade since they eat the rooting material right out from under the plants. Most native understory plants in temperate sugar maple forests are mycorrhizal so that declines in abundance or colonization rates of mycorrhizal fungi caused by earthworm invasion could lead to changes in the understory plant community. Goblin fern (*Botrychium mormo*) is a rare mycorrhizal plant dependent on thick organic horizons, and has been extirpated in areas invaded by earthworms (Gundale 2002). The declines of sugar maple (*Acer saccharum*) seedlings during earthworm invasion (Hale 2004) could be partially due to reduced mycorrhizal colonization rates (Lawrence et al. 2003).

The species *Lumbricus rubellus* (commonly called leaf worms) are especially effective at rapidly removing the forest floor and have the maximum impact on plant communities compared to the other common species of earthworms (Hale 2004). The species *Dendrobaena octeadra*, on the other hand, lives in leaf litter rather than consuming it, and therefore it changes the forest ecosystem very little. Impacts in spruce or pine-dominated forests are relatively small, since the high C:N ratio of the leaf litter is unpalatable to earthworms, and populations remain low. The nightcrawler (*L. terrestris*), eat mainly freshly fallen leaf litter, and can maintain a soil profile devoid of duff indefinitely.

Earthworms can cause a forest decline syndrome whereby initial mortality of plants caused by earthworm invasion is enhanced by a higher ratio of deer to plants, which leads to more mortality and elimination of seed sources necessary for recovery. Species of plants that are non-mycorrhizal, such as *Carex pensylvanica*, and those that secrete secondary compounds that earthworms and deer avoid, such as *Arisaema triphyllum*, take over the plant community after earthworm invasion. In some forests earthworm invasion leads to reduced availability and increased leaching of N and P in soil horizons where most fine roots are concentrated, and the loss of P has been linked to decline of sugar maple (Hale et al. 2004, Paré and Bernier 1989). Other studies show that P leached during earthworm invasion is replaced by P brought up by earthworms from lower horizons, thus keeping availability in the upper horizons high (Suarez et al 2004). Currently there are no studies of earthworm impacts on ecosystem-level productivity.

The degree of plant recovery and species that recover after invasion varies greatly among sites and depends on complex interactions with soil processes and herbivores. Ecosystem changes caused by European earthworm invasion are likely to alter competitive relationships among plant species, possibly facilitating invasion of exotic plant species such as buckthorn (*Rhamnus cathartica*) into North American forests (Heneghan 2003), leading to as yet unknown changes in successional trajectory.

Literature Cited

Bohlen PJ, Groffman PM, Fahey TJ, Fisk MC, Suarez E, Pelletier DM and Fahey RT (2004a) Ecosystem consequences of exotic earthworm invasion of north temperate forests. Ecosystems 7: 1-12

Bohlen PJ, Groffman PM, Scheu S, Hale C, McLean MA, Migge S, and Parkinson D (2004b) Exotic earthworms as agents of change in north temperate forests in North America. Frontiers in Ecology and the Environment (in press)

Bohlen PJ, Pelletier DM, Groffman PM, Fahey TJ and Fisk MC (2004c) Influence of earthworm invasion on redistribution and retention of soil carbon and nitrogen in northern temperate forests. Ecosystems 7: 13-27

Gundale MJ (2002) Influence of exotic earthworms on the soil organic horizon and the rare fern Botrychium mormo. Conservation Biology 16: 1555-1561

Hale CM, Frelich LE, and Reich PB (2004) Exotic European earthworm invasion dynamics in northern hardwood forests of Minnesota, U.S.A. Ecological Applications. In Press.

Hale CM (2004) Ecological consequences of exotic invaders: interactions involving European earthworms and native plant communities in hardwood forests. Ph.D. Thesis, Department of Forest Resources, University of Minnesota, 169 pp

Heneghan L (2003) And when they got together.... The impacts of eurasian earthworm and invasive shrubs on Chicago woodland ecosystems. Chicago Wilderness Journal 1: 27-31

Paré D and Bernier B (1989) Origin of phosphorous deficiency observed in declining sugar maple stands in the Quebec Appalachians. Canadian Journal of Forest Research 19: 24-34

Suarez ER, Fahey TJ, Groffman PM, Bohlen PJ, and Fisk MC (2004) Effects of exotic earthworms on soil phosphorous cycling in two broadleaf temperate forests. Ecosystems 7: 28-44

The Disturbance History of Northern Maine Old-Growth Forests

Alan S. White, Shawn Fraver, Erika L. Rowland, and Unna Chokkalingam
Department of Forest Ecosystem, University of Maine, Orono, ME

Introduction and Objectives

The current species composition, structure, and function of forests are closely tied to their disturbance history, i.e. the past is key to understanding the present. This premise underlies much of our research on old-growth forests and also is recognized as important by many land managers. For example, ecological forestry is based on silvicultural prescriptions that mimic natural disturbances, and ecological reserves are often designed to be large enough to accommodate typical disturbances.

Over the past ten years, our research has concentrated on three interrelated questions: 1) what is the current composition and structure of old-growth forests in northern Maine, 2) what disturbances have occurred in these forests and what are their characteristics (rates, sizes, causes, etc.), and 3) have these characteristics been constant over time and space? In this presentation we concentrate on the second question.

Study Area

Although Maine is the most heavily forested state in the U.S., it has relatively few old-growth forests, as is typical of much of the East. Most of these forests are small and often occur in atypical conditions relative to the surrounding landscape. However, the Big Reed Forest Reserve (BRFR), owned by The Nature Conservancy, is a notable exception. It is relatively large (ca. 2000 ha) and contains multiple examples of forest types and environmental conditions common in the northern Maine landscape. As such, it provides an ideal setting for studying natural disturbances.

Methods

The research approach we used to obtain the results presented at this conference involved a combination of dendroecology (i.e., using tree-ring analysis) and stem mapping. Disturbances are recorded in tree rings as periods of suppression followed by significant, abrupt, sustained increases in radial growth, or rapid early growth that indicates development in the open as opposed to under an intact canopy. Although such information can reveal the percentage of a plot affected by a disturbance, it does not indicate whether the disturbance occurred in one location within the plot or as small gaps dispersed throughout the plot. However, if we know where each tree is located, we can reconstruct the locations and sizes of disturbances.

Over the years, we have established 50 plots ranging in size from 1500 to 5000 m^2 across the BRFR in different forest types (including hardwood, mixed wood, cedar seepage, cedar swamp, mixed conifer, and spruce) in a variety of environmental conditions. Along with recording many typical ecological parameters, we cored all trees ≥ 10 cm dbh on all plots. Additionally, all trees were mapped in eight plots and were tallied in a 10 m by 10 m grid system in another eight.

Results and Discussion
We found no evidence of stand-replacing disturbances over the last 150-200 years. All plots were multi-aged, there were virtually no shade intolerant, early successional tree species, and very little charcoal was found. Although several hurricanes reportedly reached northern Maine over the past two centuries, none affected these plots to the extent of establishing a new cohort across the entire plot. Nor did spruce budworm outbreaks cause extensive mortality, even in conifer-dominated stands. In fact, seldom did any plot have more than 35% of its area disturbed in any given decade.

Instead of stand-replacing events, small gaps (< 0.1 ha) have dominated the disturbance history of these plots. Gap-forming agents included insects, diseases, and wind. Despite the varied species composition across plots, average rates of disturbance were remarkably consistent across forest types, ranging from 9 to 12% of plot area disturbed per decade. The one notable exception was the cedar swamp type, which only averaged about 5% per decade.

Despite consistent average rates of disturbance, rates varied considerably from decade to decade. Periods of high disturbance were separated by periods of relative quiescence. Although overall temporal patterns were at best weakly correlated with species composition, peak periods were common to many plots regardless of forest type. We speculate that this is due to the overlap in composition among forest types. For example, many types include red spruce and thus were susceptible to spruce budworm outbreaks. Similarly, American beech is common to many plots, all of which were affected to some degree by the killing front of the beech bark disease in the 1940s and 1950s.

Ongoing work with several colleagues is focusing on whether the disturbance patterns at BRFR are consistent over longer time periods and larger geographic areas. The former is being addressed with pollen and charcoal analyses from small hollows within some of our plots, whereas the latter involves analysis of historical land survey records from across northern Maine.

Management Implications
The most obvious silvicultural analogs to this disturbance history are individual tree selection and group selection systems. These could be applied with some flexibility in timing of entries and total area cut and still be within the historical range of variability of past disturbances. However, we must always be cognizant of the uncertainty involved in such retrospective studies, and we must consider what has changed in the current landscape and how that influences the paths we follow to achieve management goals.

Insect Biodiversity in Managed and Old-Growth Forests

Donald S. Chandler, Department of Zoology, University of New Hampshire, Durham, NH 03824.

Insect diversity has been assumed to decrease with management of forests, which has been difficult to document, since so few insect groups are known well-enough that whole insect inventories can be prepared in a reasonable amount of time. The usual practice is to choose a "focus group", which typically is chosen from those groups that are easiest to identify, rather than those that may best reflect differences between disturbed and old-growth sites. Within a focus group, species biologies may vary between those that are most successful in disturbed habitats, and those that are most successful in minimally or naturally disturbed habitats. For this reason, there has been interest in determining which habitats are most significantly affected by forest management, with an increasing focus on species associated with various types of dead and downed woody debris.

Forest management tends to produce pulses in the production of woody debris, primarily through the production of slash during the management event. This initial pulse is followed by a long period where little new woody debris is generated until the aging forest produces more as it enters its late successional stages, where the increase of woody debris levels off, and is at a level comparable to that found in old-growth forests. Cyclical timber management reduces the overall amount of available woody debris in the long term for a forest, with a concomitant effect on those organisms associated with this resource. Natural disturbance events (fire, windthrow) also produces woody debris in pulses, but the surrounding mature forests will continually generate woody debris during the intervening period, and there is no effective decades-long lull in the production of woody debris.

Many species of insects are associated with woody debris, primarily obtaining their nutrients from the succession of fungal fruit bodies or hyphae, and slime molds involved in decay of the woody debris. As the tree or portion of the tree dies, a sequence of fungi, slime molds, and associated insects is observed, depending on tree species and size of the debris (whole tree, large branch, limb). Stages of tree decomposition has been delineated by several authors for standing conifers. The initial turnover of fungi and insects is rapid and different for each year. Once past the initial ten or so years of decomposition, the following stages typically take multiple years, with the final stage (fragmentation and disappearance) of larger logs in cool climates taking decades.

Insect species that require the habitats provided during the initial few years following tree death tend to be present in low densities in old-growth forests. Their niche is often briefly present relatively in widely dispersed locations throughout an old-growth forest. Species with these requirements have been shown to be present in low numbers in many old-growth forests around the world, and be present at very low numbers or lacking in early successional forests. Populations of these species can become quite high following a natural disturbance event, such as fire or windthrow, and may be ironically high also following human management if lots of slash is left around. The difference being that in the surrounding old-growth forest there will be constant, low-intensity generation of new habitat from dying late successional trees, while in heavily logged areas there will be a long period of early-mid successional forest and a lack of suitable habitat. If there is continual removal of older trees and all slash is removed, then species that rely on the early stages of wood decomposition can be essentially extirpated from a region.

Simple models of species accumulation in forests through time have indicated that species diversity is initially low, and steadily increases until it reaches its highest point in old-growth. If the old-growth forest in this model includes a mosaic of small patches representing earlier successional stages, then it should be correct, and species richness should be positively correlated to overall forest age, particularly if we ignore the short-term increase of species richness due to the generation of slash in selectively cut forests. This aside, based on studies in New Hampshire, this doesn't seem to be true for species richness of beetles associated with woody debris. While beetle species composition does change between the various stages of wood decomposition, overall species richness is close for all the stages in a comparison between a mature forest selectively cut 40 years previously, and an old-growth forest. What does stand out for the old-growth forest is the doubling of species abundance for the faunas of all the early stages of wood decomposition, which can be attributed to the significantly higher amounts of woody debris. A few rare beetle species were taken only in the old-growth forest, and a small number were clearly most abundant in the old-growth, as were some other species found only in the younger forest, or were clearly more abundant there.

One beetle group, the Pselaphinae (Staphylinidae) did have species richness positively correlated with forest age, but they are predators rather than fungivores. The Pselaphinae was chosen as the focus group for a study in Australia at the Styx River State Forest (northeastern New South Wales), where there was a year long comparison of the faunas of old-growth dry sclerophyll, wet sclerophyll, and warm temperate rainforest with the faunas of nearby forest sites that had been selectively cut 30-40 years previously. The fauna in each type of forest was found to be an order of magnitude higher than for northern temperate forests, with 80-130 species forming the local community at each site. Species richness was found to be positively correlated with forest age for the dry and wet sclerophyll forests, but not for the rainforest sites.

Total abundance was clearly higher in the dry sclerophyll and rainforest sites, but not the wet sclerophyll forests. One species, an obligate myrmecophile, is associated with an ant that was extremely abundant at the cut wet sclerophyll site, composing 60% of the fauna there. If this species is ignored, then total abundance of all the free living species was also clearly higher for wet sclerophyll. So, as has been found in other studies with this group, species richness and abundance is typically higher for the free living species of this group in old-growth.

Models for species richness in old-growth also hypothesize that there will be species present that will not occur in earlier, disturbed forests. As indicated above, many of these species will also be found in recently disturbed forests, if there is a source of recently killed trees left as a habitat. Looking at data for approximately 150 wood associated species in New Hampshire, and 230 members of the Pselaphinae from Australia, there are a small number of species that seem to be clearly abundant in old-growth, and do not occur in younger mature forests. These species amount to 1-2% of the species studied. Those restricted to old-growth in New Hampshire are associated with stages 2-3 in decomposition of trees, while the biology for those Pselaphinae restricted to old-growth forests in Australia is not known.

Adaptive Forest Management & Ecological Forestry

Ehrhard Frost, Certified Ecoforester & New Hampshire Licensed Professional Forester, Full Circle Forestry, Thetford, VT 05075

The practice of forestry in this country is very young, only about 100 years old; it is younger than the maximum attainable age of bigtooth or quaking aspen. Our silvicultural systems, derived from Europe, applied orderly agricultural models to the forest ecosystem. Forestry emphasized simplification and uniformity of the forest for the singular purpose of commodity production. Rotation ages, cutting cycles and diameter objectives were rigidly applied. Regeneration methods were developed for the sole purpose of regenerating and growing commercially important tree species. As society demands an increasingly intricate array of amenities from the forest, and as we realize that maintaining ecological function is essential to the production of these amenities, it follows that silvicultural systems must naturally evolve to address both societal demands and natural functions.

A change of perspectives is the first essential element necessary to implement ecological forestry. The forest must become the focus; forest process, not forest products, must provide management imperatives. Forest structure, diversity, function, complexity and processes are necessary, and in fact, are responsible for creating the products and amenities desired and demanded by our society.

Foresters must also embrace an element of humility to effectively practice ecologically based forestry. It is essential for foresters to recognize and appreciate the limits of our individual and collective knowledge if we truly intend to practice an ecologically based silviculture instead of merely hanging “Green” window dressing on our profession and maintaining the status quo.

New nomenclature and terminology is also required to move beyond the traditional confines of evenaged and unevenaged forest management. New definitions broaden perspectives, allow for a wider range of options and expand the walls and shapes of the boxes we draw around forest management and silvicultural systems. Expanded definitions and new terminology allow us, as foresters, to move into a new and dynamic role in concert with the forest ecosystem instead of in opposition to it. Dynamic systems require dynamic, not rigid, management.

Forest management and applied silviculture practiced from a humble perspective that acknowledges that prescriptions are nothing more than working hypotheses with uncertain outcomes, requires an adaptive management approach. Management must be designed to enhance learning, knowledge and awareness. Management must be flexible to adapt to changes in both knowledge and conditions. Management must be as dynamic as the very system it hopes to manage. Only through observation and monitoring can foresters continually hone their management skills and avoid management pitfalls. This requires active, ongoing involvement, site specific knowledge and a continual search for better understanding.

Ecological forestry is necessarily based on a new perspective and new terminology, both of which facilitate a new approach to forest management. The following basic principles and guidelines should form the foundation for determining silvicultural prescriptions within the context of ecological forestry.

- Maintain soil structure and productivity. Maintain nutrient cycles by retaining organic material on the forest floor and above ground as both live and dead trees. Do not interrupt the downslope movement of soil, water and nutrients.

- Maintain the naturally occurring species composition of **all** plants and animals. Utilize silviculture to restore the composition of radically altered and/or degraded forests to a naturally occurring species mix for the site.

- Harvest only from the abundance and retain and protect the rarities. Utilize silviculture to create diversity of species, size and age classes and forest structures. Attempt to increase minority species that would naturally occur on sites within stands and throughout ownerships.

- Maintain higher stocking levels than traditionally recommended for optimum, short rotation timber production. Utilize long cutting cycles, generally 15 to 25 years. Remember, though it may be natural for a tree to fall, it is not natural for that tree to move off site. There is life in death, and the decomposition process is a part of the essential forest energy flow.

- Utilize silviculture to stimulate the development of species and structures that will naturally evolve over time on a site. Thin stands early to emulate the stem exclusion stage and promote development of a complex understory. Harvest to mimic natural disturbance. Use what is traditionally known as single tree and group selection. Recognize that natural disturbances occur regardless of human management; leave the stand replacing events to Nature.

- Incorporate perpetual, variable retention of all stand structures and elements to ensure that the entire range of naturally occurring forest structures (i.e., retained organic material, snags and snag replacements, Legacy Trees, mycorrhizal fungi and other forest components) are present in the forest. Legacy Trees will remain for their natural life cycle; they represent the perpetual retention component of a multi-aged retention silvicultural system. Strict criteria for the number of trees or basal area/acre are not necessary. However, recognizing the critical role these Legacy Trees play and the structures and functions they support, is necessary for successful implementation. Generally, retained Legacy Trees should fall in a range of 10 to 20% of the basal area of a "fully stocked stand" (by traditional guidelines). This translates to 10 to 25 square feet of retained basal area, represented by roughly 5 to 13 trees/acre that are 18 inches DBH and greater, in hardwood stands. In softwood stands retain between 18 and 52 square feet of basal area/acre or about 9 to 25 trees/acre, depending on the forest type. Retain Legacy Trees that represent the range of species and form found within stands. These Legacy Trees provide a biological legacy for subsequent cohorts, provide essential elements of stand structure and insure the continued function of the forest. Maintaining the dynamic natural processes of the forest is the only certain mechanism that will allow truly sustainable human extractions from that forest.

- Practice multi-aged management. Visualize regeneration as a continuous wave-like pattern rather than a definitive point in time triggered by age or diameter. Multi-age management requires working at various crown levels within stands. Integrate noncommercial practices, with the application of commercial treatments.

