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MP753: The Role of Interfering Plants in Regenerating Hardwood Stands of Northeastern North America

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An Annotated Bibliography for American Beech (*Fagus grandifolia* Ehrh.), Striped Maple (*Acer pensylvanicum* L.), Hobblebush (*Viburnum alnifolium* Marsh.), Hayscented Fern (*Dennstaedtia punctilobula* L.), New York Fern (*Thelypteris noveborecensis* L.), Bracken Fern (*Pteridium aquilinum* (L.) Kuhn), Raspberries (*Rubus* spp.), and Pin Cherry (*Prunus pensylvanica* L.f.)

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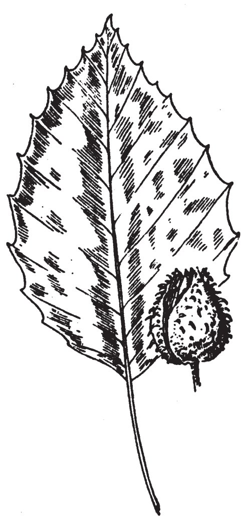

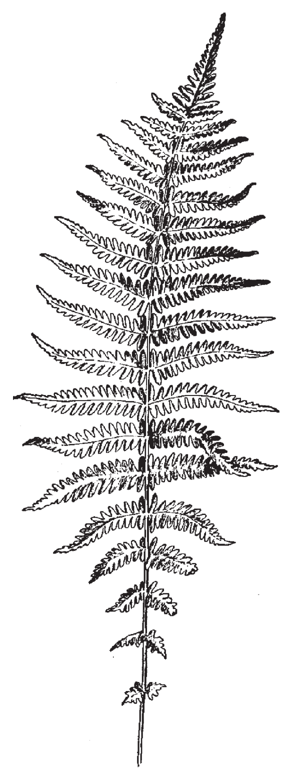

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MAINE AGRICULTURAL AND FOREST EXPERIMENT STATION
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Contents

INTRODUCTION

Past research and management experience in northern hardwood forests indicate that species like American beech, striped maple, hobblebush, hayscented fern, New York fern, bracken fern, raspberries, and pin cherry may interfere with regeneration of desirable tree species. This interference often involves inter-specific competition, reducing essential resources shared by two or more species. Problems commonly relate to the rapid growth, tall stature, and/or persistence of these interfering plants. When at a high density, they cast such a heavy shade that smaller seedlings of other species may fail, and advance regeneration may die or not develop.

A dense beech understory often reflects a complex of factors. Yet the balance between them may differ from one locality to another. Commonly, the lasting effects of beech bark disease have caused a decline and death of overstory beech, apparently leading to an increase of root suckers around the infected trees. So even though seed production may also decrease, vegetative reproduction by root suckering and stump sprouting maintain or increase the population of small understory beech. Additionally, ungulates largely avoid beech as a source of browse. So in areas of high ungulate density, prolonged and intensive browsing commonly fosters the development of a beech understory and oppresses more palatable species among the advance regeneration. The compounding effects of these two factors, alone, have led to a build-up of small beech beneath many hardwood stands. Then any overstory cutting simply promotes development of the overtopped beech, increasing ground-level shading, and causing a stand conversion by the domination of beech.

Similarly, the presence of understory striped maple seedlings and saplings often forebodes important interference following overstory cutting. Striped maple persists in many stands as widely-spaced small seedlings. And due to their high shade tolerance, these remain alive for many years in an evenly heavily-shaded understory. The small trees grow rapidly following release, and soon begin producing abundant seed. A wide dispersal adds new seedlings that also grow rapidly and produce additional seed. As a result, a scattered population of striped maple may become reinforced. And by their rapid development, the seedlings soon overtop other species and oppress the development of more desired ones.

Hobblebush is commonly present in the understory of northern hardwoods on moist sites, though it is not widely recognized as an interfering plant. Hobblebush reproduces vegetatively by rhizomes that develop into thick pockets of new plants when harvesting operations disturb the forest floor, injure hobblebush stems, and reduce understory shading. Though their spatial distribution is often limited, these dense areas of hobblebush shade the ground beneath and may prevent successful regeneration of trees.

The extremely dense shade cast by spreading ferns, particularly hayscented and bracken ferns, interferes with the survival and development of tree seedlings in some northern hardwood forests. Excessive frond litter and root mats can also prevent adequate root development, reduce light quality, alter soil chemistry, and prevent seed from reaching a suitable rooting medium. Increased understory light levels after an overstory disturbance, abundant soil moisture, fire, and herbivory all promote fern proliferation, while excessive and repeated cold or drought deter fern development and propagation.

Dense raspberries commonly develop beneath hardwood stands reduced to <60–65 ft^2/ac basal area. Seedlings emerge from seeds that remained dormant in the litter for even several decades. Roots of these scattered new raspberry plants expand, and new suckers arise from them. By about the third year, raspberries will have formed an almost complete cover across a site, except where logging removed the litter layer along skid trails. Yet even where it becomes dense, raspberries do not normally prevent emergence of a new hardwood cohort, particularly at sites having abundant and well-distributed advance regeneration and/or a well-distributed component of mid-tolerant or shade-intolerant tree species. These grow through the raspberries by 5–7 yrs after overstory cutting, and the shade-intolerant raspberries decline thereafter. They may linger for a longer time at sites lacking fast-growing tree species or that had little well-developed advance regeneration, in imperfectly-drained soil, in some mid-western parts of the range of northern hardwoods, and among spruce-fir-hardwood forests.

Pin cherry may regenerate in abundance following shelterwood seed cutting or clearcutting, or may be absent or limited among the new cohort. Managers cannot predict its occurrence in advance of overstory cutting. Pin cherry seeds remain viable in the forest floor for at least 4–5 decades, and germinate when heavy overstory cutting heats the litter layer, promoting decomposition that releases nitrogen. Yet while pin cherry seedlings may not become obvious for up to 3 yrs following overstory disturbance, the new trees quickly grow taller than most other species. Research in New York indicated that a pin cherry density of 3,000/ac or more results in reduced stocking of other species. In Pennsylvania, even 1,500/ac interfered with seedling-origin regeneration of other species, and 3,000/ac or more inhibited development of sprout-origin trees.

This Annotated Bibliography

While accessible literature includes many references to these species, the information remains scattered. No one has previously consolidated the separate reports for easy reference, nor summarized the findings relative to interference with tree regeneration. This annotated bibliography serves that purpose. It was commissioned and funded by the Cooperative Forestry Research Unit (CFRU) at the University of Maine, whose members identified interference to regeneration as a key issue for managers who needed to regenerate northern hardwood species. We acknowledge their support.

This document provides an extra level of detail than one would find in a standard review of literature. Yet we abstracted the papers only for information dealing with their role in interfering with regeneration of desirable hardwood trees. The source publications may cover other topics not pertinent to interference of hardwood regeneration, and we excluded that information. Ultimately, the resulting document served as the foundation for five reviews of literature that summarize our findings. They will be published in an applied forestry journal appropriate to northeastern North America.

We included published papers, conference and workshop proceedings, and other documents reporting the results of past research and management trials. The compiled abstracts emphasize the nature of interference by the target species, and review management strategies for reducing the negative effects on regeneration of high-value hardwoods. To facilitate access to the many abstracted papers and reports included here, we organized them by subject as shown in the Table of Contents.

To identify the sources, we used several keywords to comprehensively search available electronic databases. These included

Keywords (used alone and in combination with one another)

American beech, striped maple, hobblebush, ferns, hayscented fern, New York fern, bracken fern, raspberries, pin cherry (and their corresponding scientific names), stump sprout, root sucker, stool shoot, root sprout, beech bark disease, northern hardwood forest, hardwood regeneration, advance regeneration, natural regeneration, stand development, shade tolerance, interfering understory trees, woody plant competition, understory beech, herbicide, cleaning practices, site preparation, canopy gap, gap species, suppression, release, plant strategies, reciprocal replacement

Databases

Agricola, Article First, CABDirect, Dissertation Abstracts Online, WorldCat, Proceedings First, Google Advanced Search

To assure thorough coverage of these general topics, we circulated a list of the bibliographic citations to several individuals who have worked in hardwood silviculture and related disciplines. We acknowledge suggestions by:

- Stephen Horsley, William Leak, Walter Shortle, David Houston (retired), and Phillip Wargo (retired) of the U.S. Forest Service
- James C. Finley of Pennsylvania State University; Dudley Raynal and Paul Manion of SUNY College of Environmental Science and Forestry; Marianne Krasny of Cornell University; and Peter Hannah (retired) of the University of Vermont

For consistency and precision in the language of our abstracts, we added some footnotes to define a term, based upon the Society of American Foresters' The Dictionary of Forestry (Helms 1998), or after a definition given by the author. Where appropriate, we took the liberty to substitute a more universal term. In addition, we noted other sources related to the one abstracted. Also, some abstracts have references to herbicides no longer registered for forestry application. We included those papers for historical information and to document the effects.

PART I: AMERICAN BEECH, STRIPED MAPLE, AND HOBBLEBUSH

A. Factors Leading to Interference by Woody Understory Plants

1. Species proliferation, site characteristics, and/or site and stand disturbance

1. **Bigelow, S.W., and C.D. Canham.** 2002. Community organization of tree species along soil gradients in a northeastern USA forest. Journal of Ecology 90:188–200.

Beech saplings in low light grew faster on high-Ca^{2+} than on low-Ca^{2+} soils, supporting the idea that fertility can affect shade tolerance. Beech trees present at the sites were predominantly of root sucker origin, and remained connected to neighboring trees. Positive effects of calcium availability on shade tolerance may result from increased photosynthate produced and transferred through connected root systems.

2. **Canham, C.D.** 1988. Growth and canopy architecture of shade-tolerant trees: Response to canopy gaps. Ecology 69(3):786–795.

Aboveground growth of beech was significantly greater in gaps (low light levels with mean light intensity ~ 2.9%) than under a closed canopy, regardless of origin (seedling or root sucker). Sugar maple seedling growth was not correlated with gap light levels. However, beech growth over prolonged periods beneath a closed canopy was greater than adjacent sugar maple saplings. Beech abundance may increase under conditions of little canopy disturbance, while sugar maple abundance may increase following gap formation. Nonetheless, both species may develop in small gaps (15–75 m^2) after only small increases in light, due to their shade tolerance and growth responses.

3. **Canham, C.D.** 1989. Different responses to gaps among shade-tolerant tree species. Ecology 70(3):548–550.

An increase of light by 1–2% of full sunlight will trigger a growth response among understory saplings of beech and sugar maple. Beneath a closed canopy, beech shows higher growth rates than sugar maple. Under small gaps, sugar maple growth rates are twice that of beech. Survival of these species may depend more on the frequency of overstory disturbance and the length of periods of release and suppression than on gap size or light levels, per se.

4. **Canham, C.D.** 1990. Suppression and release during canopy recruitment in *Fagus grandifolia.* Bulletin of the Torrey Botanical Club 117(1):1–7.

The study compared growth responses of beech and sugar maple after periods of suppression and release. Both species responded to even small gaps with significant height growth, but growth was not correlated with elevated light levels beneath large gaps. Beech saplings showed higher growth rates than sugar maple beneath a closed canopy, suggesting a lower threshold of light required for release. This may indicate that species with modest responses after overstory gap creation, such as beech, are not affected as much by longer periods of suppression as are species with stronger responses.

5. **Eyre, F.H., and W.M. Zillgitt.** 1953. Partial cuttings in northern hardwoods of the Lake States: Twenty year experimental results. USDA Forest Service Technical Bulletin 1076.

Beech is very shade-tolerant, perhaps more so than sugar maple, but not as long-lived and of smaller stature. In stands of the Lake States, beech will sprout vigorously from small stumps, but those sprouts will not mature. Beech also produces root suckers.

6. **Forcier, L.K.** 1975. Reproductive strategies and the co-occurrence of climax tree species. Science 189:808–809.

Beech, sugar maple, and yellow birch trees <2.0 cm dbh were tallied to describe how these species contribute to ecosystem stability. Beech seedling populations exhibited the most stable behavior, a result of this species' high survival rate under a closed canopy. Maple's occurrence in the canopy was associated with beech seedlings and saplings, but poorly associated with maple regeneration. Beech and yellow birch overstories were not associated with seedlings of those species. Beech root suckers were strongly associated with a beech overstory. Root suckers may not develop into mature canopy trees, but they may delay the site occupation by yellow birch and sugar maple, and lead to increased beech importance through time.

7. **Gabriel, W.J., and R.S. Walters.** 1990. *Acer pensylvanicum* L. Striped maple. P. 53–59, in Silvics of North America. Volume 2, Hardwoods. Burns, R.M., and B.H. Honkala (Eds.). USDA Forest Service Agriculture Handbook 654.

Striped maple is a small tree or large shrub growing under small gaps and in the understory of northern hardwood forests. It is commonly found in well-drained sandy loams on northern slopes of upland valleys. Common associates include American beech, sugar maple, yellow birch, and hobblebush. Growth and development of this very shade-tolerant understory tree is slow beneath a closed canopy, but trees as old as 40 yr show substantial height growth upon release.

A maximum height of 15 m limits striped maple to the lower canopy, where it often occupies openings for more than 100 yr.

Seeds ripen in September and October and disseminate in late fall. Quantities range from 13.75 seeds/mi^2 to 1.25 seeds/mi^2, decreasing with distance from a parent tree[1]. Seeds buried in mineral soil or humus will germinate during the first year, but those under the current year's leaf litter will not germinate until the second year. Removing two-thirds of stand basal area reduced the delay of seed germination, and clearcutting eliminated it altogether. Even so, total germination dropped sharply with complete overstory removal. Striped maple will reproduce vegetatively by layering or basal sprouting.

[1]Parent tree is widely used to refer to one whose root system supports root suckers. The correct term is ortet, with root suckers being ramets of that tree.

8. **Gill, D.S., J.S. Amthor, and F.H. Bormann.** 1998. Leaf phenology, photosynthesis, and the persistence of saplings and shrubs in a mature northern hardwood forest. Tree Physiology 18(5):281–289.

Leaf phonologies of saplings and overstory trees of beech and hobblebush were quantified in a 72-yr-old northern hardwood forest at the Hubbard Brook Experimental Forest in the White Mountains of New Hampshire. Leaf expansion occurred earlier in understory beech than among overstory trees (beginning May 16, reaching full expansion by June 1, and retaining full leaf until Sept 11). Overstory yellow birch and white ash leaf expansion occurred significantly later than beech (reaching full expansion on June 30), and these species retained leaves for a shorter period (senescence by early Sept). Hobblebush leaves expanded earlier than both understory and overstory beech (beginning May 10, reaching full expansion by June 8, and retaining full leaf until Sept 11). A slower rate of leaf expansion caused hobblebush to reach full leaf size one week later than beech. Overall, understory plants reached full leaf expansion earlier and remained in leaf later than the overstory, possibly due to a vertical temperature gradient from the forest floor to the canopy top.

Survival by understory stems may be related to carbon gain when the overstory is not fully closed, especially during the spring light phase. Thus, leaf phenology of understory saplings may be important to shade tolerance.

9. **Gould, W.P.** 1966. The Ecology of *Viburnum alnifolium* Marsh. PhD. thesis. SUNY College of Forestry at Syracuse University. Syracuse, NY.

Hobblebush has shallow roots, mostly limited to the organic layers. The shrub occurs commonly underneath well-stocked forests at moist, well-drained sites, and throughout mesic forests of eastern North America. Dense thickets may interfere with regeneration of desirable tree species. Leaves open early in the growing season, and bushes in medium shade have larger leaves than ones under heavy shade. Hobblebush begins fruiting at an early age, but produces little fruit in deep shade. Seeds do not germinate readily, so seedling regeneration is uncommon. By contrast, hobblebush reproduces readily by layering and sprouting, and probably regenerates primarily by vegetative means. Mowing will induce sprouting, particularly from stems cut close to the ground. Layering occurs commonly in logged areas, where stems bent to the ground readily develop roots. These grow rapidly after overstory cutting. Deer browse heavily on hobblebush, and particularly in winter. The reduced humus and moisture of upper soil layers made for a poor environment to sustain hobblebush in large clearcuts and clearcut patches. Selection cutting stimulated hobblebush, but stem numbers declined by about 15 yrs.

10. **Hamilton, L.S.** 1955. Silvicultural characteristics of American beech. USDA Forest Service Northeastern Forest Experiment Station, Beech Utilization Series Number 13.[1]

Sapling beech can withstand long periods of oppression and grow normally when light is admitted. Root suckers can remain attached to the parent[2] root system for photosynthate, and may not be truly suppressed. However, they become flat topped and develop crooked stems after release.

Beech has a dense network of branched roots that occupy the humus, with deep feeding roots in the mineral soil. Root grafting is common. Roots develop suckers most frequently after injury, but suckers also form where no apparent disturbance has occurred. Suckers are often deformed and infected by rot from the old root system, and rarely attain merchantable size. Root suckering occurs when harvesting leaves residual beech, increases understory light, and injures the roots. When dense, root suckers inhibit the growth of more valuable species. Beech stumps produce sprouts, but the capacity apparently diminishes after trees reach >4 in. dbh. Stump sprouts are seldom a reliable source of regeneration.

Even-aged silviculture allows the greatest discrimination against beech. Unmerchantable beech must be killed and root suckering prevented. Desirable advance regeneration must be present prior to overstory removal.

[1] See also: Rushmore, F.M. 1961. Silvical characteristics of beech (*Fagus grandifolia*). USDA Forest Service Northeastern Forest Experiment Station, Station Paper NE-161.

[2]Parent tree is widely used to refer to one whose root system supports root suckers. The correct term is ortet, with root suckers being ramets of that tree.

11. **Hane, E.N.** 2003. Indirect effects of beech bark disease on sugar maple seedling survival. Canadian Journal of Forest Research 33:807–813.

Beech seedlings and saplings (<10 cm dbh) were cut down and resprouts recut as necessary to test for the competitive effects of light on sugar maple regeneration and seedling survival. Shading was further tested by the addition of shade cloth to some cut plots. Results indicate that shade created by either beech saplings or shade cloth had a negative indirect effect on sugar maple seedlings. After six growing seasons 33% of maple seedlings remained in cut plots while uncut plots had only 1%. Plots with shade cloth added and beech removed had significantly higher survivorship (28%) than plots without treatment (15%). More sunlight reached the seedlings in the cut plots. Even so, the presence or absence of beech saplings rather than shading, per se, determined seedling mortality between July and September. This suggests that understory beech also affects below-ground processes, influencing maple survival. Current high densities of beech saplings in northeastern forests may determine the next few generations of trees.

12. **Hane, E.N., S.P. Hamburg, A.L. Barber, and J.A. Plaut.** 2003. Phytotoxicity of American beech leaf leachate to sugar maple seedlings in a greenhouse experiment. Canadian Journal of Forest Research 33:814–821.

In a controlled greenhouse experiment, applying leachate from sugar maple leaves for 12 wks to small seedlings of the same species had no effect on their development, chemistry, or physiology. Watering other sugar maple seedlings with a leaf leachate from American beech resulted in significantly lower leaf area, fewer nodes, lower biomass, higher carbon assimilation rates, and higher stomatal conductance. Secondary compounds in the leachate likely caused the effects. Field trials are needed to explore a possible allelopathic relationship between these species.

13. **Hannah, P.R.** 1999. Species composition and dynamics in two hardwood stands in Vermont: A disturbance history. Forest Ecology and Management 120:105–116.

The size of a disturbed area, the height of advance reproduction, and the amount of available growing space determine the composition and structure of future stands. With little disturbance, shade-tolerant northern hardwoods will dominate the main canopy. Partial cuttings have promoted growth of advance regeneration of beech and striped maple. Deer browsing may prevent establishment of desirable shade-tolerant species and delay main canopy species from entering the upper canopy stratum, even when abundant as advance regeneration. Instead, beech will become a dominant member of the main canopy, especially where disturbance creates only small gaps.

14. **Held, M.E.** 1983. Pattern of beech regeneration in the east-central United States. Bulletin of the Torrey Botanical Club 110:55–62.

Observations of environmental conditions related to reproductive patterns around mature beech were made over the species' east-central range. Root sucker occurrence increased from central (IN, KY) and southern (NC, TN) sites, to the northern sites (OH, WI). Among southern locations, root sucker density increased with elevation. Suckering was greater on west facing slopes with shallower soil and more exposed roots, but not limited to any one aspect. Observations along the geographic range of beech imply a shift from sexual to asexual reproduction in areas with the most severe environment. However, since microhabitat conditions also influence the mode of reproduction and abundance, either beech root suckers or seedlings may occur within any site across the range of beech.