- Eliminate and prevent the spread of exotic invasive plants. Limit disturbance and maintain dense stands for long time periods to discourage invasives. Retain 300' uncut buffers between infested areas and un-infested areas.

- Maintain a functioning forest first and foremost; all other desired outcomes will follow. Implement treatments that preserve future options and opportunities. Evaluate and modify treatments as necessary to achieve the desired goals and to accommodate an understanding of the site as more information is obtained.

- Identify, manage and protect sensitive, fragile and unusual communities and rare plants and animals. These are necessary and vital parts of the ecosystem.

- Relax utilization standards. The cost to harvest pulpwood and whole tree chips usually exceeds their value and frequently contributes to site and stand degradation. Recognize that off site removal of any portion of a tree is not natural. Only those portions of the stem and that portion of the forest that have true economic value are worth harvesting. The remaining biomass should remain on site. Recognize that whole tree harvesting is not biologically based; eliminate this harvesting technique from silvicultural prescriptions and applications.

- Relax top lopping requirements, except where human use demands this level of aesthetic manipulation. Top lopping is costly and dangerous. Lopping tops may sever established regeneration. Lopped tops do not supply the range of wildlife and micro site habitats typically found when trees fall or break. Un-lopped tops also provide regeneration with some protection from high browse pressure.

Forests are complex and, as such, must be managed for wholeness and complexity instead of efficiency and simplicity (Kohm and Franklin 1997). "A biologically sustainable forest is a prerequisite for a biologically sustainable yield (harvest)" (Maser 1994). Sustainable ecological forestry must be based on the interaction between species and the processes that both create interdependence and define ecosystems (Kohm and Franklin 1997). Time must be redefined and thought of on an ecological scale, not a human scale; foresters must think in tree time, not human time. The emphasis must be on structure, function and process, not on a desired commodity outcome. Make no mistake, society can extract commodities and amenities from the forest, but only in so far as structure, function and process are supported by both the silvicultural and forest management systems.

Literature Cited

Kohm Kathryn A., and Jerry F. Franklin, ed. 1997. Creating a Forestry for the 21st Century: The Science of Ecosystem Management. Island Press. Washington, DC.

Maser, C. 1994. Sustainable Forestry: Philosophy, Science and Economics. St. Lucie Press, Delray Beach, Florida. 373 pp.

Originally written September 2001; latest revision March 2003
Synopsis prepared September 2004

Estimating the Capital Recovery Costs of Managing for Old Growth Forests

Chris B. Ledoux, Project Leader/Industrial Engineer, Northeast Research Station, USDA Forest Service Phone: 304-285-1572, Cledoux@Fs.Fed.Us

Contemporary forest management practices require a variety of retention treatments that leave clumps, blocks, strips, or zones of existing forest cover in order to achieve a wide array of biodiversity, wildlife, visual, ecological, and old growth creation/conservation objectives. Some of these practices call for leaving a portion or portions of existing stands for extended periods of time to accomplish such objectives. Generally, the production of wood fiber (veneer, sawlogs, pulp, etc.) requires specific rotation lengths that reach either financial or biological maturity. Optimal financial rotation length is reached when discounted present net worth (PNW) is at its maximum. Optimal biological rotation length is reached when mean annual growth is at its peak. The most profitable approach is to harvest the stand at its optimal financial rotation. Treatments to accomplish other than timber/wood fiber production such as the creation of old growth forests generally require much longer rotation lengths. The further retention treatments deviate from the optimal financial rotation, the higher the monetary value/loss becomes for that treatment. For example, a young stand may reach optimal financial maturity at say age 100. However, for the same stand to grow to old growth conditions may require a rotation age of 150 or more years. The difference in financial value between these two rotation lengths is an excellent measure of the value of managing for old growth. In this paper, we provide a methodology for estimating the opportunity costs/values and capital recovery costs/values associated with alternative old growth creation objectives. The methodology is appealing because it uses a logical sequence of analysis steps that can be easily understood by the range of publics involved in forest planning activities. The results should be valuable to managers, planners, landowners, and folks associated with creating/conserving old growth forests.

Does Size Matter?

Ellen Snyder, Ibis Wildlife Consulting, Newmarket, New Hampshire

Does the size of an old growth forest matter (or the size of the trees, or the size of the "reserve" surrounding an old growth forest)? Often we associate old growth forests with big trees. But if a windstorm comes through and blows down the big trees, is that no longer an "old growth" forest?

Intuitively it seems that a bigger old growth forest is better than a smaller old growth forest, but I don't think that translates into small areas being unimportant. This may be especially true given our current point in time when so little old growth remains. Many people in the public and private sector have said that we should conserve all remaining old growth forests. I have not heard any added caveat about size, so we might assume that to mean <u>all</u> old growth forests regardless of size. And we need them throughout the region, so some are going to be small.

Mark Anderson, who follows me, will provide a much better ecological analysis of old growth forest size, such as how big is big enough. So, I thought I would spend just a bit of time discussing the various ways we might approach the issue of size. As always, the question of size is more complex than just bigger is better.

Let's look at size from multiple perspectives. This includes how size affects

- ecological integrity of the old growth forest
- research options
- human experiences
- management considerations
- landowner type (or how landowner type affects size)

First, how does size affect **ecological integrity.** Let's say by ecological integrity we mean a healthy, functioning ecosystem. Here we have two old growth sites.

- **Townsend Woods Scientific and Natural Area** is a 73-acre old growth site owned by the Minnesota Department of Natural Resources. This site is described as one of the best examples of the Big Woods--a nearly obliterated forest region in south-central Minnesota once covering 5,000 square miles--where large sugar maple, red oak, basswood, and white oak reside. Because woods are so rare in the area, this old-growth forest is an important stopover for migrating songbirds from late April to early June.
- **Big Reed Forest Preserve**, a 5,000-acre old growth area in Maine owned by The Nature Conservancy.

Townsend Woods is a remnant of the Big Woods matrix forests of southern Minnesota that is susceptible to natural and human disturbance and is isolated and fragmented and hence offers limited exchange of species and genetic material. If a disturbance, such as a windstorm were to wipe out the Townsend Woods old growth then the State of Minnesota would de-classify it as an old growth and designate another similar area as old growth. However, you can't shift old growth around the landscape if it has been eliminated elsewhere, so we need to be thinking ahead about potential old growth areas.

Big Reed on the other hand retains more characteristics of the matrix forest that occurs naturally in that region of Maine.

Do different sizes of old growth forests offer different research options?
Old growth areas provide reference areas and baselines for long-term ecological research. **The Bowl RNA**, 500 acres in the White Mountain National Forest (WMNF) and the 5,000 acre **Big Reed Forest Preserve** are two areas that are used by researchers. Big Reed is large enough to provide landscape-scale research on natural disturbances. The Bowl is an important site for comparison to silvicultural techniques used in other parts of the WMNF.

Human experience is another perspective where size has an impact. By human experiences I include educational opportunities, recreation, cultural heritage (connections to the past). If we compare three old growth sites of different sizes I think we could agree that the human experience in each of these would be different. Despite its small size the Townsend Woods is an extremely valuable site for education – to help us understand the history of the ecology and the land use in that region, yet its not big enough to provide a sense of being in a once 5,000 sqare mile Big Woods. Nancy Brook offers hiking trails and camping in the area of old growth. A much larger old growth area, say within the Adirondack State Park offers yet another type of educational and outdoor experience.

Management decisions within an old growth area might include managing for regeneration, controlling invasive species, monitoring blowdowns and other changes, designing special management plans surrounding the old growth.

The extent of active management within and around an old growth area I think is directly related to its size, condition and landscape context. If we think back to the 73-acre Big Woods old growth in Minnesota, the chance that it might blow down or be invaded by exotic species is higher than losing the old growth at Big Reed Forest Preserve to these disturbances, and therefore active management may be needed more often in the Big Woods than at Big Reed.

We can assume that where old growth is found is going to shift across the landscape over time. So, there is the issue of size of the old growth forest or patch and the size of the "natural area" in which the old growth is imbedded.

Finally, I wanted to say a few words about size of old growth areas as they relate to land ownership. It is my perspective that large areas of old growth are going to support more functional ecosystems and small areas of old growth are going to contain old growth characteristics but are not likely considered functional ecosystems. And it is much more likely that these larger areas of old growth will be owned by a landowner, public or private, where one of their primary missions is to conserve old growth, such as The Nature Conservancy or a state or federal agency with a old growth as a specific purpose in their enabling legislation. Smaller old growth areas are typically owned by industrial and non-industrial private woodland owners and some agencies that need to balance competing or other higher priorities.

All sizes and all ownership types are of benefit, but it is important to recognize the capabilities of a given landowner to provide old growth areas versus old growth characteristics.

Birds in Managed and Old-growth Forests of Northern Maine

John M. Hagan, Manomet Center for Conservation Sciences, 14 Maine St., Suite 305, Brunswick, ME 04011, ph:207-721-9040; e-mail: jmhagan@ime.net

The importance of old-growth forest to biodiversity is one of the most fundamental research questions. No vertebrate species appears to depend exclusively on old-growth forest in the Northeast. To better understand whether any bird species might strongly prefer old-growth forest, we conducted point count surveys at 537 locations in central and northern Maine to document bird abundances in different forest types, ages, and management regimes. We combined data from two separate studies, one in the Moosehead Lake area, and the other in the Munsungan Lake area north of Baxter State Park (Figure 1). A variety of habitat types, from clearcuts to mature softwood and hardwood forest, were surveyed in the Moosehead Lake study area. Partial-cut stands and old-growth stands (Big Reed Forest Reserve) in both hardwood and mixedwood forest were surveyed in the Munsungan Lake area.

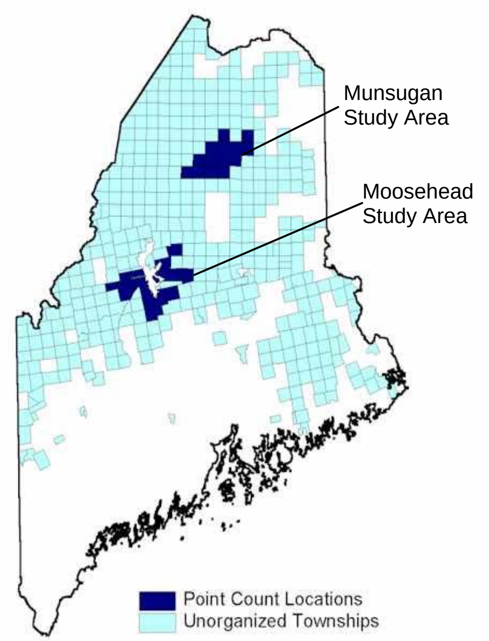


Figure 1. Locations of the two bird point count study areas.

We encountered 87 bird species overall. Fourteen species had their highest abundance in clearcuts and young even-aged, regenerating forest. Three species were most abundant in medium-age forest. Twenty species were most abundant in partial-cut forest, and 17 species were most abundant in mature forest. Only 6 species showed their highest abundance in old-growth forest (Table 1), and no species was restricted to old-growth. An additional 33 species were considered too uncommon to determine habitat associations using point counts. Nine of these 33 species were never detected within the 50-m radius point count circle.

The 6 species that had their highest abundance in old-growth forest (Big Reed Forest Reserve) (Table 1) had a relatively low ‘x-factor’, meaning that these species also were abundant in younger forest. The Evening Grosbeak, with the largest x-factor, was detected in all forest types of the Munsungan study, and clearly is not dependent on old-growth. A case cannot be made that any of these species that had their highest abundance in old-growth are dependent on old-growth. Most of them are abundant throughout the managed forest landscape. All but one of the 6 species are showing an increase, or significant increase, in Maine according the Breeding Bird Survey. The Eastern Wood Pewee is showing non-significant decline.

Different bird species benefit from different forest practices. To help ensure that all species are maintained in the managed forest landscape, we recommend that large-scale forestland management strive to keep at least 25% of any given township (10,000 – 25,000 acre unit of

Table 1. List of species that had their highest abundance in old-growth forest (Big Reed Forest Reserve). The abundance is the maximum abundance value observed in any mature forest type (birds/circle). The x-factor is the maximum abundance observed for old-growth forest divided by the maximum abundance in any other forest type. The greater the x-factor the more important partial-cut stands are for overall abundance of this species in the forest landscape. The Breeding Bird Survey (BBS) trend indicates the population trend of this species in Maine between 1966 and 1996 (BBS web site).

Species	Abundance	x-factor	BBS Trend[1]
Evening Grosbeak	0.22	1.29	+
Black-capped Chickadee	0.70	1.25	++
Eastern Wood Pewee	0.17	1.21	-
Hairy Woodpecker	0.20	1.18	+
Blackburnian Warbler	1.11	1.03	++
Red-eyed Vireo	1.08	1.02	++

[1] Legend: '-' = non-significant decrease; '--' = significant decrease; '+' = non-significant increase; '++' = significant increase; 'nd' = no data available from BBS for this species.

area) in mature forest cover with at least 75% canopy closure. In addition, we recommend that this mature forest be retained in blocks of 500 – 1000 acres each.

At the stand level we recommend that forest managers develop strategies to keep some large-diameter trees and snags well-distributed throughout the landscape. One approach to meeting this recommendation is to retain small intact patches (0.5 – 2.0 acres) of forest within harvest blocks (either clearcut or partial-cut blocks). Retention patches should be centered around large trees or snags, or some other feature of ecological importance, such as vernal pools. This practice, when implemented on a wide scale, could function to provide large trees and snags in future stands.

The point count survey method is not conducive to studying uncommon birds or birds with low densities or large territories. Such species (e.g., owls, raptors) or secretive species should be better understood in managed forests. The best way to learn about forestry effects on these species may be to conduct detailed individual species studies. We suggest that targeted-species studies represent the next generation of work on birds and forestry in the Northeast.

Key Conclusions:

1. No (studied) bird species appears to require old-growth forest.
2. Many "countable" birds are good indicators of silviculturally mature forest, but not old-growth.
3. In general, vertebrates do not appear to rely on old-growth in northern New England.
4. Dependencies on late-successional and old-growth forest are much stronger for non-charismatic flora, such as lichens and mosses. The importance of old forest to these species cannot be ignored if biodiversity is to be maintained in a well-distributed manner across northern New England.

A more detailed report of the information contained in this abstract can be obtained at www.manometmaine.org.

Nitrogen Retention in Eastern Old-Growth Forests: Early Warnings of Nitrogen Saturation

Christine Goodale, Cornell University, Ithaca, NY 14853

Human activities such as combustion of fossil fuels have increased the deposition of reactive nitrogen (N) compounds onto eastern forests to rates 4-15 times those occurring under pre-industrial conditions. Nationwide, emissions of nitrogen oxides increased from the 1940s through the mid-1970s, and have been relatively constant since then. Deposition of nitrogen varies considerably across country, with the highest rates of N deposition occurring in the eastern U.S. As a constituent of acid rain, nitrate deposition can have acidifying effects on forest soils, streams, and lakes, similar to effects from deposition of sulfate. However, the role of N deposition is complicated by the fact that N is actively taken up by plants and microbes and has a complex cycle within forest ecosystems. The process by which the biological capacity for N uptake is overwhelmed by chronic N deposition is termed "nitrogen saturation" (Aber et al. 1989). Because old-growth forests are expected to have relatively low rates of biomass accumulation, they should be particularly sensitive indicators of nitrogen saturation (Vitousek & Reiners 1975, Aber & Driscoll 1997). This hypothesis was tested by measuring rates of N cycling and N export from old-growth and successional stands in the White Mountains of New Hampshire, and by re-sampling streams from old-growth and successional stands that were first measured in the mid-1970s.

The White Mountains are a particularly good area to examine forest response to N deposition because the region has received elevated rates of N deposition since at least the mid-1960s (~7-9 kg N ha^{-1} y^{-1}; Likens & Bormann 1995), and because extensive records of historical land use enable selection of replicate plots and whole watersheds of known disturbance history. White Mountain forests enjoyed relative freedom from intensive logging until about 1870, when the state of New Hampshire sold off large tracts to timber and paper companies. Introduction of logging railroads to the region shortly thereafter allowed loggers access to mid- and high-elevation red spruce forests. Extensive clear-cutting followed until about 1920, driven by increased demand for lumber and by innovations in paper-making that enabled softwoods to be used for pulp. Lower-elevation hardwood stands were cut in some areas for specialty industries (wood flooring, bobbins, shoe pegs) and for fuel for some of the early railroads. Logging practices at the time left tree tops and branches on-site, creating a fire hazard during periods of drought. About 17% of the White Mountain region burned during this period (Goodale 2003). Public concern over the extent of logging and fire eventually brought about the passage of the Weeks Act in 1911, which established the National Forest system. Yet before the federal government could purchase White Mountain tracts, foresters were sent out to map and evaluate forest condition. Many of these tract maps have survived at the White Mountain National Forest headquarters in Laconia, NH, and nearly 60 tract maps were digitized as a part of this project. These maps provide a record of the extent of early 20th century logging, fire, and old-growth forest across the region.

The role of forest history in affecting soil N cycling was assessed by using the historical land use information to select five sets of burned, logged, and old growth stands. Two 400 m^2 plots were established in each stand. At each plot, stand biomass was estimated by applying allometric equations to measurements of diameter at breast height. Soil N cycling (net N mineralization and nitrification) was measured from 9 pairs of soil cores per plot. Old-growth stands (261 t/ha) had more aboveground biomass than successional stands (192 t/ha). Total net mineralization did not vary by land-use history, but net production of nitrate was twice as high in old-growth stands as in logged or burned stands, which did not differ from one another. Stocks of N in the forest floor and the top 10 cm of mineral soil did not differ by land-use history, but forest floor C stocks were larger in successional stands than in old-growth stands, leading to lower C:N ratios in old-growth stands. Across all plots, forest floor C:N ratio proved the best predictor of soil nitrification rates. The excess nitrate production in old-growth soils appears to result from excess N accumulation relative to C accumulation (Goodale & Aber 2001).

The role of forest history in controlling forest N retention at the catchment scale was assessed by using the land-use history information to identify 3 logged sites, 4 burned sites, and 4 old-growth sites, where 2-4 small catchments occurred within each site. Streamwater samples were collected monthly from October 1996 through September 1997, and analyzed for the concentration of nitrate, ammonium, dissolved organic nitrogen (DON). Monthly water flux was estimated at each catchment using the PnET-II model. Annual N export in streamwater was estimated by multiplying modeled monthly water flux by measured N concentration. Nitrogen retention is the fraction of N inputs to the system not lost during the same time period. For this and many other studies, N retention was calculated as: (estimated total N deposition – stream N export) / total N deposition. Patterns of stream N concentration varied greatly by the form of N considered. Ammonium concentrations were always low (<10 μg/L). DON concentrations varied by stream, with means ranging from 42 to 121 μg/L. However, DON did not consistently vary seasonally or by land-use history. By contrast, concentrations of nitrate consistently peaked during the dormant season and fell during the growing season, particularly in old-growth catchments where dormant-season nitrate concentrations reached 200-300 μg/L. Averaged by land-use history, total N export from old-growth catchments (2.4 kg ha^{-1} y^{-1}) more than doubled N export from logged or burned catchments (1.1 kg ha^{-1} y^{-1}), with difference driven by differences in nitrate export (Goodale et al. 2000). A comparison among sites with measurements of both soils and streamwater indicated that stream nitrate export increased with net nitrate production in soils. A comparison of stream N exports with estimated N deposition inputs indicated that N retention decreased with stand age, although even old-growth stands retained a significant fraction of inputs (> 60%).