15. **Hibbs, D.E.** 1978. The Life History and Strategy of Striped Maple (*Acer pensylvanicum* L.). PhD. Dissertation. University of Massachusetts. Amherst, MA.

Striped maple reproduces at an early age. A wide dispersal of seed in autumn and winter adequately establishes a scattered population of advance seedlings. Vegetative reproduction by layering or basal sprouting, respectively, are the primary means that small or large trees survive in an understory beneath a closed canopy crown. However, these modes are not important means of reproduction.

Striped maple is moderately shade-tolerant and may be shade-intolerant in extreme environmental conditions beneath openings greater than 0.1 ha. It responds rapidly after creation of canopy openings, and dominates those areas. Optimal striped maple growth occurs under intermediate light intensities (small openings, or under defoliated trees), particularly on cooler, higher, more northerly slopes and under mesic conditions. A greater number of suppressed plants were found on exposed sites, due to water shortages and/or effects of freezing, thawing, and desiccation on its thin bark. Sun-damaged leaves and multiple stems on open-grown striped maple suggest poor growth at high light intensities.

Striped maple can be oppressed up to 20 yr without dying, and seedlings up to 35 yrs old respond to release. Most advance regeneration responds to release after overstory cutting. Released plants grew at a minimum rate of 22.9 cm/yr. Unsuppressed plants grew at a rate of 27.2 cm/yr. Striped maple that became established after overstory cutting were usually suppressed. Suppression increases with decreasing light (related to higher residual basal areas, and greater lapse time since overstory cutting). Its maximum height of 15 m means that striped maple will eventually become overtopped. Growth rate is negatively correlated to crown closure, basal area, and organic horizon depth.

16. **Hibbs, D.E.** 1979. The age structure of a striped maple population. Canadian Journal of Forest Research 9:504–508.

Mortality of first-yr striped maple seedlings depended upon predation, condition of the seedbed, and genetic variation. It was rarely density dependent. After 2 yr, plant mortality decreased substantially, due to the species shade tolerance. Due to low light, mortality occurred at 16–40 yr. Beneath small gaps, striped maple survived beyond age 20 and density dependent mortality increased. Beyond 40 yr, mortality was low, at least until the overstory fully closed or a random event (e.g., windthrow) occurred.

17. **Hibbs, D.E., and B.C. Fischer.** 1979. Sexual and vegetative reproduction of striped maple (*Acer pensylvanicum* L.). Bulletin of the Torrey Botanical Club 106(3):222–227.

Seed of striped maple was concentrated in a 30-40 m radius around parent trees[1], but reportedly may disperse up to 60 m. Vegetative reproduction appeared important for increasing numbers of striped maple trees. Eight percent of the population consisted of basal sprouts formed on the lower 20 cm of the stem. Layering (where branches, stems or whole plants were bent to the ground and buried in litter) accounted for 3% of stems. No root suckers were identified. Though sparse, vegetative reproduction maintained understory striped maple populations under low light. Under those conditions, sexual reproduction and seed germination were limited. After canopy disturbance, advance stems grew rapidly.

[1]Parent tree is widely used to refer to one whose root system supports root suckers. The correct term is ortet, with root suckers being ramets of that tree.

18. **Hibbs, D.E., B.F. Wilson, and B.C. Fischer.** 1980. Habitat requirements and growth of striped maple (*Acer pensylvanicum* L.). Ecology 61(3):490–496.

Striped maple is found most often on mesic sites within the northern hardwood range. It reaches its highest densities below 750 m elevation, but tends to increase in density with altitude and on steeper slopes.

Suppressed striped maple trees in a community of beech and yellow birch grew at a rate of 22.9 cm/yr, not significantly different from ones never suppressed. After overstory cutting, growth of striped maple advance reproduction (up to age 35) increased with added understory light, but later declined when stand basal area reached 4.7 m^2/ha. Growth also decreased under densities greater than 9.2 m^2/ha, where the canopy closed and competing regeneration overtopped the striped maple. Both observations indicate that striped maple grows best under thin canopies and in small, temporary openings.

19. **Hough, A.F.** 1937. A study of natural tree reproduction in the beech-birch-maple-hemlock type. Journal of Forestry 35:376–378.

Beech reproduced by stump sprouting and root suckering following logging. By 5 yrs later, stems had not established root systems. The trees had died, possibly due to species characteristics, inadequate soil moisture, frost and winter injury, disease, or insect damage.

20. **Hough, A.F., and R.D. Forbes.** 1943. The ecology and silvics of forests in the high plateaus of Pennsylvania. Ecological Monographs 13:299–320.

Beech-maple and hemlock-beech forests are stable associations that resist disturbance by logging, fire, and destructive agents. Only after repeated burning or in frost pockets will these stands succeed to a new association of pioneer species.

21. **Hughes, J.W., and T.J. Fahey.** 1991. Colonization dynamics of herbs and shrubs in a disturbed northern hardwood forest. Journal of Ecology 79(3):605–616.

Hobblebush was among the most common shrubs established after whole-tree harvest of trees >2 cm, with minimal soil disturbance. Recruitment was strictly vegetative. Three yrs later, overall distribution of hobblebush was unaffected by overstory removal. Locations of almost all stems were associated with the presence of pre-disturbed individuals. Establishment of large numbers of stems after disturbance temporarily inhibited other species, but did not change the distributions that existed in the forest before disturbance.

22. **Jarvis, J.** 1956. An ecological approach to tolerant hardwood silviculture. Canadian Department of Northern Affairs and Natural Resources, Forestry Branch Technical Note 43.

Beech, a climax species, is seldom found in pure stands. It is most abundant and most vigorous on warm, dry slopes and ridges of the Great Lakes-St. Lawrence Forest Region. Beech is sensitive to extreme cold temperatures and reaches its northern limit farther south than sugar maple. In Ontario and Quebec it is ranked among the poorest of lumber-producing trees.

Though shade tolerant[1], it will not persist in the understory as long as sugar maple and becomes suppressed unless seedlings are released. Light overstory cuttings favor beech advance reproduction, which succeeds in openings created by logging. Girdling or poisoning mature beech (seed source) and cutting out younger trees during thinning operations could eliminate beech from a stand. Beech sprouts readily from stumps or girdled trees, but the sprouts lack vigor.

[1]References to shade tolerance contradict those as reported in citations #3, #4, and #38.

23. **Jones, R.H., and D.J. Raynal.** 1986. Spatial distribution and development of root sprouts in *Fagus grandifolia* (Fagaceae). American Journal of Botany 73(12):1723–1731.

Spatial distribution of root suckers was evaluated in 13 closed-canopy northern hardwood and hemlock-northern hardwood stands with no evidence of logging in recent years. Sucker[1] distance from the ortet (tree producing the suckers) did not differ significantly among any sprout age class (1 to 17 yr old). Ortet dbh and sucker abundance were significantly related, with greater suckering around larger trees. Fewer suckers were found around low-vigor trees, though vigor was not correlated with growth or spatial distribution of suckers. Also, root suckering was a function of superficial root density. The lack of root expansion and subsequent suckering may contribute more to beech persistence in one location than to lateral spread to adjacent areas.

Ninety-eight percent of suckers arose from roots within the surface organic horizons, at a mean depth of 2.91 cm above the mineral soil. A close association was found between sucker development and root injury, callus tissue formation, and adventitious bud development of superficial roots. Root injury was noted on most of the superficial roots inspected, but suckers also originated on roots with little to no damage. Control of root injury may help to limit beech proliferation by suckering.

[1]For consistency with other publications presented herein we used sucker in place of root sprout.

24. **Jones, R.H., and D.J. Raynal.** 1987. Root sprouting in American beech: Production, survival and the effect of parent tree vigor. Canadian Journal of Forest Research 17:539–544.

Root sukering[1] was observed on 31 mature beech trees (some healthy, and others infected by beech bark disease) within 13 closed-canopy stands. Total number of root suckers per clone was related to size of the ortet tree, in that larger trees produced more suckers on average. Production was highly variable and not coordinated with production in nearby ortets.

Sucker mortality (30%/yr) was concentrated in the 1- and 2-yr-old age classes, and was higher among individual stems than among sucker clumps. Even so, clumps have a more constant per capita mortality than single stems because individuals are buffered by higher numbers of stems in a sucker clump. Between ages 1 and 4, the proportion of dead and dying suckers declined. Proportions remained steady in all vigor classes beyond age 4, though at least one-half of the suckers had some dieback each year. Mean life expectancy of suckers was 8–9 yr. Ortet vigor had little effect on sucker production and survival, as long as the sucker-producing tree remained alive.

[1]For consistency with other publications presented herein we used sucker in place of root sprout.

25. **Jones, R.H., and D.J. Raynal.** 1988. Root sprouting in American beech (*Fagus grandifolia*):Effects of root injury, root exposure, and season. Forest Ecology and Management 25:79–90.

Root buds developed into suckers emanating off of callus tissue around a root wound. The buds expanded under low light and temperature regimes in the understory. Scraped roots had more callus than cut roots, and those had more callus than roots without injury. Suckers[1] were more numerous on scraped, exposed roots, but developed on all roots (including uninjured ones). Suckering declined with time due to mortality. Root exposure was significant in stimulating suckering, and shallow roots seem to produce more suckers. Roots treated in springtime had the highest suckering, callus formation, and bud development. When planning a harvesting operation, avoid springtime logging and take measures and minimize root damage.

[1]For consistency with other publications, we replaced the term root sprout with root sucker.

26. **Kobe, R.K., S.W. Pacala, J. Silander, Jr., and C.D. Canham.** 1995. Juvenile tree survivorship as a component of shade tolerance. Ecological Applications 5(2):517–532.

This study implemented species-specific mathematical models to predict juvenile tree survivorship as a function of light availability and growth history. Beech exhibited low probabilities of mortality at all growth rates observed in a 2.5 yr period, possibly because beech were predominantly root suckers which could be receiving carbon subsidies from parent trees. Beech had low rates of low-light mortality and slow growth in high light environments.

27. **Krasny, M.E., and L.M. DiGregorio.** 2001. Gap dynamics in Allegheny northern hardwood forests in the presence of beech bark disease and gypsy moth disturbances. Forest Ecology and Management 144:265–274.[1]

Forest gaps are canopy openings formed by the death or removal of one or more trees, and where the understory is less than 10 m in height. The study was initiated in stands at the killing front of the beech bark disease. By completion, stands had progressed to the aftermath phase. The number of canopy gaps exceeded that among stands not affected by a decline disturbance.

Gaps were classified by how they formed, either by tree decline (standing dead trees, or trees with >50% loss of branches) or tree fall (uprooted or snapped off trees). Fifty-two percent of trees creating gaps were beech, and all had beech bark disease. Gaps associated with declining beech trees decreased by 50% over the 6-yr study period, whereas treefall gaps more than tripled.

Beech regeneration increased after gap formation, and 50% of all understory stems were beech root suckers that formed as dense thickets. These limit natural soil disturbance, create dense shade, and provide an unfavorable environment for regeneration of other species. Stands had limited regeneration of sugar maple and striped maple.

[1]Also see DiGregorio, L. 1998. Radial Growth Trends of Sugar Maple (*Acer saccaharum*) in an Allegheny Northern Hardwood Forest Affected by Beech Bark Disease. M.Sc. thesis. Cornell University. Ithaca, NY.

28. **Laufersweiler, J.** 1955. Changes with age in the proportion of the dominants in a beech-maple forest in central Ohio. Ohio Journal of Science 55(2):73–80.

Beech and maple were counted and grouped by age in unmanaged stands. Data indicate that a shift in greatest relative abundance from maple to beech occurred between ages 40 and 70 yr. Beech was consistently taller than maple in each group, indicating faster vertical growth than maple. Five of eight upper canopy beech exhibited root sprouting, ranging from one to 16 sprouts per tree. If root sprouts were not tallied, maple would be more abundant in all age groupings. Sprouting may be the most important factor in the maintenance of beech dominance in the canopy.

29. **Leak, W.B.** 1978. Relationship of species and site index to habitat in the White Mountains of New Hampshire. USDA Forest Service Research Paper NE-397.

Beech grows well on washed fine till, and coarse till. It is less important on sandy sediments, silty sediments, and dry compact till.

30. **Leak, W.B.** 2003. Regeneration of patch harvests in even-aged northern hardwoods in New England. Northern Journal of Applied Forestry 20(4):188–189.

Forty-seven yrs after cutting 10 half-ac patches in a 70-yr-old, 60-ac stand, basal area averaged 64 ft^2/ac, with 26% in beech and more than 50% birches. Birches dominated 6 of the 10 plots. Trees 8 in. dbh and larger averaged 23 ft^2/ac, with a proportion of 9% beech and 60% birches. Patches supported an abundance of pin cherry and striped maple, but those stems were dead or dying by 47 yr after cutting. Patch cutting successfully regenerated birches, but beech dominated the understory in uncut parts of the stand.

31. **Leak, W.B.** 2003. Best density and structure for uneven-aged northern hardwood management in New Hampshire. Northern Journal of Applied Forestry 20(1):43–44.

Twenty-five- to 30-yr-old beech saplings growing beneath a 70-yr-old even-aged northern hardwood stand grew at an annual rate of 0.067 in. during the first 10 yr after thinning reduced the overstory to 60 or 80 ft^2 of basal area, with 45% of it in sawtimber-sized trees. The annual diameter growth decreased to 0.049 in. during the second 10-yr period following the first thinning. In the 10-yr period after a third thinning, the growth of beech saplings increased to 0.091. Understory beech saplings in an uneven-aged stand under selection system (three treatments to 75-80 ft^2 of residual basal area, with 23- and 17-yr cutting intervals over a 50-yr period) grew at annual rates of between 0.05 and 0.06 in. following the first two stand treatments. Understory beech saplings present at the time of the third cutting grew at an annual rate of nearly 0.09 in. Findings indicate that understory beech beneath both even- and uneven-aged northern hardwood stands may grow slowly after an initial cutting reduces overstory stocking, but that the growth rate increases after a second entry to the stands.

32. **Lei, T.T., and M.J. Lechowicz.** 1990. Shade adaptation and shade tolerance in saplings of three *Acer* species from eastern North America. Oecologia 84:224–228.

Pin cherry had the largest, lightest leaves with highest stomatal density and photosynthetic activity, compared to sugar maple and mountain maple. Its sympodial stem structure and large leaves create a highly efficient canopy structure (single-layer leaf display) for light interception. Striped maple sustained the greatest growth rates in height and biomass under a closed canopy.

33. **Logan, K.T.** 1973. Growth of tree seedlings as affected by light intensity. V. White ash, beech, eastern hemlock, and general conclusions. Department of the Environment, Canadian Forest Service, Publication Number 1323.

Beech seedlings were exposed to four light intensities: 13%, 25%, 45%, and 100%. Seedlings grown under the three shade treatments were all significantly taller than those grown under full light. Leaf area increased with increasing light up to 45%, but was reduced in full light. Height, root weight, and shoot weight were also less in full light. Overall, shade-tolerant species like beech sustain life at a low metabolic level, and maintain good root growth under low light.

34. **Marks, P.L.** 1975. On the relation between extension growth and successional status of deciduous trees of the northeastern United States. Bulletin of the Torrey Botanical Club 102:172–177.

In American beech, a late successional determinant species, shoot extension is 90% completed in about 30 days, early in the frost-free season. With pin cherry, an early successional species with indeterminant growth, shoot extension continues through much of the frost-free season.

35. **McClure, J.W., T.D. Lee, and W.B. Leak.** 2000. Gap capture in northern hardwoods: Patterns of establishment and height growth in four species. Forest Ecology and Management 127:181–189.

Canopy gaps created by group selection cutting ranged in area from 1619 to 2428 m^2. Beech advance regeneration up to 30 yr old grew rapidly after release and initially remained taller than beech established at the time of gap formation. Even so, the new beech grew more rapidly and approached the height of the advance beech by 15 yr. Newly established sugar maple grew faster than both beech types after gap formation. Findings suggests that individual stems of sugar maple and beech established near the time of gap formation will grow more rapidly than advance beech regeneration.

36. **Mize, C.W., and R.V. Lea.** 1979. The effect of beech bark disease in New England and New York. European Journal of Forest Pathology 9:243–248.

In the Adirondack region of NY State, beech trees <10 in. dbh were at low risk to mortality during the first 9 yrs after arrival of beech bark disease, except for ones with broken crowns or damage to the main stem within the crown. Trees that died were generally larger than ones that survived. They also had narrow crowns, sparse foliage or damaged crowns, and exposed rot or conks on the main stem.

37. **Peters, R.** 1997. Beech Forests. Netherlands: Kluwer Academic Publishers.

Key information includes

- If the shade tolerance of beech exceeds that of other overstory species, then high canopy cover and small changes in stand stocking will keep the light levels at the forest floor low and favor beech dominance.
- Vegetative regeneration becomes more important than seedling regeneration as beech reaches its altitudinal upper limit.
- *Fagus grandifolia* will become multi-stemmed under stress. Both dry and cool climates seem to favor sprouting in beech.
- *Fagus grandifolia* casts the deepest shade in the understory.
- Height growth rates of released juvenile beech exceed those of mature trees.
- Beech population structures suggest a regular recruitment into the forest canopy.
- Beech growing in gaps have tree rings that average 2–3 times as wide as those of beech at gap edges, or in the understory.

38. **Poulson, T.L., and W.J. Platt.** 1989. Gap light regimes influence canopy tree diversity. Ecology 70(3):553–555.

In small isolated gaps, juveniles of beech will survive in shade for more than 100 yr, whereas sugar maple will only persist for an average of 20 yr. Thus, advance subcanopy beech nearly always replaces upper canopy maple and frequently replaces upper canopy beech. In small, overlapping gaps, the frequency of upper canopy beech or maple replacement by maple is greater. In large gaps, beech and maple will attain canopy status. Peripheral trees shade the juveniles of other less shade-tolerant species and oppress their dense sprouts. Thus, beech and maple will only compete with each other. Understory maple takes longer to recover from oppression. However, in bright light this species has strong growth, surpassing that of beech.

39. **Poulson, T.L., and W.J. Platt.** 1996. Replacement patterns of beech and sugar maple in Warren Woods, Michigan. Ecology 77(4):1234–1253.

Previous research has shown that beech will survive for long periods in the shaded understory while slowly increasing in height. But it will not grow rapidly upward beneath gaps due to plagiotropic (horizontal) growth and absence of a single leader. Its uppermost branches are never vertically oriented, thus net vertical growth is always less than total extension growth of upper branches. Maple will survive a relatively shorter time in the understory, but rapidly increases in height if released by formation of a gap in the overstory. Therefore, as the treefall rate increases, beech dominance decreases. Also, species dominance will differ due to effect of gap frequency and size on the characteristics of understory light.

Four scenarios characterize understory dynamics in this stand:

1. Under conditions of low treefall gap frequency (100–200 yr) and small openings, beech replaced upper canopy trees. Only beech seedlings survived

to taller sizes under dense shade of the beech crowns. In large gaps (200–275 m^2), maple poles became dominant, with slower growing beech below.

2. As treefall gap frequency increased (60–100 yr), maple was released. But it quickly became suppressed and died, while understory beech grew upward and dominated the subcanopy. Beech was the dominant replacement species. The limited number of root suckers (32%) did not contribute to beech self-replacement due to high mortality after adjacent canopy beech fell.
3. Multi-tree gaps, branch gaps, and single-tree gaps occurred every 40–60 yr, releasing the maple. It eventually overtopped the initially taller beech. Beech branches continued to grow laterally beneath the maple, and filled canopy gaps upon maple decline.
4. With a high frequency of treefall gaps (0–40 yr) maple was the dominant replacement species, while beech branches continued to grow upward under the maple and more shade-tolerant species. Vertical growth of beech increased only slightly with increasing light. Understory maple was more common and became as tall or taller than beech due to frequent increases of light from nearby gaps. After multiple gaps had formed, more maple than beech entered the canopy.

Understory maple was the most abundant tree in the smallest regeneration size classes (<30 cm tall), whether beneath beech or maple canopies. All upper canopy maple had at least one large beech beneath it in the understory. Beech saplings (2.5 to 15 cm dbh) were more numerous and larger than maple under mixed canopies of maple and beech. Beech dominated trees >15 cm dbh, though overall densities of trees in these size classes were low. Beech and maple sapling mortality was higher under canopies of maple than under beech.

Beech displayed a horizontal growth advantage at all levels of light, and long lateral branches extended in the shade and in light flecks of the understory. Maple had greater vertical growth in the direct sun of multiple-tree gaps, where total extension of top branches exceeded that of beech in all height classes, and increased with maple sapling height. Under shade, maple growth was less than that of beech for all height classes.