The results that old forests have lower N retention than younger forests, combined with expectations that old-growth forests should be more vulnerable to chronic N deposition, suggest that stream N exports should have increased in White Mountain streams over the last 30 years. In the mid-1970s, a series of streams were sampled on Mt. Moosilauke, NH, draining both old-growth stands and stands logged in the early 1940s (Vitousek & Reiners 1975). These streams were re-sampled in 1996-97 with 4 seasonal collections. Most surprisingly, stream nitrate concentrations decreased by 60% across all watersheds. This change was much larger than might be explained by changes in methods or differences in hydrologic conditions, and is consistent with the observed change in stream nitrate observed at the Hubbard Brook Experimental Forest between the mid-1970s and mid-1990s (Likens & Bormann 1995). At Mt. Moosilauke, stream nitrate concentrations were higher at old-growth than successional catchments in both the 1970s and the 1990s, but both types of catchments had lower nitrate concentrations in the 1990s. The cause for this decline remains difficult to explain, with possible influences from climate variation, increasing atmospheric CO_2, or other indirect effects of other alterations in atmospheric chemistry.

Even though stream nitrate concentrations in the White Mountains have decreased, they remain significantly higher in this region of elevated N deposition compared to more pristine regions (Hedin et al. 1995). Across the Northeastern U.S., mean stream nitrate concentrations for the mid-1990s increased with increasing rates of N deposition, although there is substantial variation among catchment receiving similar rates of N deposition (Aber et al. 2003). Differences in stand successional status appears to explain a large portion of this variability, with particular sensitivity of old-growth stand to N deposition.

Aber, JD & CT Driscoll. 1997. Effects of land use, climate variation, and N deposition on N cycling and C storage in northern hardwood forests. Global Biogeochemical Cycles. 11(4):639-648

Aber, JD et al. 1989. Nitrogen saturation in northern forest ecosystems. BioScience 39(6):378-385.
Aber, JD et al. 2003. Is nitrogen deposition altering the nitrogen status of northeastern forests? BioScience 53(4):375-389.

Goodale, CL. 2003. Fire in the Mountains: a historical perspective. Appalachia 54(3):60-75.

Goodale, CL et al. 2000. The long-term effects of disturbance on organic and inorganic nitrogen export in the White Mountains, New Hampshire. Ecosystems 3:433-450.

Goodale, CL & JD Aber. 2001. The long-term effects of land-use history on nitrogen cycling in northern hardwood forests. Ecological Applications 11(1): 253-267.

Goodale, CL et al. 2003. An unexpected nitrate decline in New Hampshire streams. Ecosystems 6:74-86.

Hedin, LO, et al. 1995. Patterns of nutrient loss from unpolluted, old-growth temperate forests. Ecology 76:493-509.

Likens, GE & FH Bormann. 1995. Biogeochemistry of a forested ecosystem. 2nd ed. Springer-Verlag, New York. 159 pg.

Vitousek, PM & WA Reiners. 1975. Ecosystem succession and nutrient retention: a hypothesis. BioScience 25(6): 376-381.

Effects of Old-Growth Riparian Forests on Adirondack Stream Systems

William S. Keeton[1], Clifford E. Kraft[2], Dana R. Warren[2], and Andrew A. Millward[2]
[1] University of Vermont, Rubenstein School of Environment and Natural Resources, Burlington, VT 05405. [2] Cornell University, Department of Natural Resources, Ithaca, NY 14853.

Introduction

Relationships between riparian forest structure and in-stream aquatic ecosystem habitat characteristics are poorly understood in the northeastern United States. This limits our ability to predict the long-term effects of riparian restoration projects, which often assume increases in riparian functionality as forest stands mature and develop complex structural characteristics. Our research a) describes structural attributes associated with late-successional riparian forests; and b) assesses linkages between these characteristics and indicators of in-stream habitat structure. Key linkages investigated include variations in light availability, coarse woody debris, and associated relationships with in-stream habitat structure (e.g. debris dams and plunge pools). We hypothesize that structurally complex, old-growth riparian forests have strongly associated effects on stream systems, including in-stream habitat conditions that are significantly different from streams surrounded by young to mature forests. Our study focuses on mixed northern hardwood-conifer forests in the Adirondack Mountains of upstate New York. Based on previous research in the Adirondacks (Kraft et al. 2002), it is likely that boulders and stream size also influence variability of in-stream structure. To investigate this, we further explore interactions between forest structure and site-related geomorphic factors.

Methods

Data Collection

Our study was conducted in the southwestern portion of the Adirondack State Park of New York. Study sites were located in three areas: the Adirondack League Club preserve, the Five Ponds wilderness area, and the Pigeon Lakes wilderness area. We sampled a total of 19 sites along 150-300 meter long, 1st and 2nd order stream reaches. Riparian vegetation was dominated by mixed northern hardwood-conifer forests. Sites were classified as mature forest (6 sites), mature with scattered remnant old-growth trees (3 sites), and old-growth (10 sites). At each site, five transects were placed parallel to the stream channel: one along the channel center and two on each side. Side transects were placed inside the forest 5 and 30 m respectively from the channel edge. Leaf area index (LAI) was measured with a Li-Cor 2000 meter at 20-30 randomly selected points along transects. Coarse woody debris volume (CWD) was measured along each transect using a line-intercept method. Hemispheric photos were taken at 3-5 randomly selected intervals along the mid-point of stream channels. Additional metrics of forest structure and composition were inventoried using 8-10 variable radius prism plots randomly nested within the transect grid. Height and crown structure of sampled trees were measured with an Impulse 200 laser rangefinder. In-stream structures, including logs > 30 cm diameter, woody debris dams, boulders > 50 cm width, pools > 10 cm depth, sediment bars, and side channels were mapped using high-precision Global Positioning Systems (GPS). For each structural feature mapped, data was recorded describing dimensions, size, and function (e.g. pool forming element, debris dam anchoring element, bank armoring element, etc.).

Data Analysis

Sample sizes (min 12, max 19) varied by statistical test. In some cases, a reduced set of sites was used if a) CWD had been artificially removed from the stream, b) CWD appeared to have been removed by ice-flows (i.e. at the widest site); or c) data for a specific parameter were not availability from a subset of sites. We used single-factor ANOVA and two-way Tukey comparisons to test for significant differences ($\alpha = 0.05$) in sampled parameters. Equal variance assumptions were confirmed using tests of variance (*F*-tests); *T*-tests assuming unequal variance were used when variance assumptions were not met. Linear regression modeling with alternate curve fitting was used to evaluate relationships between paired continuous variables. We used a log-likelihood ratio, goodness-of-fit (*G* test) to test for significant differences between observed distributions of pool-forming boulders and pool-forming CWD. We used a two-part multivariate analysis to model pool density as a function of multiple predictor variables representing forest structure, in-stream structure, and channel geomorphology. The first part consisted of Classification and Regression Tree (CART) analysis performed using S-Plus statistical software. For the second step we used multiple, linear regression analysis also run in S-plus. We used a single term deletion, forwards and backwards stepwise modeling procedure. Multiple regression modeling provided a useful validation of the CART analysis, because the regressions assessed variability across all sites rather than between partitioned groups of similar sites.

Results

Coarse Woody Debris and Debris Dams

Mean in-stream CWD volumes were significantly ($P < 0.001$) higher at old-growth sites (200 m^3/ha) compared to mature sites (34 m^3/ha) or mature sites with remnant old-growth trees (126 m^3/ha). Volumes were correlated ($R^2 = 0.42$, $P = 0.005$) with the basal area of adjacent riparian forests based on regression results. CWD volumes on the riparian forest floor were significantly higher ($P = 0.001$) at old-growth sites and mature sites with old-growth remnants (159 m^3/ha) than mature sites (86.16 m^3/ha). The volume of CWD within riparian forests was predictive ($R^2 = 0.43$, $P = 0.003$) of CWD recruitment and accumulation in stream channels. In-stream CWD volumes also varied with bankfull width. There was a statistically significant ($R^2 = 0.52$, $P = 0.026$), negative exponential trend of decreasing CWD with increasing bankfull width. CWD volume was positively correlated ($R^2 = 0.48$, $P = 0.013$) with the density of large logs (> 30 cm diameter) as well as debris dams ($R^2 = 0.26$, $P = 0.043$) in stream channels.

Pools

Large log density, rather than CWD volume itself, was predictive of pool density ($R^2 = 0.32$, $P = 0.046$). A logarithmic curve explained the most variability in this relationship. Pool density (log transformed) declines significantly ($R^2 = 0.43$, $P = 0.022$) with increasing bankfull width at our sites. There was a significantly higher proportion of CWD-formed pools relative to boulder-formed pools at old-growth sites as compared to mature sites ($P < 0.001$). Along old-growth stream reaches, 49 and 40% of pools were formed by CWD and boulders respectively, with the remainder not attributable to a specific pool-forming element. The proportions were reversed at mature sites: CWD formed 20%, boulders formed 58%, and the remaining pools were unrelated to either.

Multivariate analyses supported our hypothesis of an interaction between riparian forest structure and site-specific geomorphology. CART analysis identified the strongest predictors of pool density from a set of predictor variables that included forest age class, basal area, large log density, stream bankfull width, and boulder density. Of these, log density, bankfull width, and boulder density, in decreasing order of significance, were the strongest predictors of values of the dependent variable (pool density). Multiple regression analysis produced a final model that was consistent with the CART results. However, the regression model, selected from the same initial set of predictor variables, included only log density and bankfull width. This suggests that these two variables explain the most variation in pool density when assessed across all sites. The model was statistically significant ($P = 0.024$), explaining 56% of variation in pool density.

Light Availability

We used Leaf Area Index (LAI) as an indicator of multiple aspects of vertical forest structure, including light availability. LAI over stream channels showed a strong negative relationship with bankfull width ($R^2 = 0.62$, $P = 0.004$), with decreasing overhead foliage as streams widened. LAI values decreased most precipitously for streams wider than 6 m bankfull width. When our analysis was restricted to streams < 6 m wide, mean LAI over stream channels was not significantly greater ($P = 0.084$) for old-growth (4.9) than for mature stands (3.7) or mature stands with remnants (3.6). There was no significant difference ($P = 0.239$) between age classes for LAI within adjacent riparian forests either. However, the standard deviation of LAI was significantly greater ($P = 0.049$) along old-growth stream channels compared to younger sites. This indicates that LAI is more spatially variable over old-growth stream channels. Visual inspection of hemispheric photographs supported our interpretation of patchy canopy structure over old-growth streams; a more homogeneous, closed canopy was characteristic of our mature riparian sites.

Discussion

Old-growth riparian forests in the Adirondacks strongly affect in-stream habitat characteristics, including CWD availability, pool density, and the light environment. Basal area is positively correlated with stand age in Adirondack northern hardwood-conifer forests based on our research and previous studies (Woods and Cogbill 1994, Ziegler 2000). At our sites, higher basal areas generate greater accumulations of downed coarse woody debris, both within the riparian forest and in the stream channel. CWD volume positively correlates with the density of large logs and debris dams. Pools form above and below these structures. Consequently, pool density is higher in old-growth reaches. This research corroborates work done in the Pacific Northwest by Montgomery et al. (1995) who found that high LWD abundance in those streams can significantly increase pool frequency. Increased pool densities provide habitats for a range of aquatic biota (Wallace et al. 1995, Gowan and Fausch 1996, Roni and Quinn 2001). LWD provides a variety of other ecological and abiotic functions in stream ecosystems, including retention of sediment and organic material, which can have significant implications for stream nutrient cycling (Valette et al. 2002, Brinson and Verhoeven 1999).

The average volume of CWD in old-growth channels (199 m^3/ha) was substantially higher than previously reported for upland old-growth northern hardwoods in the Adirondacks by Ziegler (2000) (139 m^3/ha) and McGee et al. (1999) (126 m^3/ha). It is possible that CWD accumulations in old-growth streams are higher than in upland forests due to a) disturbances (e.g. flooding and bank under-cutting) along forest-stream edges (Gregory et al. 1991) and b) decreased decomposition rates for fully submerged logs. CWD accumulations (“debris dams”) have a number of additional effects on aquatic ecosystems, which also include retention of organic matter for detritus-dependent biota (Bilby and Likens 1980) and dissipation of energy during flood events (Naiman et al. 1998).

Spatial variability in LAI was much higher over old-growth channels. This explains the complex light environment we observed at old-growth sites and apparent in hemispheric photographs. Light variability is related to the high frequency of canopy gaps typically found in old-growth northern hardwoods (Dahir and Lorimer 1996). As a consequence, streams move in and out of shaded and sunlit areas. This contrasts with mature forest reaches, where overhead canopies are closed and more spatially homogeneous. In-stream productivity in closed canopy riparian systems is likely to remain predominately heterotrophic (Naiman et al. 1998). We hypothesize, while not tested in this investigation, that a heterogeneous light environment present in many old-growth canopies may increase primary productivity in endogenous streams while also maintaining high allochthonous inputs and cool, shaded conditions preferred by many headwater biota.

Our findings have a number of implications for restoration and watershed management. First, restorationists should consider promoting late-successional/old-growth forest conditions where the associated in-stream habitat characteristics are desired. Second, watershed managers can use riparian forest structure as an indicator of present and future potential riparian functionality. Because riparian old-growth forests can provide high-quality stream habitats, riparian buffer systems could be designed to incorporate protected old-growth riparian corridors if possible. Where old-growth riparian forests are not currently available, mature riparian forests offer a source for future old-growth structure, provided forest management practices are employed that either maintain or enhance, rather than retard, stand development potential (Keeton 2004).

Literature Cited

Bilby, R. E., and G. E. Likens. 1980. Importance of organic debris dams in the structure and function of stream ecosystems. Ecology 61:1107-1113.

Dahir, S.E. and C.G. Lorimer. 1996. Variation in canopy gap formation among developmental stages of northern hardwood stands. Canadian Journal of Forest Research 26:1875-1892.

Gregory, S.V., F.J. Swanson, W. A. McKee, and K.W. Cummins. 1991. An ecosystem perspective of riparian zones: focus on links between land and water. BioScience 41: 540-551.

Gowan, C., and K. D. Fausch. 1996. Long-term demographic responses of trout populations to habitat manipulation in six Colorado streams. Ecological Applications 6:931-946.

Keeton, W.S. 2004. Managing for old-growth structure in northern hardwood forests. In: C.E. Peterson (ed.). Balancing ecosystem values: innovative experiments for sustainable forestry. USDA Forest Service General Technical Report, Pacific Northwest Research Station (In Press).

Kraft, C. E., R. L. Schneider, and D. R. Warren. 2002. Ice storm impacts on woody debris and debris dam formation in northeastern U.S. streams. Canadian Journal of Fisheries and Aquatic Sciences 59:1677-1684.

McGee, G.G., D.J. Leopold, and R.D. Nyland. 1999. Structural characteristics of old-growth, maturing, and partially cut northern hardwood forests. Ecological Applications 9:1316-1329.

Montgomery, D. R., J. M. Buffington, R. D. Smith, K. M. Schmidt, and G. Pess. 1995. Pool spacing in forest channels. Water Resources Research 31:1097-1105.

Naiman, R.J., K.L. Fetherston, S.J. McKay, and J. Chen. 1998. Riparian forests. Pages 289-323 in: R.J. Naiman and R.E. Bilby (eds.). River Ecology and Management: Lessons From the Pacific Coastal Ecoregion. Springer, New York, NY.

Roni, P., and T. P. Quinn. 2001. Density and size of juvenile salmonids in response to placement of large woody debris in western Oregon and Washington streams. Canadian Journal of Fisheries and Aquatic Science 58:282-292.

Wallace, J. B., J. R. Webster, and J. L. Meyer. 1995. Influence of log additions on physical and biotic characteristics of a mountain stream. Canadian Journal of Fisheries and Aquatic Science 52:2120-2137.

Vallett, H. M., C. L. Crenshaw, and P. F. Wagner. 2002. Stream nutrient uptake, forest succession, and biogeochemical theory. Ecology 83:2888-2901.

Woods, K.D. and C.V. Cogbill. 1994. Upland old-growth forests of Adirondack Park, New York, USA. Natural Areas Journal 14:241-257.

Ziegler, S.S. 2000. A comparison of structural characteristics between old-growth and post-fire second-growth hemlock-hardwood in Adirondack Park, New York, U.S.A.. Global Ecology and Biogeography 9:373-389.

Can Old Growth Be Protected Within Working Forests?
Can Working Forest Easements Protect Old Growth?

Charles R. Niebling, Senior Director, Policy and Land Management, Society for the Protection of NH Forests, 54 Portsmouth St, Concord, NH 03301

I. First a little background for perspective

Forest Society owns:

- 38,500 acres
- 141 forest reservations
- 10 counties, 82 towns
- 4 to 4,000 acres in size
- All major ecological land types represented in our ownership

Approximately 2/3 of land base considered managed ("working") forest; 1/3 designated or to be designated as natural areas (currently just over 6,000 acres)

We own land because:

- Protects open space
- Demonstrate exemplary forestry
- Test and evaluate innovative techniques in land and resource management
- Make money to support all our activities
- Protect and manage important and unique natural areas, including old growth or old-aged forests; cultural heritage resources; rare, threatened or endangered species habitat; biological diversity
- Public access for wide range of recreational uses
- Research and education

II. Can old growth be protected within working forests?

- We and many other landowners showing that it can
- Our process provides model for other owners of working forests to consider
- Bio-timber inventory provides thorough ecological analysis and basis for designation
- Natural areas designation process provides criteria for identification, permanent protection

III. Simple overview of natural area designation process

The identification and designation of natural areas is an important and long recognized goal of SPNHF land management.

Natural area designation on SPNHF properties would be determined based on the following criteria and process (from NH Ecological Reserves Steering Committee):

1. **Topographic Relief**
    a. Elevation (above 2,000 feet)
    b. Steep slopes
    c. Undulating terrain
    d. Ledge, shallow soils

   e. Large surface rocks, stoniness, glacial erratics
2. **Water bodies and protective buffers** (Use NH F & G buffer distances or USFWS?)
   a. Wetlands (hydric soils, forested wetlands, etc.)
   b. Vernal pools
   c. Riparian areas
   d. Lakes and Ponds
   e. Stratified drift aquifers or public well water sites
3. **Habitat**
   a. Enriched sites (calcium bedrock)
   b. Old-growth or exemplary old-aged forests
   c. Rare, endangered, or unique plant communities (black gum, Atlantic white cedar)
   d. Merchantable stands of timber that represents some sterling, unmolested features that should be preserved
   e. Unique/critical wildlife habitat (bear beech feeding areas, rookeries, den sites, etc.)
4. **Cultural**
   a. Historic and/or cultural features (Monson village types, etc.)
   b. High recreation use (buffers along main trails on Monadnock, areas at Rocks, as examples)
   c. Relationship to other protected lands (may have some ecological importance to other protected lands as a natural area)
   d. Donor Intent

Process

1. Properties are inventoried and management plans written
2. Staff recommends list of properties having natural areas for official designation to the Trustees' Land Management Committee. Committee critiques rationale.
3. The Land Management Committee presents these recommendations to SPNHF Board of Trustees for acceptance
4. To reverse a natural area designation requires a 2/3 vote of the Board of Trustees

IV. Can Working Forest Easements Protect Old Growth?

WE AND MANY OTHER LAND TRUSTS SHOWING THAT THEY CAN.
SPNHF philosophy: working forest easements not just about protecting working forest, but all forest values.

Simplest approach, widely applied:

Imbed "forever-wild" language in easement specific to clearly identified areas with easily monitored boundaries: managed, buffers, natural areas

- Must be easily monitored/verifiable
- Boundaries must be legally identifiable (GPS has revolutionized this consideration)
- Extent of forever-wild restrictions will obviously influence appraised value of easement and of restricted fee interest (value of easement may approach 90% of FMV – at this point easements may be of limited application)

Another approach:

Include language in easement that requires management plans to identify and set aside unique areas through inventory

- Subsequently identified in baseline documentation
- More difficult to verify/monitor
- Avoid prescribing forest practices that are difficult to measure/monitor/verify in field

V. Leave you with this question to consider

Can easements be effective tool to restore old-aged managed forests on landscape level?

One approach:
Purchase term easements (50+ years) that include purchase of timber rights
- "buying" long rotations

Using Conservation Easements to Protect Old Growth Forests

Nancy P. Smith, Executive Director, Sweet Water Trust, Boston MA 02109

Sweet Water Trust (SWT) is a foundation that helps create and fund conservation projects to safeguard wild lands, wild waters, native wildlife, and living soils in the Northern Appalachian region of New England, the Adirondacks, and Canada. We work with land trusts, state and federal agencies, foundations, corporations and individuals. Please see www.sweetwatertrust.org.

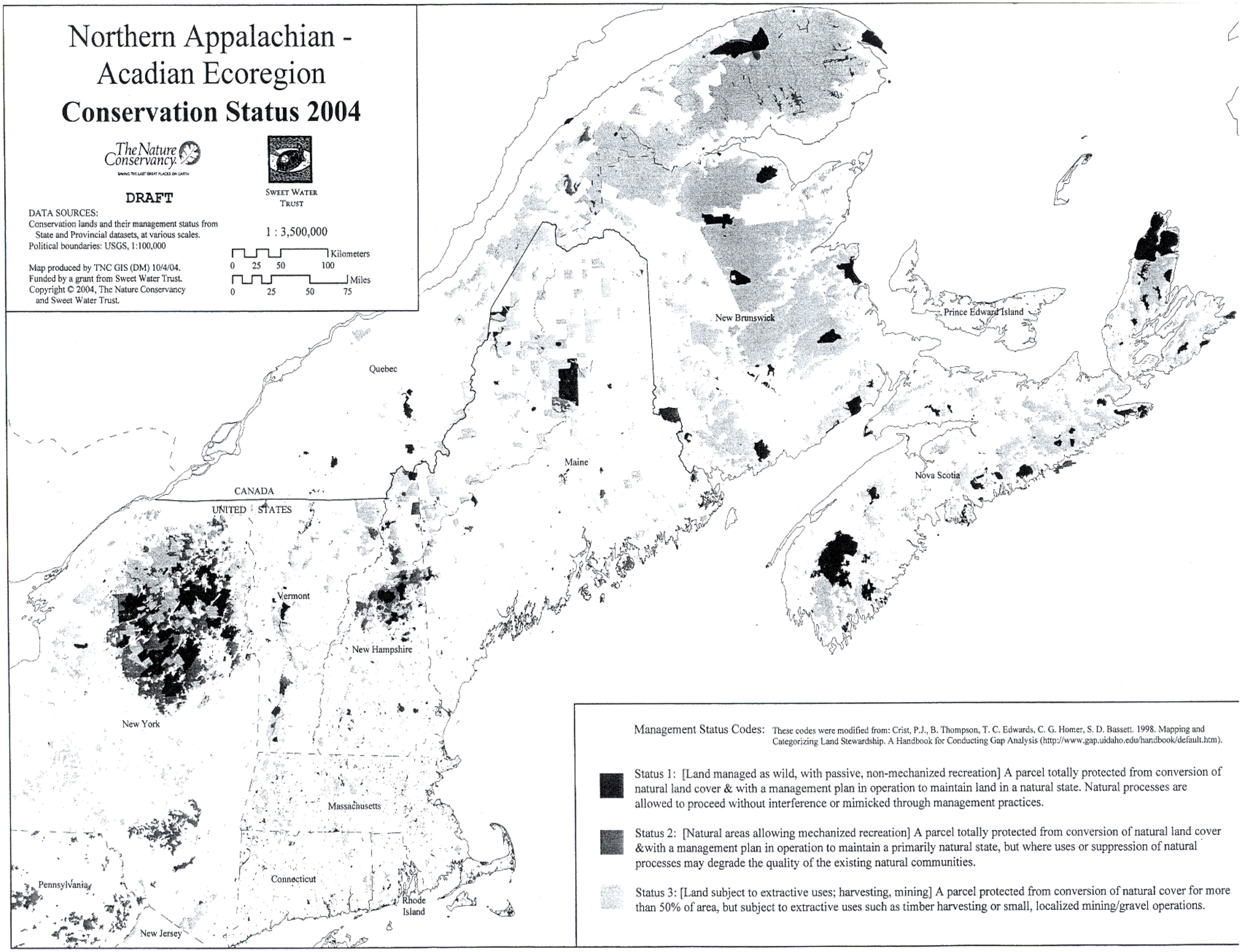
GAP Maps:
During the workshop we briefly examined a map generated by SWT and The Nature Conservancy based on data that we have collected over the past seven years, that reveals how conservation of natural lands is managed in the Northern Appalachian-Acadian Ecoregion, and surrounding areas including southern New England. For this project we modified the Management Status Code definitions from the Federal GAP program to better fit the Northeastern landscape. Sweet Water Trust's work focuses on protection of wild land. When we have the chance to conserve old growth forests, we always try to protect these lands to be managed permanently as Status 1. The data behind the maps lets us quickly see that, for example, 2% of land in Maine is protected as Status 1; 1% of Vermont is protected in that status. See map.

Forever Wild Easements:
Significant natural lands—including old growth forest—need to be protected with the best available legal instruments. On private lands, and on some public lands as well, the use of easements provides perpetual protection against shortsighted political and economic decision-making.

SWT became interested 15 years ago in writing conservation easements that set up strong, science-based permanent protection, easements that would, among other things, protect natural processes so that whole systems may flourish and where diverse species are free to evolve. Basically, SWT uses these "forever wild easements" as a second or extra layer of protection; one conservation group or agency holds the land in fee and a second group holds the easement, the rights to the land. This insures that many people have a stake in safeguarding the land into the future.

Two of the tasks we undertook as we evolved this easement were to write a comprehensive list of restricted uses without impeding the management flexibliliy needed to address unknown ecological issues of the future; and to set up a management plan process based on sound conservation science.

The model we helped design has served as the basis for easements throughout region, protecting many remnant old growth forests. It is available on our website.


Northern Appalachian -
Acadian Ecoregion
Conservation Status 2004
The Nature Conservancy
Sweet Water Trust
DRAFT
DATA SOURCES:
Conservation lands and their management status from State and Provincial datasets, at various scales.
Political boundaries: USGS, 1:100,000
Map produced by TNC GIS (DM) 10/4/04.
Funded by a grant from Sweet Water Trust.
Copyright © 2004, The Nature Conservancy and Sweet Water Trust.
1 : 3,500,000
0 25 50 100 Kilometers
0 25 50 75 Miles
Quebec
CANADA
UNITED STATES
New Brunswick
Prince Edward Island
Maine
Nova Scotia
Vermont
New Hampshire
New York
Massachusetts
Connecticut
Rhode Island
Pennsylvania
New Jersey
Management Status Codes: These codes were modified from: Crist, P.J., B. Thompson, T. C. Edwards, C. G. Homer, S. D. Bassett. 1998. Mapping and Categorizing Land Stewardship. A Handbook for Conducting Gap Analysis (http://www.gap.uidaho.edu/handbook/default.htm).
Status 1: [Land managed as wild, with passive, non-mechanized recreation] A parcel totally protected from conversion of natural land cover & with a management plan in operation to maintain land in a natural state. Natural processes are allowed to proceed without interference or mimicked through management practices.
Status 2: [Natural areas allowing mechanized recreation] A parcel totally protected from conversion of natural land cover &with a management plan in operation to maintain a primarily natural state, but where uses or suppression of natural processes may degrade the quality of the existing natural communities.
Status 3: [Land subject to extractive uses; harvesting, mining] A parcel protected from conversion of natural cover for more than 50% of area, but subject to extractive uses such as timber harvesting or small, localized mining/gravel operations.

Distribution, Composition, and Age Structure of Black Gum Swamps in New Hampshire-

Dan Sperduto, NH Division of Forests and Lands, NH Natural Heritage Bureau, PO Box 1856, Concord, NH 03301 dsperduto@dred.state.nh.us

Nyssa sylvatica Marsh. (black gum, black tupelo) is a widespread tree species of eastern North America. In New England, it is occasional and typically most abundant in swamp settings with *Acer rubrum* L. (red maple). We searched for and documented black gum at 112 locations throughout southern and central New Hampshire, and collected plot data and tree cores to examine variability in vegetation structure and composition, ecological conditions, and age structure among black gum swamps. Swamps generally occurred in small basins [<8 hectares (20 acres)] at low elevations [<305 meters (1000 feet)]; had shallow (average depth 0.9 meter), acidic (pH=4.4), moderately well decomposed peat; and were composed of species indicative of oligotrophic to weakly minerotrophic conditions. Canopy structure ranged from sparse woodland to closed-canopy forest. While size structure varied among stands, multiple size classes of black gum occurred in most plots, and the relationship between tree age and DBH was relatively strong. Together, these factors suggest that an uneven-aged stand structure may be typical of black gum swamps in New Hampshire. In addition, black gum may be the longest-lived broadleaf deciduous tree species in North America: among 20 sites where tree cores were taken, six contained black gum trees older than 500 years of age, the oldest of which exceeded 680 years. Black gum's longevity, ability to sprout from a clonal root system, and tolerance of hurricanes and other disturbances appear to be important life history traits that help maintain uneven-aged, old-growth examples of black gum swamps in New Hampshire.

A Private Landowner Perspective on Old Growth Forests

Ted Harris, The 500 Year Foundation, Lynchburg, VA 24503

Within the private sector The 500-Year Forest Foundation offers a program to aid private landowners to promote the development of old growth deciduous forests. Initially our efforts are concentrated in Virginia.

We seek out people with a long-term environmental interest for their forests and are willing to place their property under a conservation easement. We prospect a number of ways: contacting foresters, telling our story to local newspapers, having field days, and most successfully locating owners with properties already under easement to another land trust.

We look for tracts with good potential for developing into old growth forests. These forests should already have some age, preferably with the dominant trees 100 years or older. Prospective forests should be 100 acres or larger. Man-made pollutants should not have contaminated their lands.

Working closely with the landowner we develop a mutually satisfactory management strategy that satisfies the wishes of the owner and the Foundation. The goal can vary from a natural area to a sustainable working forest with trees harvested on very long rotations favoring gap creation. Several of our forests are essentially natural areas with a limited annual cut allowable for local use such as cabinet making

We are working with The Virginia Department of Conservation and Recreation through their Natural Heritage Division. We have an agreement with them to send a vegetation ecologist to view and evaluate our forests prior to an agreement with the landowner.

An inventory and ecological assessment precedes the development of a forest management plan that is prepared with the aid of forest ecologists or someone with a similar background. We are guided by a set of Forest Management Principles (hand-out, immediately follows). The plan includes a number of dimensions as you can see from the hand out. We are indebted to The Woodland Trust in England for the original set of principles. These principles have been modified on several occasions to be more topical for our eastern old growth forest management.

We believe these forests will be able to offer much to future understanding about the management of old growth. With landowner approval our forests will be available to those who are interested in doing long-term forest research.

John Scrivani, Research Forester, Virginia Department of Forestry has expressed interest in developing research plots in 500-year forests. Currently we are beginning a project with Hank Shugart, Ph.D., and Professor of Environmental Science at the University of Virginia. He believes that a correctly timed and relatively mild forest management can create an old growth forest in half the time that natural processes might generate such a condition. A graduate student, Nancy Sherman, will do this research in some of our forests.

There is great excitement about the potential for our undertaking. Become interested and be a part of this experiment for promoting the development of old-growth forests on private lands.

Forest Management Principles

The 500-Year Forest Foundation, 1133 Old Abert Road, Lynchburg, VA 24503 Phone: 434-384-2324, highview@lynchburg.net

1. **General Principles**
    a. Prepare and maintain an adaptive management plan.
    b. Take action in the forest only after careful consideration. Forest time scales are measured in generations and there is rarely any hurry to intervene.
    c. Manage for old-growth characteristics.
    d. Restore and maintain the health of the forest.
    e. Employ the best knowledge of the time in all actions.
    f. Achieve a diverse, compatible biota natural to local conditions.
    g. Work with neighboring forest owners to create corridors and hubs to be a part of the green infrastructure and to minimize forest fragmentation.
2. **Specific Principles**
    a. Produce and maintain a comprehensive inventory of forest resources.
    b. Control or remove invasive flora or fauna.
    c. Replace missing species when possible and appropriate
    d. Seek out, select, and propagate outstanding individuals of species within the forest and from nearby locations.
    e. Contain water run-off.
    f. Encourage the growth of the dominant canopy trees to full maturity and death.
    g. Restore or safeguard the persistence of all age classes within the forest.
    h. Allow natural processes to proceed on certain sites.
    i. Support research in the forest.
3. **When providing access for the public**
    a. Minimize liability; ascertain that the forest is safe.
    b. Allow pedestrian traffic to the extent that the highest good of the forest is maintained.
    c. Encourage public access for educational and "experiential" purposes, i.e., to enjoy quietly the spiritual and aesthetic qualities of the forest.
    d. Design paths and any public facilities to minimize forest impact.
4. **When harvesting**
    a. Adhere to best management practices.
    b. Harvest only when compatible with all the other principles and within the context of the management plan.
    c. Use sustainable techniques.
    d. Remove forest products in a manner that least damages the ecology.
    e. Maximize the value of the forest products through effective marketing and economic timing.

The 500-Year Forest Foundation operates by management principles that create and sustain natural and healthy woodlands. These principles conserve forests; as well as allow for forest research opportunities, establish seed lots for future forests, and promote forests as havens from cultural pressures and as sites for education and personal understanding.

July 26, 2004 Revision, from The Woodland Trust in England

Empirical Dynamics: A Process Definition of Eastern Old Growth

Charles V. Cogbill, Private Consultant, Plainfield, VT 05667

The nature of old growth is decidedly multifactoral, reflecting divergent human and ecological values. Spiritual, aesthetic, economic, political, legal, conservation, silvicultural, and ecological interests emphasize mostly structural factors based on theoretical expectations or putative examples. Moreover, the nature of eastern North American old-growth forests are confounded by the wide range of forest types, the dearth of any large reference areas unaffected by human disruption, the dominance by short-lived and rapidly decaying species, a spectra of natural disturbance regimes, and the short and changing occupational history since glacial retreat. Furthermore, contrary to well studied old-growth forests elsewhere, eastern old growth characteristics do not necessarily include great age, high absolute biomass, complex canopy structure, great accumulation of dead material on the forest floor, distinctive composition, or known dependent species. Traditional definitions of old growth are a combination of conceptual models, typical examples, and criteria of measurable standards. Significantly, most of the best known examples in the East (for example: Mettler's Woods, NJ, Pisgah Tract, NH, Cathedral Pines, CT, Gifford Woods, VT, Menomonie, WI) have varied stand histories which do not conform to the allegorical model. If the more than 75 synonyms, ranging from "primeval" to "decadent", are at all indicative, a unified definition of old growth will always be elusive. Perhaps the only useful solution is to use the proverbial Supreme Court definition that old growth is "impossible to define, but I know it when I see it."

Composition and stand structure from an extensive field survey of remnant spruce and enriched hardwood stands throughout the Northeast, including landscape analyses at Big Reed ME and Five Ponds NY, show that there are no physical or age structures which are distinctive indicators of "old growthness". Particularly poor indicators are the characteristics of individual trees or the anecdotal "history" of the site. A review of philosophical distinctions, theoretical development, and quantification of typic sites, however, does reveal that Northeastern old-growth forests do have unique, but subtle ecological processes: old-growth dynamics. The essence of a process definition of old growth is reached where the apparently antithetical paradigms of development and disturbance counter each other in an ever changing but self perpetuating state characterized as *old growth***.**

There appear to be three separate parameters which contribute to this old growth character: age, historical integrity, and stand continuity. Gordon Whitney's generic definition of "a long and uninterrupted period of development" is necessary for a site to attain a state that maintains its ecological continuity. How much time and the maximum amount disturbance tolerated then become the critical benchmarks in distinguishing old growth. Since both catastrophic natural and most human disturbances, profoundly disrupt this integrity, evidence of these factors preclude old growth status in this strict definition.

I have conducted extensive quantitative studies on the stand history and dynamics in a large sample of old spruce and enriched deciduous forests throughout the Northeast. In theory as well as empirically a median stand age of half the maximum dominant species longevity emerges as an index of degree of development. This does not necessarily express a stationary regeneration process in the size frequency structure or even a predictable shape of this curve, but expresses the continuing small disturbances at the site. Similarly the coexistence of at least two canopy generations, indicating the prominence of non-catastrophic replacement within the forest, is an appropriate threshold of disturbance. These forests are remarkably dynamic and seldom develop without disruptions, appearing chaotic. Legacies of disturbance include some widespread catastrophic (even-aged) and other small scale less intense (pulses) or variability with complicated mortality patterns distorting the age structures. In most examples the long term mortality rates are between 0.5 to 1.0 % of the trees per year, and even in the oldest stands trees seldom survive in the canopy more than 100 years. Ironically, eastern old growth contains relatively young trees and the older trees are in stands with unusual disturbance regimes and thus extreme examples, not typical old growth.