Frequency distributions of beech and sugar maple in the larger size classes in this unmanaged woodland were not significantly different over the 50 yr study period, suggesting that succession had not led to dominance of one species over the other. Overall, beech and maple will continue to coexist over a wide range of disturbance regimes, despite fluctuations in their relative presence in the canopy.

40. **Runkle, J.R.** 1990. Eight years change in an old *Tsuga canadensis* woods affected by beech bark disease. Bulletin of the Torrey Botanical Club 117(4):409–419.

Over a 10-yr period beginning in 1978, beech within an unmanaged woodland[1] decreased in importance by 26% in density, and 25% in basal area. Other species exhibited smaller drops in density and greater increases in basal area. Beech mortality was least among stems 6–10 cm dbh, and higher for larger stems. Tree regeneration was concentrated in gaps formed by death of upper canopy trees, resulting in a clumped distribution of seedlings in the understory. However, the clumps of stems tallied in 1978 became randomly dispersed by 1986, due to mortality within the clumps. Mortality increased with the proximity and size of neighboring trees. As a consequence, clumping was limited among larger size classes, and canopy trees were randomly or even regularly distributed. All other species showed mortality only for small stems, and greater than average growth for larger trees. Growth and mortality within this unmanaged woodland were highest on the same plots, and correlated to living beech basal area as recorded in 1978.

[1]This stand originated following clearcutting around 1800, and has since remained undisturbed.

41. **Sipe, T.W., and F.A. Bazzaz.** 1995. Gap partitioning among maples (*Acer*) in central New England: Survival and growth. Ecology 76(5):1587–1602.

In large gaps (300m^2), lateral branch growth contributed most to total growth of striped maple. In smaller gaps (75m^2) this species showed much greater terminal leader growth. Net leader extension, height change, and basal diameter growth of striped maple exceeded that of both red and sugar maple, except in the center of large gaps. There, basal diameter growth of red maple exceeded that of striped maple. Striped maple responds well to changing environmental conditions, with no significant reduction in overall growth on exposed sites.

42. **Stalter, A.M., M.E. Krasny, and T.J. Fahey.** 1997. Sprouting and layering of *Acer pensylvanicum* L. in hardwood forests of central New York. Journal of the Torrey Botanical Society 124:246–253.

Study sites were chosen in Allegheny hardwood forests for the predominance of striped maple: 49% of advance regeneration in proposed uncut and thinned sites, and 96% of regeneration in the proposed clearcut site. Post-treatment regeneration was classified by stem origin: layer, stump sprout, or seedling. More than 45% of stems were of vegetative origin in all NY stands, compared to 11% in MA. Percent of stems of sprout origin were greater than those from layering, but no significant difference was detected between percent of sprouts, layers, or seedlings. Sprouts were found in both uncut and clearcut sites. The clearcutting resulted in more sprouts than layers, due to pre-treatment sprouting of large diameter striped maple. Clearcuts made in previous years had lower prevalence of sprouting and layering. Layers were observed under small canopy gaps and also where small diameter sprouts from older individuals had become bent over. The location of layers corresponded closely with the position of fallen branches or logging slash. With optimal site conditions, sexual reproduction dominated. Yet in the Allegheny hardwood forest, clonal growth is important.

43. **Tubbs, C.H., and D.R. Houston.** 1990. *Fagus grandifolia* Ehrh. American beech. P. 325-332, in Silvics of North America. Volume 2: Hardwoods. Burns, R.M., and B.H. Honkala (Eds.). USDA Forest Service Agriculture Handbook 654.[1]

Beech is very shade tolerant, but less so in poor soils and cold climates. Seedling development is best under a moderate canopy cover, and not in large openings where surface soil may dry below rooting depth. In dense stands, seedlings are prevalent but grow slowly. Stump sprouts develop from buds in callus tissue. Sprouting may diminish once trees become >4 in. dbh. Root suckers developing from adventitious buds may occur after root injury or removal of the stem.

[1]Also see: Fowels, H.A. 1965. Silvics of forest trees of the United States. USDA Forest Service, Agriculture Handbook 271.

44. **Ward, R.T.** 1961. Some aspects of the regeneration habits of the American beech. Ecology 42(4):828–831.

Beech root suckers were tallied in stands of northeastern, central and southeastern Wisconsin. Root suckers were less abundant than seedlings in the northern stands, and more numerous in the southern ones. Sucker density increased slightly from south to north. Compared to small trees, larger ones more often produced suckers, and greater quantities of them. Where an obvious slope was present, an abundance of root sprouts was related to the greater number of lateral roots present near the surface on the downslope side of a tree. Sucker production was favored by a shallow litter and duff, even though roots were deeply buried. Suckers had higher growth rates than seedlings. They were also better adapted to browsing, which stimulated growth of new suckers.

In northern Ohio, northwestern Pennsylvania, western Tennessee, and west central Indiana, root suckers were not found in stands near the western range of beech, even though superficial roots were abundant and surface abrasion was noted. Suckers were the only type of reproduction in the beech "gaps" of Smokey Mountains in Tennessee, but a large proportion were dead.

45. **Wilson, B.F., and B.C. Fischer.** 1976. Striped maple: shoot growth and bud formation related to light intensity. Canadian Journal of Forest Research 7:1–7.

Striped maple will shift from oppressed to vigorous growth with small changes in light intensity beneath canopy openings caused by windthrow, tree harvest, or leaf drop. Optimum growth occurs in small gaps (40–60% solar radiation) where striped maple will dominate other species. Too much light (>80% solar radiation) may inhibit growth.

2. Deer density impacts on regeneration of desirable hardwood species

46. **Horsley, S.B., S.L. Stout, and D.S. DeCalesta.** 2003. White-tailed deer impact on the vegetation dynamics of a northern hardwood forest. Ecological Applications 13(1):98–118.

Increasing deer density led to decreasing stem density and reduced species diversity over a 10-yr period following all levels of cutting. Density of striped maple >1.5 m tall in clearcuts, and American beech in thinned plots, showed negative trends with increasing deer density. Differences included the height of beech in clearcuts, after thinning, and in uncut stands; and height of striped maple after thinning. Significant changes appeared by 3–10 yr following clearcutting, 10 yr after thinning, and only nominally within uncut stands. Deer preferred beech as a browse species in winter and late spring, but showed low preference for it at other times. They preferred striped maple in late fall and winter, but showed moderate to low preference for it at other times.

47. **Hough, A.F.** 1965. A twenty-year record of understory vegetational change in a virgin Pennsylvania forest. Ecology 46(3):370–373.

Heavy deer browsing observed over a 20-yr period in a 4,000-ac old-growth hemlock-hardwood stand reduced hobblebush vigor and eventually eliminated this understory species. Browsing preference was shifted to less palatable beech seedlings and root suckers.

48. **Marquis, D.A.** 1974. The impact of deer browsing on Allegheny hardwood regeneration. USDA Forest Service Research Paper NE-308.[1]

Number of stems in 16-yr-old clearcuts did not differ significantly between fenced and unfenced areas. Yet selective browsing by deer increased the proportions of beech, black birch, and striped maple. It virtually eliminated pin cherry from unfenced areas.

[1]Continuation of study in citation #282.

49. **Marquis, D.A.** 1981. Effect of deer browsing on timber production in Allegheny hardwood forests of northwestern Pennsylvania. USDA Forest Service Research Paper NE-475.[1]

Regeneration at 9–22 yr after clearcutting in stands with approximately 25 deer/mi^2 was not significantly different between fenced and unfenced areas. On the other hand, species composition and the number of stems >5 ft tall were importantly different. Less than one-third of unfenced clearcuts had satisfactory stocking of preferred species (i.e., ≥70% of regeneration plots with at least two stems >5 ft tall). Beech, black birch, and striped maple were more abundant in unfenced areas, showing preferential browsing by deer. Pin cherry, a fast growing succulent species, was nearly eliminated from unfenced areas.

[1]Continuation of study in citation #48.

50. **Marquis, D.A., and R. Brenneman.** 1981. The impact of deer on forest vegetation in Pennsylvania. USDA Forest Service General Technical Report NE-GTR-65.

Where deer densities exceed carrying capacities, regeneration of merchantable hardwoods is restricted. Unmerchantable beech and striped maple flourish because they are not preferred deer browse, filling gaps that would otherwise be occupied by desirable seedlings. As a consequence, browsing reduced timber values by influencing the species composition and reduced stocking of a new cohort established by overstory cutting.

Deer food production is highest under even-aged management, because of large openings created by the reproduction method cuttings. Yet 40–60% of northern hardwood forests in Pennsylvania will not successfully regenerate without fencing, herbicides, or fertilizers, regardless of silvicultural technique applied. Only a reduction of deer density to match available habitat will provide a long-term solution.

51. **Shafer, E.L., Jr.** 1965. Deer browsing of hardwoods in the Northeast. USDA Forest Service Research Paper NE-33.

Unlike most species, cut beech sprouts mostly from the tops of stumps. Though notably unpalatable to deer, young succulent beech sprouts have been extensively browsed in spring by deer in Pennsylvania.

52. **Tilghman, N.G.** 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. Journal of Wildlife Management 53(3):524–532.

Deer densities greater than 40 per 260 ha in thinned and clearcut stands, and 80 per 260 ha in uncut stands, had a detrimental impact on advance regeneration and seedling height growth. Deer browsing strongly affected the density of sensitive species (sugar maple, pin cherry, yellow birch) while beech, striped maple, and black cherry flourished. These dominated sites once stocked by the other species.

3. Beech bark disease and the changing composition of forests

53. **DiGregorio, L.M., M.E. Krasny, and T.J. Fahey.** 1999. Radial growth trends of sugar maple in an Allegheny hardwood forest affected by beech bark disease. Journal of the Torrey Botanical Society 126(3):245–254.[1]

Annual radial growth of gap-edge and subcanopy sugar maple trees in gap areas opened by overstory beech mortality was significantly greater than that of canopy trees and subcanopy trees in non-gap areas. Gaps less than 500 m^2 show no relationship between radial growth of subcanopy trees and expanded gap area. In northern hardwood forests, disturbance leaving as little as 13% of the total land area in expanded gaps may be the threshold to stimulate a growth response among subcanopy trees.

[1]See also, DiGregorio, L. 1998. Radial Growth Trends of Sugar Maple (*Acer saccaharum*) in an Allegheny Northern Hardwood Forest Affected by Beech Bark Disease. M.Sc. thesis. Cornell University. Ithaca, NY.