Ecologically the essence of old growth is the non-catastrophic replacement of one generation of the forest by another. Processes involving canopy demography are crucial. Specifically, as a stand survives beyond a single tree generation, mortality increases and the median tree age approaches half of the maximum for the dominant species. Since many aesthetic values or structures of these forests do not directly follow from this forcing functions, individual tree form or stand structure alone remain ambiguous old growth criteria. Beyond the historical mystique, the management mandates, and the surviving remnants which provide incomplete models, structural criteria should not be viewed as reliable indicators of old growth. Either actual age structure or evidence of two canopy generations, such as dead wood or active canopy replacement, provide a process definition not dependent on the absolute size or structure of the stand.

Identification & Conservation of Mt. Sunapee State Park's East Bowl Old Growth Forest

Lionel Chute, , NH Division of Forests and Lands, NH Natural Heritage Bureau, PO Box 1856, Concord, NH 03301 lchute@dred.state.nh.us

Successive inventories of Mt. Sunapee State Park have revealed significant areas of old growth forest, particularly in the East Bowl. The suspected presence of old forest on Mt. Sunapee first appeared in print in 1915, when Philip Ayres of the Society for the Protection of New Hampshire Forests (Forest Society) described sections of the forests on Mount Sunapee as "primeval". But over the years this was largely forgotten, until 1997 when forest stands containing trees more than 225 years of age were rediscovered by Chris Kane. Subsequent assessments by Division Foresters and Natural Heritage Bureau Ecologists confirmed Chris Kane's findings and warranted more in-depth study of the East Bowl area. In 2003, through funding by the Mt. Sunapee Ski Resort, the Natural Heritage Bureau completed an inventory of the East Bowl, in which 2 areas of old growth forest were identified and mapped. Collected plot data for these areas, including basal area, total number of stems and number of large stems (>19.7 in. [50 cm]), maximum tree ages and diameters, number of snags/acre, number and basal area of snags/acre, and uneven-sized diameter distribution, indicated old, late-successional forest with considerable numbers of large trees and large amounts of deadwood. A significant number of trees, both spruce and yellow birch, were found to be more than 200 years of age, including one yellow birch that exceeded 323 years. To date, the old growth stands on Mount Sunapee are the only old growth forest remnants known in Merrimack County. As a result of these findings, the Division of Forests and Lands is in the process of enrolling the Sunapee East Bowl as a State Natural Area, which has necessitated a review and revision of existing Division definitions and policies regarding State Natural Areas and their management.

From Gravel Bars to Old Growth: Primary Succession in the Zoar Valley Canyon, NY.

Thomas P. Diggins – Biological Sciences, Youngstown State University, OH

It is widely accepted that eastern old growth woodlands represent <1% of pre-European forest cover (Frelich 1995), even as new remnants are being discovered (Davis 2003, Kershner and Leverett 2003). The Zoar Valley Canyon of Cattaraugus Creek in western New York State (Figure 1) holds one such remnant that may exceed 300 contiguous ha (Hunt et al. 2002, Diggins and Kershner 2005). Gorge slopes and ridges are entirely free of deliberate human disturbance, as are a number of flat terraces along the bottom of this 100-m-deep canyon (Diggins and Kershner 2005). Zoar Valley's 22 ha of riverside terraces span 8 km of Cattaraugus Creek and support the most diverse and tallest broadleaf canopy (to 47.5 m) in the northeastern United States (Diggins and Kershner 2005). Zoar Valley contains such rarities as forest-grown black walnut and disease-free American elm growing as canopy dominant individuals.

Poorly accessible gorges are favorable locations to discover minimally disturbed old growth (Davis 2003, Kershner and Leverett 2003), but few such sites in the Northeast are large enough to include extensive and ecologically varied river terraces like Zoar Valley's. More typically bottomlands were bereft of old growth after harvest of their valuable hardwoods and clearing of land for agriculture (Robertson et al. 1978). Zoar Valley thus offers a potentially unique opportunity in the Northeast to study primary succession of riparian (i.e., fundamentally influenced by a river) forests uninterrupted by human influence.

Since 2002 our research group has catalogued canopy and understory composition and structure of Zoar Valley's terrace woodlands, most recently expanding our efforts to include emergent and intermediate forest stages on geologically younger Cattaraugus Creek floodplains. Quadrats of either 30 x 30 m (terraces) or 10 x 10 m (floodplains) were surveyed on ten separate terraces and nine separate floodplains, primarily along the Main Branch of Cattaraugus Creek (surveying protocol detailed in Diggins and Kershner 2005). Sites with obvious or suspected human influence were not considered.

Sugar maple was dominant among the 26 species occurring on raised terraces, accounting for 36.6% of basal area. In descending order, American beech, tulip tree, eastern hemlock, white ash, American basswood, bitternut hickory and American sycamore each contributed between 12% and 4% of basal area. Sixteen additional species constituted the remaining canopy and/or understory basal area. Cottonwood dominated the floodplains (31.6% of basal area), with sugar maple (young specimens), black locust, American sycamore, northern red oak and black willow each contributing between 14 and 4% of basal area.

Ordination (multivariate graphical analysis) and direct gradient analysis (after establishing stand age through tree aging) of canopy structure and species distributions are being pursued to study primary succession along a complete sequence of riverside landforms in Zoar Valley, including raised terraces that support rare bottomland old growth. Some preliminary results suggest floodplain and terrace quadrats separate into distinct aggregates when plotted on ordination axes, and that ecologically transitional zones may be identified as well. After initial colonization of gravel bars, primarily by cottonwoods, sycamores, and/or willows, floodplain woodlands develop quickly in terms of basal area and tree diversity. They then appear to mature much more gradually into the structure and composition recognized as "old growth" (Figure 1 A – D).

Examination of aerial and satellite imagery extending back to 1929, and the completion of tree aging during spring of 2005, should markedly enhance the temporal resolution of this study, leading to a more quantitative understanding of successional processes in this ecosystem. A more complete understanding of the dynamics of forest development in riparian zones will ultimately lead to more effective conservation and/or restoration of these all too often fragmented and stressed ecosystems.

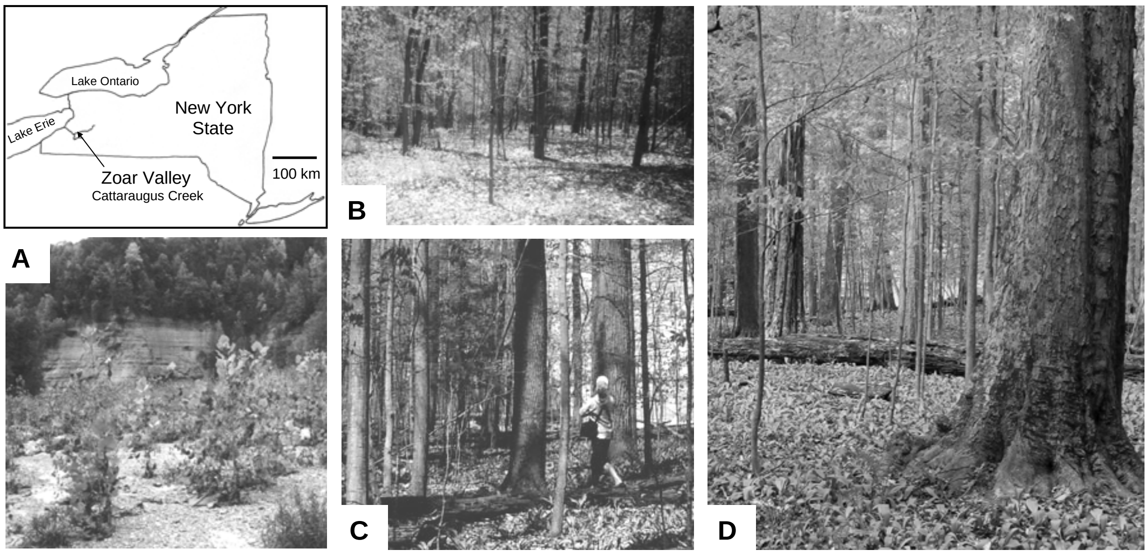


Figure 1. Zoar Valley site location and forest stages on riverside flats. A) recently-colonized gravel bar, B) young floodplain woodlands in stem-exclusion phase, C) mature but transitional terrace woodland with shade-intolerant overstory, D) late-successional old growth with shade-tolerant overstory. (photo credits: A, B, C – TP Diggins; D – B. Sinn, YSU student)

Cited References

Davis MB 2003. Old Growth in the East: A Survey (revised edition). Appalachia, Mount Vernon, KY. 249 p.

Diggins TP, and B Kershner. 2005. Canopy and understory composition of old-growth riparian forest in Zoar Valley, New York, USA. Natural Areas Journal 25: (*in press*).

Frelich LE 1995. Old forest in the Lake States today and before European settlement. Natural Areas Journal 15:157-167.

Hunt DM, GJ Edinger, JJ Schmid, DJ Evans, PG Novak, AE Olivero, and SM Young. 2002. Lake Erie Gorges Biodiversity Inventory and Landscape Integrity Analysis. New York Natural Heritage Program, Albany, NY. 167 p.

Kershner B, and R Leverett. 2003. Sierra Club Guide to the Ancient Forests of the Northeast. Univ. of California Press. 164 p.

Robertson PA, GT Weaver, and JA Cavanaugh. 1978. Vegetation and tree species patterns near the northern terminus of the southern floodplain forest. Ecological Monographs 48: 249-267.

The Importance of Coarse Woody Material in Fostering Fungal Development

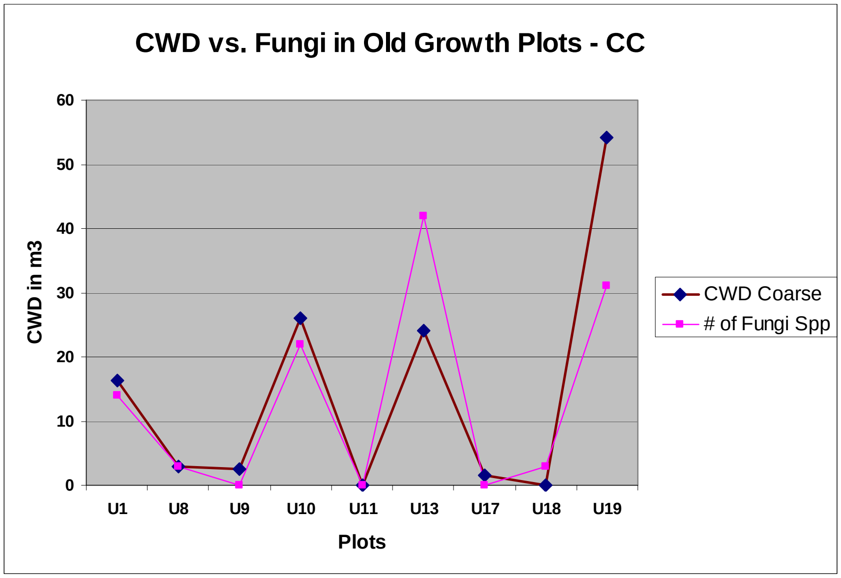
Rick Van de Poll, Ph.D., Ecosystem Management, Center Sandwich, NH 03227,
rvdp@worldpath.net

Coarse woody debris (CWD), or coarse woody material (CWM) in forested ecosystems includes downed logs and branches, stumps, snags, and surface fiber such as bark and other woody fragments. Most forests of the eastern United States and Canada accumulate CWD over time as they aggrade from early successional habitats following disturbance to mature forests with old trees of self-replicating species. Above ground biomass tends to be the greatest when these forests achieve a *late successional* condition, that is, when the rate of decomposition and respiration approximately equals the rate of biomass accumulation through photosynthesis and metabolism (Bormann and Likens 1979). When the age of the forest is equal to or exceeds the average maximal time period between large-scale natural disturbance regimes (e.g. stand-initiating events such as fire, hurricane, tornado or micro-burst wind storms), the amount and age complexity of CWD is at its highest degree of development (Cline and Spurr 1942, Foster 1988, Tyrell and Crow 1994).

Forest fungi play an essential role in the decomposition and nutrient cycling of coarse woody debris. Having co-evolved with forested ecosystems since the earliest of giant horsetail and lycopods forests of the early Cretaceous Period, they have adapted their morphology, physiology and genetic structure for survival in an increasingly complex array of forest types. Since the age of angiosperms in the late Cretaceous and early Jurassic, fungi have also developed symbiotic strategies to maximize their survival in nutrient restricted ecosystems. Although it is not known exactly how long *mycorrhizae* have been present in terrestrial ecosystems, the mutualistic relationship between plant roots and fungi have greatly benefited from the abundance and diversity of CWD.

Both saprophytic and mycorrhizal fungi optimize forested habitats with coarse woody material. Saprophytes have developed niche-separating strategies to infest dead wood from the earliest stages of near-death and death in the tree to the latest stages of decomposition on the ground. Wood-rotting fungi have colonized every tree, sapling, shrub and woody groundcover species during all stages of decomposition. Mycorrhizal fungi, as mutualistic symbionts, have also optimized the living tissues of all woody plant species, whether as *ectomycorrhizals*, those that principally form exterior sheaths of fungal tissue around the plant rootlets, or as *endomycorrhizals*, those that occupy the intercellular tissues within the plant rootlets.

The diversity and abundance of saprophytic and mycorrhizal fungi is directly correlated to the diversity and abundance of coarse woody material. Plot studies by the author over the past several years have shown that measurements of CWD in both the fine (i.e. less than 10 cm in diameter) and coarse (i.e. $\geq$ 10 cm in diameter) size classes have a high degree of correlation between the number of fungi species and CWD.



In a 30-plot study of the Hersey Mountain Forest in Sanbornton and New Hampton, New Hampshire, macro-fungi diversity on all sites with above average coarse woody debris cover had above average numbers of species. The same result was expressed in forest plots in the Ossipee Mountains, both on the north slope in 1999-2000 and on the western and southwestern slopes in 2002-2003. Seventeen plots on the north slope yielded a mean mushroom diversity in old growth sites 2.5 times the amount in non-old growth sites. At the Castle-in-the-Clouds old growth forests, the number of fungi species tightly matched the amount of coarse woody debris as shown at left.

CWD versus fungi species at Castle-in-the-Clouds 2004

In addition to the direct relationship between species diversity and CWD, several **species indicators** of CWD micro-habitat complexity have been found as well. In a releve' plot study in the Forest Society's old growth tract on Lightening Hill in Stoddard, New Hampshire, occurrences of rare fungi species were found on large, old downed logs. *Peziza brunneoviolacea* and *Baeospora aleuritius* were both found on old sugar maple logs for the first time in southwestern N.H. A survey of additional, uncommon species in old growth forests yielded a list of 27 species that were presented at the 4th Eastern Old Growth Conference in 1997 in Sweet Briar, Virginia. Since that time, this list has been expanded to 44 species, and will likely continue to grow as more research is carried out.

The loss of old growth forests in the United States has been accompanied by the loss of structural complexity in forested ecosystems. This has also brought about an increasing rarity of forest fungi associated with coarse woody debris. Although the federal government only recognizes one endangered mushroom species, Noble Polypore (*Oxyporus nobilissimus*) as found with old growth noble fir in the Pacific Northwest, no doubt many others exist. Long-term "Red List" studies in Europe have shown a gradual decline in speciation (Arnold 1991, Courtecuisse 1991, Krieglsteiner 1993, Lizon 1993), yet very little research has been done to demonstrate this loss in the United States. Given the essential role that forest fungi play in decomposition, the recycling of humates and other organic compounds, the transport of chemical nutrients across root membranes, the physical and chemical protection of plant tissues from pathogens, and increased water absorption rates, it is imperative that an investigation of this loss be instigated. Although the initiation of several All Taxa Biodiversity Inventories (ATBI) in the Great Smoky Mountains (http://www.discoverlife.org/sc/gsmnp-atbi.prospectus.html) and elsewhere in the U.S. have begun to take stock of our fungal diversity, it will take many years of sampling before tentative conclusions can be drawn about losses and trends in mycodiversity.

Citations

Arnold, E.E. 1991. Decline of ectomycorrhizal fungi in Europe. *Agriculture, Ecosystems, and Environment* 35:209-244.

Bormann, H., and G. Likens. 1979. *Pattern and Process in a Forested Ecosystem*. New York: Springer-Verlag

Cline, A.C., and S.H. Spurr 1942. The virgin upland forest of central New England: a study of old growth stands in the Pisgah Mountain section of southwestern, New Hampshire. Harvard Forest Bulletin 21, 58 p.

Courtecuisse, R. 1991. National Program for Inventory and Mapping of Mycota. *Bull. Soc. Mycol. Fr.* 107(4):161-203.

Foster, D. R. 1988. Disturbance history, community organization and vegetation dynamics of the old-growth Pisgah Forest, southwestern New Hampshire, U.S.A. *Ecology* 76:106-134.

Krieglsteiner, G.J. 1993. Verbeitungsatlas der Gros pilze Deutschlands (West). Band 2: Schlauchpilze. *Stuttgart:* Verlag Eugen Ulmer.

Lizon, P. 1993. Decline of macrofungi in Europe. *Trans. Mycol. Soc. R.O.C.* 8(3/4):21-48.

Tyrrell. L. E. and T. R. Crow. 1994. Structural characteristics of old-growth hemlock-hardwood forests in relation to age. *Ecology* 75(2):370-386.

www.discoverlife.org/sc/gsmnp-atbi.prospectus.html

Biodiversity Significance of Old-growth, Late-successional, and Economically Mature Forest

John M. Hagan and Andrew A. Whitman, Manomet Center for Conservation Sciences, 14 Maine St., Suite 305, Brunswick, ME 04011, ph:207-721-9040; e-mail: jmhagan@ime.net; web: www.manometmaine.org

Next to conversion of forest to some other land-use (e.g., to house lots, shopping malls, agriculture), the loss of older forest age classes in landscapes managed primarily for wood is a major threat to forest biodiversity worldwide. In Finland, 5% of forest species are predicted to go extinct in the next 50 years, in part as a result of efficient modern forest practices. Many of the species at risk depend on characteristics of older forest age classes, such as large living trees, large standing snags, or fallen logs.

The 26-million-acre Northern Forest region is one of the most remarkable landscapes in North America. Although forest cover has remained stable or even increased, the loss of older forest age classes from this vast forested landscape could be leading us down a biodiversity path that already has unfolded in Scandinavia. Current conservation strategies, such as conservation easements and sustainable forestry certification, do not yet address this issue in a biologically meaningful way. At least in part, this is because the scientific community has not made the case.

It is not widely appreciated that even commercially managed timberland in northern New England still has a biologically significant component of L-S forest—operationally defined here as stands in which there is a cohort of trees 100-200+ years old. Such old stands have been virtually "invisible" as either a conservation problem or conservation opportunity for several reasons. First, ecologists and the environmental community have tended to focus on conserving "true" old growth, of which there is little in our region. What old-growth remains has mostly been protected already. But forests develop along a continuum and along complex pathways; old-growth characteristics do not develop instantaneously at some magical age, but rather they accrue over time (Fig. 1). Thus, even stands with a harvest history can have old-growth characteristics. Effective conservation of forest biodiversity requires us to see the forest as plants and animals see the forest, not as black or white (e.g., pristine old-growth vs. everything else).

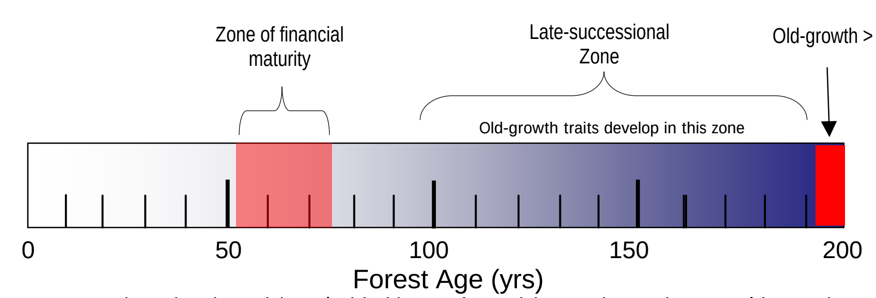


Figure 1. In northern hardwood (maple-birch) or softwood (spruce) stands, true old-growth develops at around 200(+/-) years old. Although stands can take many development pathways, old-growth characteristics begin to emerge when some trees in the stand reach about 100 years of age. Forest stands in the late-successional zone are rapidly disappearing because they are beyond the optimum financial stand age.

Nearly every economic trend, however, is pushing against the maintenance of L-S forest, more so than ever. L-S forest typically is in a steady-state condition whereby as much wood is dying as is growing each year.

From a financial perspective such lack of "net growth" is a cost to landowners. To accrue financial value there must be net wood growth. To create net growth, L-S stands need to be cut, or at least thinned. The critical question is 'can we find social, financial, and technical mechanisms to maintain and manage for L-S forest?' What can be done to maintain sufficient late-successional forest on private managed forestland to sustain L-S structures, functions, and species over the century scale? Below we list several ideas. None are mutually exclusive.

1. **Strengthen sustainable forestry programs**. The two leading sustainable forestry programs used in Maine (SFI and FSC) explicitly call for the maintenance of biodiversity. Consequently, effective and biologically meaningful management for late-successional forest should be a fundamental component of modern forest management planning
2. **Innovation with easements**. Paying landowners for the development rights of their forestland is already a common conservation strategy. A simple extension of this model would be to purchase timber rotation length on a portion of the landscape. That is, pay the landowner to allow some of their forest land to remain in (or grow into) a late-successional condition. Allowing forest to grow to, say, 150 years old, represents a cost to the landowner because the optimum financial return for rotation length is 60-80 years. Such late-successional stands could "move" throughout the landscape over the long term, but a fixed percent of the landscape would have to be in a late-successional condition at any point in time. The late-successional condition of the landscape could be verified with a slight modification to conventional timber inventory methods.
3. **Tax breaks**. In Maine, landowners get a tax break for land that has a legitimate forest management plan. An additional tax break could be given for acres in a late-successional condition, or in a late-successional management regime.
4. **Conservation Reserve Program model**. The federal government has paid farmers NOT to grow crops on some land so that it can return to native vegetation. An analogous program for forestland could be considered, whereby forest landowners are paid to NOT harvest wood (i.e., allow some of the forest to grow into a late-successional condition). This would not have to threaten the economic viability of the forest products industry, just as the Conservation Reserve Program has not threatened U.S. agriculture production.
5. **Late-successional "carbon credits."** Because airborne carbon is linked to global warming, carbon has been "monetized" to facilitate conservation action. Power plants, which produce carbon, can purchase "sequestered" carbon elsewhere to offset their carbon pollution. This offset is often forest in another region or country. Why not sequester carbon in the form of late-successional forest? Power plants upwind of New England could purchase late-successional "carbon credits" from Maine landowners, not only sequestering carbon but also protecting late-successional biodiversity (a great conservation value for the dollar).

The rate at which remaining L-S forest is being lost from northern New England is difficult to determine from existing datasets, but our field experience suggests that quick and creative solutions are needed. It is a reasonable supposition that once this age class is gone we will have crossed an "invisible" biodiversity threshold that will take decades to be fully understood or manifested.

Bats and Small Mammals in Old Growth Habitats in the White Mountains

Mariko Yamasaki, USDA Forest Service, Northeastern Research Station, Durham, NH 03824
myamasaki@fs.fed.us

Studies of bats and small mammals in the White Mountains region are limited and those studies concerned with species-old growth habitat relationships are even fewer. The following summary highlights what has been learned about bat and small mammal species-habitat relationships in the White Mountains region.

Bats

Broadband ultrasonic detection and mist net survey work (Krusic et al. 1996; Krusic and Neefus 1996) has identified nine bat species (*Eptesicus fuscus*, *Lasiurus cinereus*, *L. borealis*, *Lasionycteris noctivagans*, *Pipistrellus subflavus*, *Myotis lucifugus*, *M. septentrionalis*, *M. leibii*, and *M. sodalis*) present during the snow-free seasons. Radiotelemetry work by Sasse and Pekins (1996) has also identified maternity colony habitats used by female northern long-eared bats.

What's been learned so far?

- Bat foraging activity across the forest landscape is highest over still water (e.g., lakes and ponds); flight activity is concentrated along bat "features" – roads, trails, and stream corridors (Krusic et al. 1996; Krusic and Neefus 1996).
- In forest stand comparisons – flight activity was highest in regenerating hardwood clearcuts ($\bar{x}$ = 20 ac) and regenerating softwood group cuts ($\bar{x}$ = 0.5 ac), and large sawtimber hardwood stands (Krusic and Neefus 1996); foraging activity was highest in regenerating softwood group cuts (Krusic et al. 1996).
- Northern long-eared bat (NLE) females form maternity colonies in cavity trees and snags in New England (Sasse and Pekins 1996). NLE females move among roost sites; and roost snags and cavity trees throughout the three-week sample period.
- NLE females use roost sites in and around managed forest; in patches of trees with larger than average diameters and more snags than the surrounding forest area. Roost sites were often near water. Roost snags and cavity trees had larger diameters; and roost snags were taller than available snags and live trees. Selected roost snags were more often in beech and had more bark remaining (e.g., more recently dead) than samples of available snags (Sasse and Pekins 1996).

Small Mammals

Small mammal sampling efforts (e.g., live, snap, and pitfall trapping) have identified 25+ species in five taxonomic families (e.g., shrews, moles, squirrels, mice and voles, and jumping mice). Generally, six species (*Blarina brevicauda, Sorex cinereus, Peromyscus maniculatus, P. leucopus, Clethrionomys gapperi, and Napaeozapus insignis*) comprise 90 to 95 percent of captures, depending on the year and prior season's hard mast crop.

What's been learned so far?

- Vegetative structure has little effect on small mammal distributions in old growth northern hardwoods in the Bowl RNA (Gore 1988). Most small mammals are ubiquitous across the forest landscape with a few exceptions (DeGraaf et al. 1991; Lovejoy 1975; Yamasaki, unpublished data).

- Short-term sampling of small mammal populations across managed, unmanaged, and remote landscapes across the WMNF indicates a broader array of small mammals captured in managed plots compared with remote plots across the WMNF (Yamasaki, unpublished data).
- Long-term sampling suggests significant yearly variation in species composition and abundance complicate comparisons of silvicultural treatments (Yamasaki, unpublished data). Sampling protocols need to reduce sources of error associated with trap type, skill level, placement, and weather (Kirkland and Sheppard 1994) to better compare results from other areas.

Conclusions

- Managed landscapes can provide suitable habitats for large- and small-diameter cavity dwellers when appropriate standards / guidelines that incorporate wildlife habitat elements are followed.
- Forest bat habitat concerns are being addressed on managed landscapes.
- There are no bat or small mammal old-growth obligate species in NH forests today.
- Continued loss of early successional habitat is a much more pressing habitat conservation issue for some reptiles, birds, and mammals in New England.

Literature Cited:

DeGraaf, R.M.; Snyder, D.P.; Hill, B.J. 1991. Small mammal habitat associations in poletimber and sawtimber stands of four forest cover types. Forest Ecology and Management. 46: 227-242.

Gore, J.A. 1988. Habitat structure and the distribution of small mammals in a northern hardwoods forest. Pages 319-327. *In*: Szaro, R.C.; Severson, K.E.; Patton, D.R. (eds.). Management of Amphibians, Reptiles, and Small Mammals in North America. Proceedings of the symposium, July 19-21, 1988, Flagstaff, AZ. USDA Forest Service Gen. Tech. Rep. RM-166.

Kirkland, G.L., Jr.; Sheppard, P.K. 1994. Proposed standard protocol for sampling small mammal communities. Pages 277-281. In: Advances in the Biology of Shrews. Merritt, J.F.; Kirkland, G.L., Jr.; Rose, R.K. (eds.). Carnegie Mus. Nat. Hist. Spec. Pub. 18.

Krusic, R.A., M. Yamasaki, C.D. Neefus, and P.J. Pekins. 1996. Bat habitat use in White Mountain National Forest. J. Wildl. Manage. 60(3): 625-631.

Krusic, R.A.; Neefus, C.D. 1996. Habitat associations of bat species in the White Mountain National Forest. Pages 185-198. *In*: Barclay, R.M.R.; Brigham, R.M. (eds.). Bats and Forests Symposium, October 19-21, 1995, Victoria, British Columbia, Canada. Res. Br., B.C. Min. For., Victoria, B.C. Working Pap. 23/1996.

Lovejoy, D.A. 1975. The effect of logging on small mammal populations in New England northern hardwoods. Univ. Connecticut Occasional Papers 2(17): 269-291.

Sasse, D.B.; Pekins, P.J. 1996. Summer roosting ecology of northern long-eared bats (*Myotis septentrionalis*) in the White Mountain National Forest. Pages 91-101. *In*: Barclay, R.M.R.; Brigham, R.M. (eds.). Bats and Forests Symposium, October 19-21, 1995, Victoria, British Columbia, Canada. Res. Br., B.C. Min. For., Victoria, B.C. Working Pap. 23/1996.

Using Remote Sensing to Identify and Map Old Growth

Sam Stoddard, UNH Cooperative Extension, 629A Main St, Lancaster, NH 03584
sam.stoddard@unh.edu

Remote sensing technology offers a variety of useful methods for the identification and mapping of old growth forests. Methods vary from airborne to satellite platforms, and from photographic to electro-optical scanners and laser altimetry (LIDAR) techniques.

Remote sensing techniques are useful in discriminating many of the physical characteristics that are normally associated with old growth forests. These characteristics include: a preponderance of "old" trees and "large" trees; multiple crown layers; presence of snags and coarse woody debris; little or no evidence of human disturbance; and spatial heterogeneity.

Several examples of stereo aerial photographic images of old growth forests and trees were presented. Individual old trees can be distinguished by size, crown form and presence of decay. Forest stands can be distinguished by tree size variations, horizontal patchiness, vertical foliage distribution, live and dead biomass, gap formation and gap closure rates. Species discrimination on the basis of horizontal and vertical morphological characteristics was discussed. General concepts of image interpretation were presented, including primary recognition elements such as: shape, texture, tone, location, size, pattern, shadow and feature association.

Examples of black and white, natural color and color infrared aerial photography were provided showing image characteristics of sample old growth forests in Ontario, California, and New Hampshire. The advantages and disadvantages of each type of photography were presented. Vegetation reflectance curves showing percent reflectance plotted over wavelength illustrated the importance of the near infrared portion of the electromagnetic spectrum for the discrimination of vegetation.

Multispectral analysis using such products as LANDSAT Multispectral Scanner data and LANDSAT Thematic Mapper data was provided along with selected examples. Image classification based upon spectral signatures to distinguish and map land cover, including old growth vegetation, was summarized.

The relatively new technique of using laser altimetry to collect information about the vertical characteristics and three-dimensional structure of forests was presented. NASA's Laser Vegetation Imaging Sensor (LVIS) is a centerpiece for several research efforts currently in progress in the northeast in collaboration with the USDA Forest Service Northeast Research Center to investigate forest structure, productivity and biogeochemical cycling. Mapping of the Hubbard Brook and Bartlett Experimental Forests in New Hampshire was shown, which measures the vertical extent and characteristics of forest cover. Research performed by Jeanne Anderson and Mary Martin of UNH Complex Systems in collaboration with ML Smith of the USDA Forest Service Northeast Research Center; Ralph Dubayah, et al of the University of Maryland; and J. Bryan Blair of NASA illustrates the potential for integration of spectral and LIDAR data. Ongoing and future research efforts are necessary to refine algorithms and modeling, which will improve the effective integration of diverse remotely sensed data, and ultimately improve the identification and mapping of forests, including old growth forests.

Aerial Canopy Signatures of Old Growth Forest

Chris Kane, Society for the Protection of New Hampshire Forests

Heterogeneous canopy structure is a characteristic of old growth condition for many forest types in New England. Forests composed of predominantly late successional species of mixed ages including some very old trees are a result of a very old, naturally-managed stand which have experienced a minimum of catastrophic disturbance. When viewed from the air, the canopy of many old growth examples exhibit distinctive textures of the upper canopy that are an artifact of natural tree death and replacement. Aerial photography can be an effective and efficient tool for locating and studying old growth forest stands.

Cultural use such as settlements, pastures and woodlots, as well as boundaries of ownership leave noticeable patterns that can be detected on aerial photographs. Visible cultural remnants include roads, trails, walls, cellar holes, fences, homogeneous forest stands, early successional species predominance, abrupt stand discontinuity and geometric forest patterns. Detection of human influence provides context for identifying undisturbed, potential old growth remnants.

Old growth characteristics which are potentially detectable on aerials include individual large and old trees, condition of canopy trees, significant deadfall, random canopy gaps of various ages, species composition and contrast with surrounding forest signatures. Canopy signatures of old growth are site, stand history and species composition dependent. Study of coverages for known old growth examples will help develop a search image for other examples of that forest type.

A comparison of the range of aerial coverages available for a target area increases the confidence of interpretation. Coverages may include black & white, color, infrared and digital formats, with some flights many decades old. Variables include flight altitude, season, time of day, atmospheric clarity and cloud cover, and overlap of stereo pairs. Stereo viewing of pairs is especially useful in interpreting canopy texture. Studying the most recent coverage first will eliminate recently disturbed areas from consideration, while studying the oldest available coverage will reveal artifacts of older cultural use. The application of GIS using recent digital aerial coverage holds promise for more sophisticated study of old growth canopy structure.

Finding Rich Mesic Forest: A Remote Sensing and Geographic Information Systems Approach (master's thesis draft)

Pete Ingraham, Society for the Protection of NH Forests, 54 Portsmouth St, Concord, NH 03301

Abstract
Rich mesic forests (RMF), a nutrient-enriched, sugar maple-dominated subset of the northern hardwood forest, are considered an exemplary natural community in New Hampshire. There is considerable interest within the scientific and conservation community in mapping their extent. This study employed a combination of hyperspectral remote sensing and geographic information systems (GIS) data to create a model of high-probability RMF sites in the White Mountain region. Multiple linear regression was applied to forest biometric data to classify an AVIRIS image for percent foliar biomass of Sugar Maple and Beech. These classifications were combined with digital elevation model (DEM) derived landscape position and soil moisture indexes and bedrock geology to create the final model. Field surveys of high-probability sites revealed that the model did detect RMF sites as well other enriched and sugar maple rich sites.

Executive Summary
Natural resource conservation necessarily relies on geographic information. To protect natural communities in New Hampshire a method to define their full extent would be a useful tool. Natural communities in New Hampshire have been modeled theoretically using geographic information systems (GIS), but relatively few attempts have been made to use remote sensing for direct detection. This study focused on the White Mountain region, and uses a combination of hyperspectral remote sensing and ancillary GIS data to detect rich mesic forest (RMF), a New Hampshire Natural Heritage Bureau (NHB) designated exemplary natural community in New Hampshire.

RMF are a nutrient-enriched subset of the northern hardwood forest. RMF typically have a sugar maple (*Acer saccharum*) dominated canopy, with rich-site canopy associates such as white ash (*Fraxinus americana*), basswood (*Tilia americana*), and ironwood (*Ostrya virginiana*). These canopy species generally occur to the exclusion of other northern hardwood species such as beech (*Fagus grandifolia*) and yellow birch (*Betula alleghaniensis*). RMF also harbor many unusual (in New Hampshire) herbaceous species.

The AVIRIS (Airborne Visible / Infrared Imaging Spectrometer) hyperpectral remote sensing instrument senses upwelling radiation (ie. light) in 224 bands from approximately 400nm to 2500nm in contiguous 10nm bands. Multiple linear regression was used to relate forest biometric data from the Bartlett Experimental Forest and AVIRIS reflectance bands. This resulted in a classification of percent foliar biomass for sugar maple and beech. Sites with high sugar maple content and low beech content are given a higher weight in the RMF model.

Sources of RMF enrichment are many, varied, and, in some cases, not completely understood. Two major sources are from colluvial processes related to landscape position and from base cation rich bedrock (particularly calcareous geologies). Digital elevation model (DEM) data was used to model landscape position. Preference was given to those landscape settings where colluvial processes are likely to occur such as in coves, ravines, cliff bases, or toeslopes. Bedrock geology data was classified in a broad index of calcium quality. This index informed the degree to which colluvial processes affect the likelihood of an RMF occurrence; on Ca-poor sites, colluvial processes dominate, on Ca-rich sites, colluvial processes play less of a role. DEM derived landscape position (combined with the Ca quality index), DEM derived soil moisture soil index, and the AVIRIS sugar maple / beech classification were combined into a final model which output a probability of RMF occurrence.

Sixty-six (66) sites were field checked to assess the accuracy of the model. A chi-square analysis of the distribution of enriched sites (ie. sites the model assessed as likely to be RMF) versus validation sites (ie. sites the model assessed as unlikely to be RMF) revealed that the model is significantly more likely to detect enrichment than not. As a result of this study 13 new RMF occurrences and 25 new Semi-rich mesic forests (another NHB defined natural community) were identified.

This method for detecting natural communities will hopefully serve as a model for future studies. In addition, it demonstrates that remote sensing and GIS can be used as an effective tool for natural resource managers and conservationists alike.