54. **Fain, J.J., T.A. Volk, and T.J. Fahey.** 1994. Fifty years of change in an upland forest in south-central New York: General patterns. Bulletin of the Torrey Botanical Club 121(2):130–139.

In the absence of harvesting, upland forests of NY will be influenced by mortality of overstory beech and basswood, and root sucker production of the former species. High deer densities may influence recruitment of sugar maple and hemlock. Unpredictable events creating large overstory gaps may successfully recruit mid-tolerant species.

55. **Filip, S.M.** 1978. Impact of beech bark disease on uneven-aged management of a northern hardwood forest. USDA Forest Service General Technical Report NE-45.

Cuttings were made in 1952 and 1975 using the single-tree selection system in stands where beech comprised 53% of the cubic-foot volume. The primary objective was to salvage weakened, diseased beech and develop a balanced diameter-class distribution of desired species of high vigor and quality. Additionally, cultural treatments were applied in 1956 and 1963 to release sugar maple saplings overtopped by understory beech. By 1976, the stand was in better condition than in 1952, but still deficient for healthy trees of sawtimber size.

The author suggests modifying a silvicultural plan to fit stand conditions, including timely harvest (10 yr interval or less) and cultural operations among the immature age classes. A combination of group selection (½-ac opening) and single-tree selection would remove mature trees and increase proportions of light demanding species, while shaping stand structure and salvaging beech as needed. Treatments in aftermath forests should favor commercial species other than beech, but not completely discriminate against it. Do not hold beech beyond 18 in. dbh, nor other species over 22 in.

56. **Houston, D.R.** 1997. Exotic pests of eastern forests: Beech bark disease. P. 29–41, in Proceedings of the Conference on Exotic Pests of Eastern Forests. April 8–10, 1997. Nashville, TN. K.O. Britton (Ed.). U.S. Forest Service and Tennessee Exotic Plant Council.[1]

Beech bark disease, a complex of the beech scale insect *Cryptococcus fagisuga* Lind. and *Nectria coccinea* var. *faginata* Lohm. and Watson, became established in Nova Scotia in 1890 and has spread as far south as the Tennessee-North Carolina border. Initial build up of scale populations precede the invasion of Nectria pathogens, often killing more than 50% of beech trees >10 in. dbh and damaging others 1–4 yr after initiation. Openings created by mortality and salvage cuts can lead to development of stands dominated by root sprout and seedling origin beech, be devoid of associated species, and serve as hosts for new outbreaks.

Stands in front of the disease should be managed by reducing the beech component, discriminating against overmature trees with signs of decay, and removing advance beech regeneration using herbicides. In aftermath forests, management should remove the dead and declining trees, and treat understory beech by herbicides. Resistant beech can be left. But to prevent root suckering, harvesting must minimize damage to residuals and to exposed roots. Less than 1% of beech stems are resistant. Many occur in groups, facilitating management operations to discriminate against diseased trees. Increasing the population of resistant trees is currently the most promising approach for reducing impacts of the disease.

[1]This paper synthesizes publications by the author and other contributors. For further details regarding beech bark disease, refer to the citations listed in its bibliography. See also, Sage, R.W. 1996. Impact of beech bark disease on northern hardwood forests of the Adirondacks. Adirondack Journal of Environmental Studies 3:6–8.

57. **Mielke, M.E., D.R. Houston, and A.T. Bullard.** 1987. Beech bark disease management alternatives. P. 272–280, in Proceedings of the USDA Forest Service Integrated Pest Management Symposium for Northern Forests. March 24–27, 1986. Cooperative Extension Service, University of Wisconsin–Extension. Madison, WI.

Stands at the killing front of beech bark disease, or in the aftermath stage, should be evaluated for seedlings and root suckers that show little to no defect or signs of the disease complex. Uninfected trees can be left, but affected ones should be removed.

58. **Ostrofsky, W.D., and D.R. Houston.** 1988. Harvesting alternatives for stands damaged by the beech bark disease. P. 173–177, in Healthy Forests, Healthy World. Proceedings of the Society of American Foresters National Convention. Rochester, NY. Society of American Foresters, Bethesda, MD.

Beech bark disease, combined with poor timber harvesting practices, left stands with high proportions of beech originating from root suckers. Where advance reproduction of beech is present, it will likely become part of the next stand, as well. Root sprouting may be controlled by minimizing soil disturbance and root injury through careful marking and layout of skid trails, or use of a swing-to-bunch feller-buncher that does not traverse the entire stand. Summer cuttings are recommended to reduce stump sprouting. Winter logging may minimize root damage and subsequent suckering if the ground is frozen and cushioned by snow. Herbicide applied to advance reproduction by the chop and squirt method before logging has proven successful in killing stems. Larger beech must also be treated to prevent root suckering after harvest. Post-harvest herbicide treatments are applied after new sprouts have developed for 2 yr and may be preferred because this reduces the risk of missing individual stems and also controls herbaceous competition that develops after the overstory cutting. It also allows a single entry to apply the herbicide, using pre-existing skid trails.

59. **Shigo, A.L.** 1972. The beech bark disease today in the northeastern United States. Journal of Forestry 70:286-289.

Summarized in Houston (1997). See Abstract #56 for that publication, referring to it for more detailed historical information regarding the spread of beech bark disease.

B. Threshold Densities Where Interfering Plants Affect the Regeneration of Desirable Hardwoods

60. **Bohn, K.K.** 2001. Method for Predicting American Beech Development in the Understory of Uneven-aged Northern Hardwood Stands After Cutting. M.Sc. thesis. SUNY College of Environmental Science and Forestry. Syracuse, NY.

Five uneven-aged stands in central New York and the Adirondack region were examined to determine the influence of advance American beech (*Fagus grandifolia* Ehrh.) on the regeneration and growth of species after cutting treatments. A 5x5 matrix was established to show shifts in importance of understory beech through time. The level of beech present in both the pre- and post-cut period was measured using a Species Index Value (SIV) based on the relative abundance and relative dominance of the understory species. It is determined by calculating the relative number of stems, as weighted by their height class. Findings show that the post-cut importance of beech was dependent on its status before the treatment. Plots with either very low or very high beech SIV changes little after cutting, while plots with moderate levels of beech (SIV range of 0.26 to 0.75) showed more frequent shifts in beech abundance after the treatment. Stand-level trends point towards an increase in the importance of beech through time. The transition matrix gives foresters a means to forecast the probable level of beech importance after cutting based upon precursor conditions.

61. **Bohn, K.K., and R.D. Nyland.** 2002. Forecasting development of understory American beech after partial cutting in uneven-aged northern hardwood stands. Forest Ecology and Management 180:453–461.

A transition matrix based on Species Importance Values (proportion of stems on a plot weighted by height class) indicate that beech regeneration will not likely increase after harvesting where it was previously absent or sparse. Sugar maple may adequately develop instead. Stands with medium, high, or very high levels of understory beech will likely become dominated by beech regeneration after cutting. Those stands warrant site preparation before overstory removal. By applying data from milacre regeneration plots to the transition matrix, users can forecast the likely proportion of non-beech regeneration in an uneven-aged northern hardwood stand after selection cutting.

62. **Marquis, D.A. 1987.** Assessing the adequacy of regeneration and understanding early development patterns. P. 143–144, in Managing Northern Hardwoods. R.D. Nyland (Ed.). SUNY College Environment Science and Forestry, Faculty of Forestry Miscellaneous Publication 13 (ESF 87-0002). Society of American Foresters Publication 87-03.

Beech root suckers and striped maple interfere with desirable species where more than eight beech stems of any size are present on a 6-ft radius plot.

C. Silvicultural Prescriptions for Controlling Interfering Understory Plants

1. Cutting treatments and understory regeneration

63. **Bicknell, S.H.** 1982. Development of canopy stratification during early succession in northern hardwoods. Forest Ecology and Management 4:41–51.

Advance regeneration of beech in a strip cut had initially faster growth than associated species. It gradually decreased in rate, ending up in the lowest stratum of the canopy after six growing seasons. Beech developed leaves earlier than yellow birch, pin cherry, and aspen. It maximizes growth before leaf flush of other species decreased light levels beneath the main canopy. Pin cherry had the slowest initial growth, but grew longer during each growing season, and dominated the upper canopy by yr 6. Striped maple had a greater annual height increment than beech or sugar maple, but not pin cherry. It occupied an intermediate canopy position. Overall, shade-tolerant species with determinate growth had slower growth rates. Shade-intolerant species had indeterminate growth and grew faster. These traits may explain why shade-tolerant species (e.g., beech and sugar maple) increased in growth upon release, and shade-intolerant species (e.g., yellow birch and pin cherry) initially develop more rapidly.

64. **Blum, B.M., and S.M. Filip.** 1963. A demonstration of four intensities of management in northern hardwoods. USDA Forest Service Research Paper NE-4.

Light increased with the heavier cuts (light selection to diameter-limit), favoring greater proportions of shade-intermediate and shade-intolerant species in the regeneration. The abundance of shade-tolerant advance reproduction reduced the percentage of shade-intolerant seedlings, regardless of cutting intensity. The cutting method will not likely alter advance reproduction, but can affect the eventual composition of a new cohort.

65. **Curtis, R.O., and F.M. Rushmore.** 1958. Some effects of stand density and deer browsing on reproduction in an Adirondack hardwood stand. Journal of Forestry 56:116–121.

Hardwood regeneration was evaluated 15 yr after cutting stands in a northern hardwood forest by clearcutting, shelterwood method, and selection system. Initial stand densities averaged 112 ft^2/ac. Beech was the most abundant species in larger sapling sizes on the clearcut site, while more desirable species remained in the 0–1 ft class. The selection system applied in 1939 left 72 ft^2/ac, and the second entry in 1949 left 65 ft^2/ac. Both treatments favored development of a beech understory. The shelterwood cut reduced stand basal area to 50 ft^2/ac, and proved best for regenerating sugar maple, yellow birch, and white ash. Despite removing high proportions of beech, basal area growth of beech increased following all treatments, regardless of residual stand density. On control plots, beech was the only species that developed into sapling sizes in substantial numbers. A moderately heavy cut that removes high proportions of the beech component will favor desirable regeneration.