A Comparison of Floristic Diversity in Old-Growth versus 100 Year-Old Hardwood Forests of the White Mountains

Leslie M. Teeling-Adams, Ph.D., Lee, NH 03824

A long-standing debate exists in the scientific literature over whether managed forests will ever regain the species diversity of old-growth stands. In temperate hardwood forests, herbaceous species comprise the predominant component of the flora, often representing upwards of 70% of species. Diversity in this community therefore exerts critical influence on the system's floristic diversity overall yet, while tree species succession and response to disturbance has been extensively researched, little similar effort has focused on understory herbaceous communities (Goebel et al. 1999; Halpern and Spies 1995; Johnson et al.1993; Meier et al. 1995; Roberts and Zhu 2002; Teeling-Adams 2003; Teeling et al. 2001).

This study conducted large-scale (7-8 ha), comprehensive botanical inventories of three matched-pair old-growth and mid-successional (90-100 year old) secondary-growth beech-maple hardwood stands in New Hampshire's White Mountain National Forest, and compared their floristic diversity. Old-growth sites were within USDA Forest Service Research Natural Areas and Long Term Ecological Research sites, and thus have the potential to serve as reference locations for long-term biological diversity monitoring. A systematic reconnaissance surveying approach was employed rather than using plot-based methods, as sampling may underestimate the abundance of species with contagious distributions and lends increased risk of missing rare species altogether. Taxa of both description have been theorized to be among the better indicators of primary systems (Halpern and Spies 1995; Kimmins 1997; Meier et al.1995; Mueller-Dumbois and Ellenberg 1974; Peterken and Game 1984; Roberts and Zhu 2002; Rooney and Dress 1997; Sobey and Barkhouse 1977; Spies 1991; Whitford 1949; Whitney and Foster 1988). Although exceedingly rare, full-inventory studies yield the most comprehensive data for the assessment of true species diversity and are particularly indicated in the assessment of old-growth systems. This investigation constitutes the first comparative study of this kind in New England.

In the combined 45.7 ha of the six sites, 147 species in 55 families were encountered. Herbaceous species composed the majority of the flora at all sites. One hundred thirty-two species were found in the old-growth sites and 92 species were found in the secondary forest sites; only 19% of the total species list were species in common to both forest types. According to restricted randomized complete block ANOVA results, old-growth floras were found to be significantly richer in total, herbaceous, woodland herbaceous, and unique herbaceous species (species occurring only in one forest type or the other). In an attempt to assess the importance of microhabitats associated with mature gap-phase dynamics, species associated with wet soils, moist and/or rich soils, dry soils, and open, disturbed sites (as per Gleason and Cronquist 1991; Voss 1985, 1996) were also analyzed. Over 75% of the species unique to old-growth sites were of rare or infrequent ranked abundance, and over 60% of these unique species were associated with wet and/or moist/rich soils, a difference which closely approached but did not achieve significance. No clear trend was apparent between the two forest types for species associated with dry soils, or open, disturbed sites.

Numerical classification of the study sites using TWINSPAN and ranked abundance data of the total species list separated secondary from old-growth sites in two divisions. Ward's minimum variance cluster analysis corroborated these results and further grouped the sites using herbaceous, woodland herbaceous and vernal herbaceous species subsets. Species associated with wet soils and species associated with moist and/or rich soils showed similar clustering patterns. Dominance-diversity curves of the two forest types' herbaceous and woodland herbaceous species were significantly different according to Chi^2 results, with more species of rare, infrequent, and (to a lesser extent) dominant abundance occurring in old-growth sites. Sørensen's similarity index indicated old-growth floras to be more similar in their total, tree, shrub and herbaceous communities than secondary floras.

The importance of rarely- and infrequently-occurring herbaceous species in the old-growth floras – and specifically among these, species associated with wet microhabitats – was deemed among the most significant findings of this study. While not directly measured, these wet microhabitats in old-growth sites were observed to be associated with the dispersion and reticulation of site drainage patterns due to extremely heterogeneous forest floor microtopography. It is believed the steeps and stifles created by these conditions provided a gradient of moisture conditions responsible for the observed species diversity. In almost all cases the statistically significant differences in floristic diversity revealed in this study were not reflected in tree community data alone. It should also be noted that inclusion of the significant number herbaceous species of rare and infrequent abundance (and conversely, dominant abundance) directly affected many statistical outcomes. These results suggest that reliance on tree data or plot-based herbaceous data alone to infer eastern hardwood forests' recovery from disturbance would be misleading.

References

Gleason, H. and A. Cronquist. 1991. Manual of Vascular Plants of the Northeastern United States and Adjacent Canada. 2nd ed. New York Botanical Garden, Bronx, NY.

Goebel, P. C., D. M. Hix and A. M. Olivero. 1999. Seasonal ground-flora patterns and site factor relationships of secondary-growth and old-growth south-facing forest ecosystems, southeastern Ohio, USA.Nat.Areas J. 19: 12-19.

Halpern, C. B. and T. A. Spies. 1995. Plant species diversity in natural and managed forests of the Pacific Northwest. Ecol. Appl. 5: 913-934.

Johnson, A. S., W. M. Ford and H. Hale. 1993. The effects of clearcutting on herbaceous understories are still not fully known. Conserv. Biol. 7: 433-435.

Kimmins, J. P. 1997. Forest Ecology: A Foundation for Sustainable Management. 2nd ed. Prentice-Hall, Upper Saddle River, NJ.

Meier, A. J., S. P. Bratton and D. C. Duffey. 1995. Possible ecological mechanisms for loss of vernal-herb diversity in logged eastern deciduous forests. Ecol. Appl. 5: 935-946.

Mueller-Dumbois, D. and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley & Sons, Inc., New York.

Peterken, G. F. and M. Game. 1984. Historical factors affecting the number and distribution of vascular plant species in central Lincolnshire. J. Ecol. 72: 155-182.

Roberts, M. R. and L. Zhu. 2002. Early response of the herbaceous layer to harvesting in a mixed coniferous-deciduous forest in New Brunswick, Canada. Forest Ecol. Manag. 115: 17–31.

Rooney, T. P. and W. J. Dress. 1997. Species loss over 66 years in the ground layer vegetation of Heart's Content, an old-growth forest in Pennsylvania, USA. Nat. Areas J. 17: 297-305.

Sobey, D. G. and P. Barkhouse. 1977. The structure and rate of growth of the rhizomes of some forest herbs and dwarf shrubs of the New Brunswick-Nova Scotia border region. Canad. Field-Naturalist 91: 177-383.

Spies, T. A. 1991. Plant species diversity and occurrence in young, mature and old-growth Douglas-fir stands in western Oregon and Washington. Pp. 111-121 in: Wildlife and vegetation of unmanaged Douglas-fir forests. Ruggiero, L. F., K. B. Aubry, A. B. Carey and M. H. Huff, coords.Pacific Northwest Forest Range and Experiment Station General Technical Report PNW-GTR-285.

Teeling-Adams, L. M. 2003. A Comparison of Floristic Diversity in Old-Growth versus Mid-Successional Secondary-Growth Hardwood Forests of the White Mountain National Forest, New Hampshire, USA. Ph.D. Dissertation, University of New Hampshire, Durham, NH.

Teeling, L. M., G. E. Crow and G. L. Wade. 2001. Floristic Diversity of the Experimental Watersheds of the Hubbard Brook Experimental Forest, New Hampshire, USA. Rhodora 103: 263-292.

Voss, E. G. 1985. Michigan Flora: A Guide to the Identification and Occurrence of the Native and Naturalized Seed-Plants of the State. Part II. Regents of the University of Michigan, Ann Arbor, Michigan.

-------- 1996. Michigan Flora: A Guide to the Identification and Occurrence of the Native and Naturalized Seed-Plants of the State. Part III. Regents of the University of Michigan, Ann Arbor, MI.

Whitford, P. B. 1949. Distribution of woodland plants in relation to succession and clonal growth. Ecology 30: 119-208.

Whitney, G. G. and D. R. Foster. 1988. Overstory composition and the determinants of the understory flora of woods of central New England. J. Ecol. 76: 867-876.

Ecological Economics and Long-Term Investments in Forest Management: Presentation Summary

Spencer Phillips, The Wilderness Society, W. Charleston, VT 05872

Protected forest areas, including old-growth reserves, designated wilderness, roadless areas and others, provide numerous economic benefits to society. The difficulty is that few of these benefits are reflected completely, if at all, in formal markets. The market price of these benefits is therefore discounted by buyers and sellers. As with any good, when the price of these old growth benefits is too low, we overuse – we waste – the benefits and the forests that produce them. Left to its own devices, the market will supply an inefficiently low level of carbon sequestration, biodiversity protection, air and water filtration and even scenic amenities.[1]

The challenge for economists interested in a more efficient level of old growth forest protection is to articulate the magnitude of the non-market value of those forests and then to propose and advocate for institutions, whether public policies or new market mechanisms, that acknowledge and account for those values.

Economic Values of Old Growth Forests

Assuming that the values of old-growth forests are at least akin to the values of designated wilderness and other areas, the following provides a general picture of the various economic benefits of eastern old growth forests and the magnitude of their values.

Regional economic diversification. Economic research documents that people and businesses locate where the quality of life is considered good, based in part on a clean, natural environment and high-quality recreational opportunities. Retirees and "footloose" businesses, in particularly, bring dollars and opportunities to areas with high-quality amenities.

- In a survey of 11 fast-growing counties across the country, Rudzitis and Johansen (1991) found that 45 percent of long-time residents and 60 percent of recent migrants to counties containing designated wilderness areas on federal lands indicate wilderness is an important reason for living in those counties.
- Rasker (1994) found that entrepreneurs cite quality-of-life factors over business-climate factors (cheap labor, low taxes, lax environmental standards) as reasons for locating and keeping their businesses near protected public lands. (See also Power 1996 and Florida 2000).
- Lewis and Plantinga (2001) found that conservation lands in the northern forest region stretching from Maine to Minnesota are associated with higher net migration that, in turn, engenders growth in employment. People seek (or stay in) areas with wildland amenities, and jobs follow people.
- Based on their research, Freudenburg and Gramling (1994) state: "…it needs to be recognized as a serious empirical possibility that the future economic hope for resource-dependent communities of...the United States could have less to do with the consumption of natural resources than with their preservation."

[1] For a more on the concept of the total economic value of forests and how markets under-count that value, see Phillips, Spencer, "The Value of Nothing," at http://www.eco2eco.net/Contact/PDFs/valueofnothing.pdf.

Property enhancement. Protected land can enhance the value of nearby private property.

- In the region surrounding the Green Mountain National Forest in Vermont, land values are 19 percent higher in towns that contain wilderness, while land prices decrease by one third of one percent with every kilometer farther away a wilderness boundary (Phillips 2004).

Lower public service costs. Open space typically generates local tax revenue in excess of the costs of the public services that such land requires. Cows and moose, it is said, don't ride school buses.

- Recent studies in Maine and the Adirondacks conclude that towns with more open space have lower tax rates (Ad Hoc Associates 1997) and that the amount of protected land does not affect individuals' tax bills (Ad Hoc Associates 1996). (See also American Farmland Trust 1992, Commonwealth Research Group 1995, Tibbetts 1998, Lerner and Poole 1999).

Ecosystem services. Ecosystem services include air and water filtration, climate regulation, maintenance of biodiversity, scenic beauty, and other benefits that nature provides free of charge. Where they are not available, people must provide them.

- Water filtration is one example. The U.S. Forest Service estimates that 60 million Americans — more than one-fifth of the nation's population — get their water from sources with headwaters on national forests, which supply 6 percent of runoff east of the Mississippi River and 33 percent in the West. At a minimum, this water is worth $3.7 billion annually (Sedell et al. 2000).
- Carbon sequestration is another example. Mature, fully stocked forests sequester carbon to help slow the process of global warming. Carbon credits are already being exchanged for prices ranging from $1 to $20 per ton around the world, or $300 to $600 per acre (Walls 1999).
- Costanza et al. (1998) estimate the value of all ecosystem services on temperate forests like Vermont's at $122 per acre per year. Less than a tenth of this sum stems from the production of raw material such as timber, while about a third is from all direct use values, including recreation.
- In a more recent study focused on wilderness areas in the lower 48 states, Loomis and Richardson (2001) estimate the value of federally designated wilderness areas for carbon storage, climate regulation, and waste treatment (filtering of air and water) services at between $2.0 billion and $3.4 billion per year.

Passive use. Option value (what it's worth to preserve the option of future use), bequest value (what it's worth to protect a resource unimpaired for future generations), and existence value (the value that people place on preserving a resource even if they have no expectation of using it in the future) collectively comprise passive use values.

- Loomis and Richardson (2000) estimate the passive use value of wilderness in the eastern United States at about $4 per acre per year.

Recreation. Direct use through visitation of protected forest areas is perhaps the most obvious economic value. Even so much of the value of that visitation is not traded in markets.

- Loomis and Richardson (2001) estimate that the value of eastern wilderness to visitors is about $44 per acre each year and that these visitors generate an additional $44 per acre per year in spending in nearby communities. That spending translates into support for one job for every 550 acres of wilderness. A National Sporting Goods Association survey estimates that participation in wilderness camping and hiking by nearby residents alone totaled 630,000 visitor days of backpacking and 460,000 visitor days of hiking in 1998, an increase of 158 percent over 1990.

Science. Aldo Leopold (1949) wrote that wilderness supplies a "base datum of normality, a picture of how healthy land maintains itself as an organism." Wilderness is the control by which scientists can judge the impacts of management on other parts of the landscape.

- Using the production of new scientific information as a proxy for this value, Loomis and Richardson (2001) estimate that research conducted in or based on wilderness areas contributes some $5 million to the U.S. economy each year.

Institutions for Respecting and Protecting Old Growth Forest Values

Beyond obvious measures like expanding the number and size of protected areas (wilderness and ecological reserves, forever-wild easements, etc.) environmental and ecological economics might also suggests new market mechanisms that can bring at least some of the values enumerated above to bear on market transactions and, therefore, producer and consumer behavior.

One strategy is to target timberland investors and to develop new investment vehicles that look beyond mere timber value (which generally drives management toward shorter rotations and loss of ecosystem service and other values) to consider the many values of older forests. One approach would be to identify so-called "patient capital" for investments in forestland. Institutional investors, including university endowment funds, and some individuals may be able and willing to wait for longer periods before harvest, which would allow conditions on even commercial timberland to attain some old-growth characteristics. These same investors might be willing to create private reserves within their timberland holdings.

Certification programs, like that of the Forest Stewardship Council, provide both standards to ensure environmentally responsible management (including the creation of reserves for larger land holdings) and recognition in the marketplace for participating landowners. That recognition may encourage greater patience on the part of some forestland investors.

By tying sound management to the sale of timber, certification creates an implicit incentive for the production of old-growth benefits. Another possibility is to create explicit incentives by developing and participating in formal markets for a broader range of forest values. Carbon sequestration, water filtration, recreation and value (enhancement) are all marketable benefits created when forestland is well-managed and protected for the long term.

The Global Climate Exchange, part of the Chicago Board of Trade, can facilitate the sale of carbon credits generated by owners of old-growth forests. Cooperative agreements with water bottlers or enhanced "current-use" tax benefits negotiated with municipalities would enable forestland owners to monetize the water quantity and quality values they generate through responsible management of older forests. Similar agreements with recreation/tourism businesses would ensure the long-term provision of scenic and recreational amenities while attaching a cash flow to currently non-marketed (or under-marketed) forest assets.

Through the concerted application of these and other ideas, timberland investment and management organizations could be transformed into *forestland* investment and management organizations. By monetizing more of the forest's values (internalizing the external benefits of old-growth forests), such organizations would make run-of-the-mill forestland investors participants in the protection and enhancement of broad public values.

Community Forestry Bonds are another institution or investment vehicle that could be augmented by greater consideration of old-growth values. Bonds would be issued to pay for the public purchase of forestland or easements on forestland. Long-term management guidelines would be included in the easement provisions or public management plan. To help pay for the bonds, an incremental Land Transfer or Land Gains taxes would apply to nearby land sales. This would capture the windfall created by the protected area and would only be paid by buyers who are purchasing a more valuable property or sellers collecting the windfall. Other appropriate sources of revenue to pay for such bonds include an excise fee on municipal water supplies or general property taxes that recognize the value to all residents of preserving scenic and recreational amenities in the community.

Implementing any of these ideas will require creativity and hard work by academics, advocates, land owners and policy makers. But it is work that needs to be done, for left to its own devices, the market will not provide sufficient old-growth forests and the values they produce in the eastern United States.

References

Ad Hoc Associates. 1996. Property Taxes, Growth, and Land Conservation in the Adirondacks. The Adirondack Council, Elizabethtown, NY.

Ad Hoc Associates. 1997. Open Land, Development, Land Conservation and Property Taxes in Maine's Organized Municipalities. Maine Coast Heritage Trust, Brunswick, ME.

American Farmland Trust. 1992. Does Farmland Protection Pay? Northampton, MA.

Commonwealth Research Group, Inc. 1995. Cost of Community Services in Southern New England. Southern New England Forest Consortium, Chepachet, RI.

Costanza, R., et al. 1998. The value of the world's ecosystem services. Ecological Economics 25: 3-15.

Florida, R. 2000. Competing in the Age of Talent: Environment, Amenities, and the New Economy. Report prepared for the R. K. Mellon Foundation, Heinz Endowments, and Sustainable Pittsburgh. Carnegie Mellon University, Pittsburgh, PA.

Freudenburg, W.R., and R. Gramling. 1994. Natural resources and rural poverty: A closer look. Society and Natural Resources Vol. 7.

Leopold, A. 1949. Wilderness. In: A Sand County Almanac. Oxford University Press, Oxford, UK.

Lerner, S., and W. Poole. 1999. The Economic Benefits of Parks and Open Space: How Land Conservation Helps Communities Grow Smart and Protect the Bottom Line. The Trust for Public Land, Washington, DC.

Lewis, D., and A.J. Plantinga. 2001. Public Conservation Land and Economic Growth in the Northern Forest Region. Misc. Publication 748. Maine Agricultural and Forest Experiment Station, Orono, ME.

Loomis, J.B., and R. Richardson. 2000. Economic Values of Protecting Roadless Areas in the United States. Washington, DC: The Wilderness Society, June, 34 pp.

Loomis, J.B., and R. Richardson. 2001. Economic values of the U.S. Wilderness System: Research evidence to date and questions for the future. International Journal of Wilderness 7(1): 31-34.

Phillips, S. 2004. Windfalls for Wilderness: Land Protection and Land Value in the Green Mountains. Ph.D. Dissertation. Virginia Polytechnic Institute and State University, Blacksburg, VA.

Power, T.M. 1996. Lost Landscapes and Failed Economies: The Search for a Value of Place. Island Press, Covelo, CA.