Plots inside deer exclosures erected between 10 and 13 yr after cutting were dominated by sugar maple, yellow birch, and white ash seedlings taller than 1 ft. Plots outside the exclosures had beech and hobblebush of comparable size. Species diversity and reproduction density were greater on the shelterwood and clearcut plots, while only small increases occurred in the control and selection plots. Factors specific to this study site (e.g., plot interspersion with areas of uncut timber, and sites near deer yarding areas and with hunting restrictions) may have influenced the degree of browsing. Findings suggest that managers should not disregard the possible impact of deer upon regeneration in northern hardwood stands.

66. **Donoso, P.J., R.D. Nyland, and L. Zhang.** 2000. Growth of saplings after selection cutting in northern hardwoods. Northern Journal of Applied Forestry 17(4):149–152.

In a stand managed by selection system to a residual density of 73 ft^2/ac in 1974 and 82 ft^2/ac in 1993, beech and sugar maple saplings grew at similar rates, reaching 1 in. dbh in 26 yr. Trees that grew less than 67% of their lifespan in unmanaged conditions (small, but old trees) took 34 yr to reach the 1-in. threshold. Trees that grew with more than 67% of their lifespan after selection cutting (young and intermediate trees) took 33% less time to reach the 1-in. threshold. In the first 10 yr after cutting, young and intermediate-aged trees grew more rapidly in height than older ones. Height growth rates during the period 11 to 19 yr after cutting gradually decreased to levels similar to those before the selection treatment, suggesting the onset of oppression by shading.

67. **Grisez, T.J.** 1960. Slash helps protect seedlings from deer browsing. Journal of Forestry 58:385–387.

Slash was left on site after harvesting to compare the frequency of browsing within and outside slash piles. Commonly browsed species (black cherry, yellow birch, and striped maple) were twice as abundant in slash piles than in the open. Beech stems were more abundant in the open than in slash piles. Greatest differences were in the 1–3 ft size class, suggesting that slash may hamper development of beech seedlings and suckers. With no browsing, it is reasonable to infer that all species would be more numerous in the open. Slash piles likely deter the establishment of all species, but it affects the palatable ones less than does browsing by deer.

68. **Hannah, P.R.** 1987. Potential of beech and striped maple to dominate regeneration on eastern hardwood sites. P. 511–512, in Proceedings of the Sixth Central Hardwood Forest Conference. February 24–26, 1987. University of Tennessee, Knoxville, TN. R.L. Hay, F.W. Woods, and H.R. DeSelm (Eds.). University of Tennessee, Knoxville.

In undisturbed stands, beech comprised from 27 to 85% of all understory trees >4.5 ft tall, and 44–73% were root suckers. Striped maple comprised 10–53% of stems. Shelterwood-cut stands (40 ft^2/ac) had 14,000 beech suckers/ac and 9,700 seedlings/ac, compared to 3,800 beech suckers/ac and 5,000 seedlings/ac in uncut stands. Heavy shade following cutting will restrict growth of seedlings, suckers, and stump sprouts.

69. **Hannah, P.R.** 1991. Regeneration of northern hardwoods in the northeast with the shelterwood method. Northern Journal of Applied Forestry 8(3):99–104.

The shelterwood method was applied to northern hardwood stands in Vermont to evaluate subsequent regeneration of preferred and less desirable species. Residual densities of 50–60 ft^2/ac, 70–80 ft^2/ac, 90–100 ft^2/ac, and 110–120 ft^2/ac were randomly assigned to plots at four sites. Sugar maple, yellow birch, and white ash stems <3 ft tall (seedlings) increased in density by 3 yr in nearly all stands. Striped maple seedlings were the most abundant of the less preferred regeneration, followed by beech and hobblebush. Despite the increase of these undesirable species, preferred seedlings outnumbered them by 5 to 1, assuring adequate desirable regeneration. Less preferred saplings outnumbered desired species 2 to 1 at 6 yr after treatment. Beech and striped maple dominated on 62–87% of plots under all residual densities, except for plots cut to 50 ft^2/ac.

Sugar maple seedlings and saplings increased the most under residual densities of 90–100 ft^2/ac. Yellow birch and white ash were best established under 70–80 ft²/ac. Though beech was least plentiful and showed patterns of decline in the 90–100 ft²/ac plots, it increased by an average of 690 saplings/ac, distinguishing beech as the principal competitor. Striped maple was present on all plots, and most abundant at sites where there was a sufficient, viable seed source. Where more than 50% of the advance regeneration is of less desirable species, consider site preparation before or coincident with shelterwood seed cutting.

70. **Jensen, V.S.** 1943. Suggestions for the management of northern hardwood stands in the Northeast. Journal of Forestry 41:180–185.

At 5 yrs after clearcutting, the abundance of sugar maple, beech, and striped maple depended on their size and frequency as advance regeneration. They grew tallest when free of interference from shade-intolerant species. Pin cherry, not present as advance regeneration, outnumbered all other stems >4 ft tall, and grew most rapidly after clearcutting. However, due to its shade intolerance and short life span, this species should not survive beyond 20–30 yr. Hobblebush, abundant before cutting, was replaced by *Rubus* spp., ferns, and grasses.

71. **Jones, R.H., R.D. Nyland, and D.J. Raynal.** 1989. Response of American beech regeneration to selection cutting of northern hardwoods in New York. Northern Journal of Applied Forestry 6:34–36.

Beech seedlings and root suckers were compared in two northern hardwood stands treated by single-tree selection cutting, based on tallies of pre-cut advance regeneration and stem counts 13–14 yr after the cutting. The findings were used to develop alternatives for controlling beech in uneven-aged systems.

Pre-cut seedlings and suckers were equal in proportion, but root suckering was proportionally more significant in post-cut stands than in the pre-cut populations. Overstory beech stocking was different in both stands, but correlated with pre-cut and post-cut regeneration. Significant stocking of beech in pre-cut stands tended to result in low regeneration of beech in post-cut stands. Conversely, where beech stocking was low before harvest, post-cut regeneration tended to be high. Possibly, retention of overstory beech reduced the initiation of root suckers after treatment, since post-cut regeneration was predominantly of root sucker origin. However, limited sprouting may reflect a geographic variation in sucker formation, and have no relationship to density of overstory beech.

Pre-cut beech regeneration was 35–68% seed origin, and it grew rapidly following selection cutting. Beech predominated where deer browsing was a problem. Both circumstances are viewed as important precursors to significant understory beech development following cutting, and indicate the need for control measures before or at the time of cutting treatment. Silvicultural prescriptions that include reducing beech seedling populations and removing large diameter beech trees may prove useful for long-term beech control.

72. **Kelty, M.J., and R.D. Nyland.** 1981. Regenerating Adirondack northern hardwoods by shelterwood cutting and control of deer density. Journal of Forestry 79(1):22–26.

Shelterwood cutting successfully regenerated desirable northern hardwood species in New York's Adirondacks after hunting of antlerless deer reduced deer density from 27 to 14 deer mi², and mistblowing of herbicide controlled understory beech. Cutting without these other treatments resulted in regeneration dominated by beech.

73. **Leak, W.B.** 1980. Influence of habitat on silvicultural prescriptions in New England. Journal of Forestry 78:329–333.

Habitat refers to the environmental conditions within a climatic-mineralogical zone that influence the productivity of forest stands. Single-tree selection favors beech development on enriched, washed coarse till and washed fine till habitats. To encourage softwoods and create a mixed-hardwood stand in sediment rich habitats, use single-tree selection or shelterwood methods. However, this will also encourage beech and red maple. To encourage birch in any of these habitats, apply the group selection method (a variation of the selection system). In fine till habitats, group selection will encourage sugar maple, but beech will comprise 50% of the stand. Group selection and shelterwood methods will favor hardwoods on dry compact till, but also encourage a softwood component. Wet compact till, outwash, or rocky habitats produce only small components of beech in a mix of softwoods, and do not need beech control.

74. **Leak, W.B.** 1988. Effects of weed species on northern hardwood regeneration in New Hampshire. Northern Journal of Applied Forestry 5:235–237.

Four cutting methods were applied to uneven-aged northern hardwoods with initial basal areas ranging from 120 to 130 ft²/ac. Treatments included: clearcut (complete removal in some areas, and a partial overstory removal leaving 34 ft²/ac in other areas); diameter-limit cutting to 64 ft²/ac; moderate selection cutting to 83 ft²/ac; light selection cutting to 95 ft²/ac. Regeneration was measured after 1 and 8 yr to evaluate the influence of striped maple, beech, and pin cherry. Regeneration was considered adequate when desirable species dominated 40% or more of sample plots.

Regeneration of commercial species was low where striped maple was present. This species ranged from 5.5 to 8.8% of tallied trees 3 ft tall to 1.5 in. dbh, and was most abundant after lighter cutting. Beech maintained dominance at all residual stocking levels, but the percent composition of beech did not significantly change over the eight growing seasons. Pin cherry increased in dominance with heavier cutting, ranging from 1 to 8.4% of dominant reproduction. Though a low percentage of commercial species were found on sites dominated by pin cherry (residual densities below 83 ft^2/ac), this species was not associated with a significant reduction in stocking of any species except yellow birch at the partially clearcut sites.[1] Stocking of sugar maple and white ash in all treatment plots showed little to no negative effect from the interfering species.

[1]For further information, refer to Safford, L.O. and S.M. Filip, 1974. Biomass and nutrient content of 4-year-old fertilized and unfertilized northern hardwood stands. Canadian Journal of Forest Research 4:549–554.

75. **Leak, W.B.** 1999. Species composition and structure of a northern hardwood stand after 61 years of group/patch selection. Northern Journal of Applied Forestry 16(3):151–153.

Group/patch cuttings (averaging 0.5 ac in size) were applied throughout a 114-ac tract. Some openings had residual softwoods up to 6 in. dbh. After 61 yrs, plot basal area averaged 133 ft^2/ac. Beech stems dominated, followed by sugar maple, red maple, and yellow birch. For stems >6 in. tall, the proportion of beech was 40% or more, and that for birches and ash only 10%. Findings indicate that periodic application of small patch cutting (0.5 ac) in mature northern hardwoods will maintain basal area of 20% in birches and ash, or one-third in shade-intolerant and intermediate species.

76. **Leak, W.B., and S.M. Filip.** 1977. Thirty-eight years of group selection in New England northern hardwoods. Journal of Forestry 75:641–643.