Rasker, R. 1994. A new look at old vistas: The economic role of environmental quality in western public lands. University of Colorado Law Review 65: 369-99.

Rudzitis, G., and H. Johansen. 1991. How important is wilderness? Results from a United States survey. Environmental Management 15(2): 227-233.

Sedell, J., et al. 2000. Water and the Forest Service. FS-660. USDA Forest Service, Washington, DC.

Tibbetts, J. 1998. Open Space Conservation: Investing in Your Community's Economic Health. Lincoln Institute of Land Policy, Cambridge, MA.

Walls, J. 1999. Carbon sequestration: Making sustainable forestry pay. Practitioner: Newsletter of the National Network of Forest Practitioners 13: 6-7.

Trees of Mystery

Closing Remarks by Sy Montgomery

It's an incomparable honor to speak before experts on our most ancient and mysterious and complete forests. I don't have your scientific expertise. I don't have your management know-how. What can I offer? I am a writer, so I can tell stories—stories of people around the world who understand, in a deep and old way, the importance of what you are doing.

All you have to do is stand in the presence of Tane Mahuta to understand. Tana Mahuta is a kauri tree, 2,100 years old. He stands 169 feet tall, and measures 45 feet around. He might live to 4,000. When I visited this astonishing being, the remnant of a tremendous, subtropical forest that once covered 4 million acres of New Zealand, I understand why the Maori people call him Lord Forest.

Early Europeans likened the ancient kauri forests to cathedrals. The Maori knew they were more than a man-made place to worship our puny conception of God. They understand that even an individual tree could BE God.

And they knew that the ancient trees and the creatures who lived among them were intricately connected.

I saw this clearly in the heart of the Peruvian Amazon. Seven years ago, I found myself hanging seven stories up a machimango tree, suspended by a rope over black waters where people were fishing for piranhas.

My climb, at first, was a means to an end: I had hoped by scaling the tree's heights I would attain a vantage point to let me better observe, in the dark water below, the strange, pink river-dwelling whales who were the subject of my book Journey of the Pink Dolphins. I was journeying into a leafy world of tyrants and lovers and hunters, a vegetative world of epic struggles and passions.

The machimango was a mecca for other lives. Centipedes, snails, wasp nests, epiphytes. But the tree itself was also vibrantly alive. Its every movement, over many decades, was recorded in the architecture of its woody flesh. Up that tree, searching for dolphins, I could see what you well know: that plants are capable of a breathtaking range of sophisticated behaviors: moving, hunting, courting lovers, signaling their fellows and even waging war.

Many of us are blind to this here in the West, in the 21st century. Plants are just what some animals eat. Forests are scenery, or "buildable land," or board feet of lumber, or "resources" to be "developed." But our ancestors knew that trees are creatures of mystery. Trees are capable of bestowing wonders. Forests are holy places. And the people who live close to the earth still remember.

My guides in the Amazon were happy to show me some of the wonders that trees give us. Food, drugs, even light in the darkness. But trees are more than mere resources. Many Amazonians accord to each tree a sort of personhood. "Person," as my pastor once explained, is a word that derives from the word Persona, which means "mask." Each person, made in God's image, was like one of the masks God wears in this world. Seen in this way, people, animals, fish, insects, and trees are all "masks" or "faces" of the holy and mysterious Creator.

In fact, a tree may have been one of the Creator's first masks. At least that's what the stories say. One of the central myths of Amazonian people, and of people around the globe, is the story of the World Tree. Many river cultures say the first living thing was the World Tree. The Shibibo say the World Tree was full of the water that gave birth to the Amazon itself, and its fishes, animals and people.

Reverence for trees is not, of course, confined to Amazon or jungle cultures. Old German laws imposed ferocious penalties for peeling the bark of standing trees (the culprit's navel was cut out and nailed to the part of the injured tree and his guts wound like a bandage around the missing bark.) Pre-Christian Slavs worshipped trees and groves, as did the oak-loving Druids. The sacred fig tree was worshipped in ancient Rome. In North America, the Hidatsa Indians so respected even the shade cast by the cottonwood that, if properly approached, the shadow of the cottonwood would reveal secrets to the seeker.

And this, trees still do.

On the southwest lawn of Cambodia's ancient Angkor Wat, the largest religious edifice in the world, stands a huge tree, its trunk 30 feet around. It bears the heart-shaped leaves of the Bo, the species of ficus beneath which the Buddha attained enlightenment.

I had come here while researching Search for the Golden Moon Bear: Science and Adventure in Pursuit of a New Species. But I was no longer looking for bears. On this, my fourth expedition, I was searching for hope. I found it in this tree.

Buddhism affirms that trees bestow blessings beyond material use. Trees, say Buddhist legend, give birth to angels: the Kontans are mystical singers and musicians born from sweet-smelling trees. The nearest of the Buddhist heavens is Daovaduengsa, where divine trees, the Parichart, bloom with flowers so fragrant that those who smell them can recall former lives. Trees help us to remember who we are.

The giant ficus on Angkor Wat's lawn does not attract anywhere near the attention given its man-made, limestone neighbor. But like the machimango in the Amazon, the ficus is a hub of life. Large red ants course along scent trails. Four, foot-tall brown termite nests stand like sentinels at its base. Birds twitter hidden among the spreading branches.

At the tree's base, someone has erected two crude shrines. In Southeast Asia, the old animist beliefs coexist graciously alongside Buddhism, and the spirits of trees are often venerated. Throughout my travels in Cambodia, Thailand and Laos, even on the streets of the national capitols, I would often see trees beneath which people had made offerings of incense, flowers, fruit, milk.

Beneath the Bo at Angkor Wat, both the shrines were made from tins for cooking oil. Each shrine sheltered a single brick, a tiny altar in front of which people make offerings to the spirit of the tree. Someone had burned incense there that morning.

My companion, Dianne Taylor-Snow, asked aloud, "I wonder who is the spirit that lives here?" And then, like an answer, came a rare breeze, stirring the heart shaped leaves of the ancient creature. "It's talking to you," Dianne said.

In every forest, if we pause and listen, we are blessed with the chance to hear that whispered answer. You can hear it. Bless you for your work, and thank you.

Poster Abstracts

TITLE: Twelve years of liana dynamics in an old-growth southeastern floodplain forest.

AUTHORS: Allen[1], Bruce P., Charles Goebel[2], and Rebecca R. Sharitz[3]
AFFILIATION: [1]Department of Natural Resources, The Ohio State University, Columbus, OH 43021 allen.851@osu.edu, [2]School of Natural Resources, Ohio Agricultural Research and Development Center, The Ohio State University, Wooster, OH 43210, [3]University of Georgia's Savannah River Ecology Laboratory, Drawer E, Aiken, South Carolina 29802

ABSTRACT: During the twelve years since Hurricane Hugo devastated portions of the old-growth floodplain forest of the Congaree National Park, liana communities have responded to the changes in forest structure. Liana populations were studied across hydrologic and disturbance gradients in ten 1-ha plots established during the winter and spring 1989-90, re-sampled in 1994, 1998, and 2002. In heavily damaged areas, liana density initially decreased dramatically when the host tree was severely damaged but exceeded pre-hurricane density within twelve years. Stem densities of *Rhus radicans* decreased by 55% initially in heavily damaged bottomland hardwood forests. In less disturbed bottomland hardwood forests, vine communities have steadily increased in density in the twelve years since the hurricane. Lianas appear to have a higher stem mortality rates than trees or shrubs in the Congaree floodplain. Liana diameter growth rates continue to reflect size- and species-specific differences, as well as colonization patterns and post-hurricane host damage.

Bruce P. Allen is a PhD student in wetland forest ecology at the Ohio State University, **P. Charles Goebel** is an assistant professor in forest ecosystem restoration and ecology at the Ohio State University, **Rebecca R. Sharitz** is a professor of botany at the University of Georgia and a senior ecologist with the Savannah River Ecology Laboratory.

TITLE: Remote Detection of Forest Structure and Land-Use Legacies in the White Mountains of New Hampshire.

AUTHOR: Anderson, Jeanne.
AFFILIATION: Complex Systems Research Center, University of New Hampshire, Durham New Hampshire, 03824.

ABSTRACT: The spatial patterning of forest structure often reflects complex environmental and historical controls (Foster et al. 2003). Yet, the knowledge base regarding the impacts of historical legacies on forest structure and biological diversity is highly variable. In recent decades, three-dimensional structural data, from either field or remote methods, have been infrequently measured (Lefsky et al. 2002). Lidar sensors, however, provide an option for the rapid collection of data at a scale sufficient to describe structural metrics for thousands of acres at a time. They are also capable of revealing historical legacies remotely (Dubayah et al. 2000). This study assesses the accuracy of lidar-derived canopy heights in a northern temperate forest by comparing heights obtained from a wide-footprint lidar to ground-based measurements. It also investigates the geospatial patterning of tree height across a gradient of varying land-use and natural disturbance histories in the Bartlett Experimental Forest in Bartlett, New Hampshire.

TITLE: Dynamics of mid-tolerant hardwoods in an old growth reserve: The College Woods, Durham, New Hampshire

AUTHORS: Asahina, Haruka; Thomas Lee, and Robert T. Eckert.
AFFILIATION: University of New Hampshire, Department of Natural Resources, Durham, New Hampshire, 03824

ABSTRACT: Our goal was to examine the relationship between the dynamics of mid-tolerant hardwoods and disturbance history in an old Transition Hardwood-White Pine-Hemlock forest in New Hampshire. The size structures and the relative abundances of tree species, and the ages of the mid-tolerant hardwoods, red oak (*Quercus rubra*), black oak (*Q. velutina*), black birch (*Betula lenta*), and red maple (*Acer rubrum*) were studied in the 26 ha College Woods Natural Area (CWNA), Durham, NH. The CWNA contains white pine > 300 years in age and hemlocks > 200 years. All trees > 2 cm DBH were tallied and their DBH measured in 117 randomly located, 200 m^2, circular plots. Increment cores were collected from randomly selected trees and dendrochronological techniques were used to estimate establishment year and radial growth rate of each tree. Historical data on human and natural disturbances were also collected.

Eastern hemlock (*Tsuga canadensis*) was the most abundant tree in all size classes and, along with American beech (*Fagus grandifolia*) showed a size structure typical of growing or stable populations. White pine (*Pinus strobus*) occurred as scattered large, emergent individuals, while red maple, red oak, black oak, and black birch showed unimodal size structures (with little or no regeneration) typical of declining populations.

Dendrochronology showed that there was continuous recruitment of the four mid-tolerant hardwood species from 1896-1960, probably as a response to canopy opening by logging from 1896 to 1919 and by major hurricanes in 1938 and 1954. The relationship between these disturbances and tree species was supported by the age structure, spatial distribution of tree ages, and historical records. After 1960, there was no tree recruitment perhaps due to a lack of new canopy openings.

In the absence of disturbance, the future composition of CWNA would be dominated by American beech and eastern hemlock. Tree death caused by beech bark disease and other minor disturbances may allow some black birch, red maple, and perhaps red oak to persist on the site. Black oak will decline and may be lost from the site. The persistence of mid-tolerant hardwoods in CWNA will depend on future disturbance regimes and the size of the seed source within the reserve as well as in adjacent stands.

TITLE: Conservation of Biodiversity in the East: The Role of Early Successional and Mature Forests

AUTHOR: Cynthia Fleming
AFFILIATION: Eastern Regional Ecologist, The Wilderness Society
cynthia_fleming@tws.org

ABSTRACT: Throughout the East, the conservation of biodiversity and the maintenance of healthy ecosystems depends to a significant degree on management for two very different types of habitat — early and late successional forests. Both are of conservation interest because both are important to biodiversity, including the fate of rare and declining species, and data show that wildlife species associated with both types of habitat are in decline in the East.

Changes in habitat and species composition across the eastern states pose a dilemma for land managers concerning whether both types of habitat can be maintained in a manner that sustains healthy ecosystems and viable populations of associated species.

This Science & Policy Brief poster describes the historical context and current status of both early and late successional forest habitats. It also discusses the challenges inherent in managing for species that depend on these two habitat types and recommends actions that should be considered at regional and local scales. To address these issues and help achieve the goal of conserving biodiversity in the East, The Wilderness Society recommends the following:

- Manage public forest lands administered by the federal government for values and resources that are not ordinarily available or protected on private lands.
- Identify lightly roaded or mostly intact mature forest areas and protect them from logging and road construction.
- Position managed habitats close to existing early successional land uses to lessen the impacts of fragmentation across the landscape.
- Use the natural disturbance regimes as models in managing forests for biological diversity.
- Focus on the protection of existing stable shrublands and permit natural disturbance events where possible.
- Manage for early successional habitat on public forest lands in a way that does not jeopardize the integrity of large, intact, mature forest areas.

ADDITIONAL INFORMATION: Spencer Phillips, a resource economist with The Wilderness Society, will present the poster.

TITLE: The Maryland Old Growth Forest Inventory

AUTHOR: Harry A. Kahler
AFFILIATION: Natural Heritage Program, Maryland Department of Natural Resources, Savage River Complex, 108 Headquarters Lane, Grantsville, MD 21536

ABSTRACT: Eastern old growth forests provide unique, high-quality habitats for a number of wildlife species due to the increased presence of large live trees and snags, cavities, complex vertical structure, and coarse woody debris in these systems. To locate and characterize the remnant old growth forests of Maryland, the Natural Heritage Program of the Maryland Department of Natural Resources (DNR) began a statewide inventory of old growth forests in January 2003. Criteria to define old growth forests were developed by an interdisciplinary

committee of DNR staff and outside experts. A list of potential old growth areas was identified through the use of old aerial photographs, satellite data, timber harvest records, and information from forest experts, DNR staff, and the public. Data were then collected at these sites to address age and structural criteria that comprise the definition of old growth developed by the committee. Data collected include tree age and condition, structural complexity, species composition, presence of canopy gaps and pit and mound topography, index of coarse woody debris, evidence of disturbance, and approximate size of stand. Potential sites were reviewed by the committee and evaluated on the basis of the old growth criteria. Last year, more than 100 sites were evaluated throughout Maryland, with a focus on state lands. In western Maryland alone (Garrett and Allegany Counties), 24 stands totaling over 340 ha were found to meet the old growth forest definition. Oldest tree age estimates varied from 200 to 475 years, and stand sizes varied from 2 to 90 ha on these oak-dominated forest remnants. Although work continues to focus on state forestlands, reviews have begun statewide on significant private lands as well. When inventorying is complete, these forest fragments of old growth will be evaluated at multiple scales to assess best management strategies and policies for their conservation.

TITLE: Changes in the composition and structure of an old-growth white oak forest in northeastern Ohio

AUTHORS: [1]David M. Hix, [2]P. Charles Goebel, and [2]Clayton E. Dygert
AFFILIATION: [1]School of Natural Resources, The Ohio State University, Columbus, OH 43210, [2]School of Natural Resources, OARDC, The Ohio State University, Wooster, OH 44691

TITLE: Johnson Woods State Nature Preserve is one of Ohio’s largest and least-disturbed old-growth forests (62.7 ha). This remnant (once known as Graber Woods) was cited by E.L. Braun in her classic text as an example of a white oak-dominated forest located on morainal swells developing toward the beech-maple type. According to the pre-European settlement surveys this area of Ohio was dominated by white oak (*Quercus alba* L.) and American beech (*Fagus grandifolia* Ehrh.). Dendroecological analyses have indicated that some of the largest white oak are over 400 years old, and have experienced episodes of release from suppression. Over the past several years we have investigated several aspects of the ecology and history of this forest, including a study of recent canopy gaps that revealed an important portion (17.7%) of this old-growth forest was in gaps, most of which were large in area (100-400 m2). Other recent studies have described both the spring ephemeral and summer ground-flora communities associated with floodplains along a small headwater stream flowing through the forest. In this study, we sampled a network of variable-radius plots to determine the composition and structure of the current forest. The diameter distribution is indicative of a multi-cohort forest. All layers of the woody vegetation (tree, sapling, seedling, standing dead, and downed woody debris) indicate a shift in species dominance. Although white oak remains an important canopy species, sugar maple (*Acer saccharum* Marsh.) and American beech have increased in importance over the past 70 years (based upon a comparison with Braun’s observations). Similarly, although white oak seedlings are common in the ground flora layer, white oak was entirely absent in the sapling layer. Based on a comparison of these results with the earlier surveys, it appears that Johnson Woods is following Braun’s predicted successional trajectory towards a mesophytic or beech-maple forest type.

ADDITIONAL INFORMATION: P. Charles Goebel, Ph.D., Forest Ecosystem Restoration & Ecology, School of Natural Resources, OARDC, The Ohio State University, 1680 Madison Avenue, Wooster, OH 44691-4096

TITLE: Structure and composition of old-growth forests in the Cold River Gorge of Northwestern Massachusetts

AUTHORS: [1]Anthony W. D'Amato and [2]David A. Orwig
AFFILIATION: [1]Department of Natural Resources Conservation, University of Massachusetts, Amherst, MA 01003, [2]Harvard University, Harvard Forest, Petersham, MA 01366

ABSTRACT: The forest composition and structure of six recently discovered old-growth stands within the Cold River Gorge in western Massachusetts were analyzed. This region contains some of the few remaining old-growth forests in Massachusetts as well as some of the oldest documented trees in the state. All sites were characterized by extremely steep slopes (mean = 81.3 %) and ranged in elevation from 330 to 480 m.a.s.l. Stands were located on northern or northwestern slopes and ranged in composition from mixed *Tsuga canadensis/Picea rubens* forests to northern hardwood forests containing mixtures of *Acer saccharum, Fagus grandifolia*, and *Betula alleghaniensis*. All sites were characterized by uneven-aged forests with a range of tree sizes and ages. In addition, the forests contained sapling thickets of *Acer pensylvanicum*, *Tsuga canadensis*, *Fagus grandifolia*, and *Kalmia latifolia* in areas with a recent history of canopy disturbance. Extensive dendroecological analyses of these sites revealed *T. canadensis* ranging from 36.4 to 54.7 cm dbh to be between 289 and 487 years old, while *F. grandifolia* trees were between 150 and 225 years old and *Betula lenta* were up to 328 years old. Discrepancies in the distribution of age classes between plots, stands, and topographic positions suggest that the disturbance history of these sites has been dominated by small-scale disturbances such as windthrow and may indicate a differential susceptibility to disturbance based on forest composition as well as topographic and physiographic setting.

Anthony D'Amato is a Ph.D. student at the University of Massachusetts, Amherst, MA
David A. Orwig is a forest ecologist with the Harvard Forest in Petersham, MA.

ADDITIONAL INFORMATION: David A. Orwig, Ph.D., Forest Ecologist, Harvard University 978-724-3302 ext.250, Harvard Forest Web, P.O. Box 68 Petersham, MA 01366