Group selection cutting was applied over 38 yr to stands composed of 70% shade-tolerant species (beech, sugar maple, eastern hemlock, and red spruce), 25% intermediates (yellow birch, white ash, and red maple) and 5% shade-intolerants (paper birch). The goal was to increase the proportion of intermediate and shade-intolerant species. All hardwoods >2 in. dbh were cut from each group, leaving softwood saplings and small poles. After 38 yr, intermediates comprised nearly one-third of trees 4–12 in. dbh. Beech root suckers dominated the 2-in. class, growing in dense thickets. Beech did not dominate the larger size classes.

Group selection cutting removes clusters of mature trees and promotes growth of intermediate and shade-intolerant species. If combined with single-tree selection, these methods would also shape stand structure and remove high-risk or overmature trees. Residual stocking using the combined method should maintain a basal area of about 65–80 ft^2/ac in trees ≥6 in., with at least 30–35 ft^2/ac in acceptable sawtimber.

77. **Leak, W.B., and D.S. Solomon.** 1975. Influence of residual stand density on regeneration of northern hardwoods. USDA Forest Service Research Paper NE-310.

Effects of residual stand density (100, 80, 60, 40 and 0 ft^2/ac in trees ≥4.5 in. dbh) and structure (60, 45, and 30% sawtimber) on understory development was examined. Plots were also treated by frilling and chemically injecting unwanted trees. Nine growing seasons after cutting, beech had increased slightly, but consistently, in stands at low residual basal area. Striped maple showed no consistent response to residual density. Hobblebush increased slightly in plots with progressively lower residual density down to 40 ft^2/ac, but was absent in the clearcuts.

78. **Leak, W.B., and R.W. Wilson, Jr.** 1958. Regeneration after cutting of old-growth northern hardwoods in New Hampshire. USDA Forest Service Research Paper NE-677.

Regeneration patterns were evaluated after three cutting methods. Pretreatment stands had nearly 60% of basal area in beech, but more than one-half of the advance reproduction in sugar maple and less than 25% in beech. Removing all trees ≥4.6 in. dbh from areas larger than 5 ac favored shade-intolerant species (paper birch and aspen), intermediates, and shade-tolerants in proportions of 2:1:2. Selection cuts (one-third of basal area removed in trees down to 1.6 in. dbh, singly or groups of two or three trees) favored shade-tolerant species. Sugar maple regeneration surpassed beech in height growth and density. Patch cuts (0.1–0.6 ac) removed hardwoods to minimum dbh of 1.6 in. and softwoods to 4.6 in. This promoted intermediate species interspersed with shade-tolerant ones in a ratio of 1:2. Where advance seedlings (shade tolerants) were absent, selection or patch cutting resulted in more regeneration of intermediate and shade-intolerant species.

79. **Mader, S.F., and R.D. Nyland.** 1984. Six-year response of northern hardwoods to the selection system. Northern Journal of Applied Forestry 1:87–91.

Selection cutting was applied following residual structure guidelines of Arbogast (1957)[1], but to 15 ft^2/ac below the recommended level due to insufficient stocking in large sawtimber. Beech, striped maple, and eastern hophornbeam dominated the 3 ft tall to 1 in. dbh class by 6 yrs. Pre-cut plots with advance regeneration of desirable species ≥1 ft tall had desirable stocking 6 yr after the selection cutting. Trees 6 ft tall to 2 in. dbh were 70% commercially valuable species.

[1]Arbogast, C., Jr. 1957. Marking guide for northern hardwoods under selection system. USDA Forest Service, Lake States Forestry Experiment Station, Station Paper Number 56.

80. **Marquis, D.A.** 1965. Regeneration of birch and associated hardwoods after patch cutting. USDA Forest Service Research Paper NE-32.

Amount and size of reproduction was surveyed in several 3-yr-old patches ranging in size from 0.10 to 0.67 ac. Beech, striped maple, and pin cherry were abundant in most patches. Pin cherry and striped maple had reached 10–12 ft tall and 1 in. dbh (the tallest species, averaging 6 ft), and excluded all other species in some areas. Similar results were seen within patch openings in second-growth stands. In another area, pin cherry was a minor component. Instead, striped maple and beech root suckers dominated. Striped maple had become established before the cutting and survived in the dense shade. Once released by overstory removal, it grew in height at the rate of 2–3 ft/yr. Beech root suckers were numerous, and difficult to treat using basal sprays. The dominance of pin cherry, striped maple, and beech may result from a lack of advance regeneration of more desirable sugar maple and yellow birch. An experimental weeding showed the potential for temporarily releasing yellow birch overtopped by faster growing competitors.

81. **Marquis, D.A.** 1967. Clearcutting in northern hardwoods: Results after 30 years. USDA Forest Service Research Paper NE-085.

Winter clearcuts were applied to a stand with 122 ft^2/ac in trees ≥4.6 in. dbh. Advance regeneration was dominated by shade-tolerant species: 26% beech; 56% sugar maple; 16% striped maple; 1% conifers. After cutting, raspberries covered the area, along with hardwood stump sprouts and root suckers, and weed trees like pin cherry. By 5 yr, aspen, pin cherry, and paper birch were dominant, but pin cherry began to die by 15 yr. At 25 yr, 56% of the total basal area (55.9 ft^2/ac) was aspen, paper birch and white ash. Twenty-six percent (25.4 ft^2/ac) was beech and sugar maple, present as codominants. Altogether, shade-tolerant species accounted for 63% of stems. Early release treatments were recommended to maximize growth and quality of valuable shade-intolerant and intermediate species.

82. **Marquis, D.A.** 1981. Removal or retention of unmerchantable saplings in Allegheny hardwoods: Effect on regeneration after clearcutting. Journal of Forestry 79:280–283.

A stand containing 106 ft^2/ac in trees ≥0.5 in. (91 ft^2/ac in trees ≥5.5 in.) was clearcut in 1937, and saplings mowed in portions of the stand. Beech represented 74% of the overstory basal area and sugar maple 17%. Beech (1031 stems/ac) and sugar maple (2497 stems/ac) dominated the advance reproduction (5000/ac) between 2 ft in height and 0.5 in. dbh. Thirty-five yr later, shade-tolerant beech and sugar maple were present on all plots, but occupied main canopy positions only where left as residuals. To encourage shade-intolerant species, keep the stand dense to discourage formation of shade-tolerant advance regeneration, or control understory stocking with herbicides. At rotation end, cut all trees larger than 1 or 2 in. dbh.

83. **Marquis, D.A., and T.J. Grisez.** 1978. The effect of deer exclosures on the recovery of vegetation in failed clearcuts on the Allegheny Plateau. USDA Forest Service Research Note NE-270.

Following protection by fencing 6–10 yrs after clearcutting, the number of seedlings continued to decrease, but surviving seedlings increased in height. Raspberries increased within fenced areas, while fern and grass cover declined. If a regeneration survey shows that 70% of the 6-ft radius plots contain 4 or more desirable seedlings, the stand will likely have 70% stocking of desirable stems > 3-ft tall after 6 yrs. Stands initially having <70% of stocked plots may require fencing or artificial regeneration to insure success.

84. **Marquis, D.A., T.J. Grisez, J.C. Bjorkbom, and B.A. Roach.** 1975. Interim guides to the regeneration of Allegheny hardwoods. USDA Forest Service General Technical Report NE-GTR-19.

Regeneration potential of stands at least 60 yr old can be evaluated by measuring advance reproduction on 6-ft radius plots. Regeneration is adequate if at least two-thirds of plots have at least 15 black cherry, or 80 stems of desirable species, <0.5 in. dbh. Alternatively, a stand could have at least two-thirds of the plots stocked with at least one-half of them having adequate small reproduction, and the remainder having at least 4 acceptable stems of desirable species 1 to 2 in. dbh, or at least 2 stems of these species 3 to 4 in. dbh. If at least 8 stems (total) of beech root suckers or striped maple are present on a 6-ft radius plot, then it is considered heavily stocked by undesirable species. If threshold levels of beech root suckers or striped maple stems occur on ≥30% of regeneration plots, a herbicide treatment will be needed to control the understory.

85. **McClure, J.W., and T.D. Lee.** 1993. Small-scale disturbance in a northern hardwoods forest: Effects on tree species abundance and distribution. Canadian Journal of Forest Research 23:1347–1360.

Species abundance in relation to gap size and location within a gap were evaluated by sampling 24-, 33-, and 44-yr-old patch cuts, ranging in size from 3,500 ft^2

to 25,600 ft^2. Gap age had a stronger effect on species relative abundance than did gap size.

Young, large gaps had high basal areas and densities of pin cherry and striped maple. Pin cherry thrives at high light and soil moisture. It was more abundant in large gaps and at gap centers, and its stocking increased with gap size. The low abundance of pin cherry in the 44-yr-old gaps of all sizes portends its disappearance as the community ages.

Striped maple basal area was uniformly low in all gaps at 44 yr, decreased with increasing gap area among the 34-yr-old gaps, and increased with gap size in the 24-yr-old gaps. Its basal area declined with gap size on steeper slopes. High relative abundance in the 24-yr-old gaps and the sharp increase in abundance with gap area at this age reflect its rapid development after release. Striped maple was more abundant under partial shade than beneath a closed canopy, but less than at the gap center.

American beech was more abundant in the 44-yr-old gaps than in younger ones, but abundance decreased with gap size. Beech advance regeneration succeeded in gaps of all sizes and at all locations, but predominated in small (<1000 m^2) gaps and at gap edges.

86. **Nyland, R.D., D.G. Ray, and R.D. Yanai.** 2004. Height development of upper-canopy trees within even-aged Adirondack northern hardwood stands. Northern Journal of Applied Forestry 21(3):117–122.

Stem analyses in northern hardwood stands treated by shelterwood cutting and understory mistblowing reconstructed early height growth patterns of dominant and codominant hardwood trees that regenerated after the seed cutting. Beech grew 1.6 ft/yr, consistently slower than sugar maple, yellow birch, and white ash. Its height growth rate also declined through time. In addition, beech had a smaller average diameter than any other species in the 29-yr-old stand. Findings supported a relationship between height growth rates and shade tolerance. Among trees established at a common time (e.g., following an even-aged regeneration method that includes a herbicide treatment to remove advance beech seedlings and root suckers), the desirable species will likely outgrow most beech stems by the end of one decade, leaving the beech in a lower canopy position.

87. **Piussi, P.** 1966. Some characteristics of a second-growth northern hardwood stand. Ecology 47(5):860–864.

An Adirondack stand previously harvested by selection cutting grew untouched for 40 yr and became dominated by American beech, sugar maple, and eastern hemlock. More than one-half of the regeneration was sugar maple (850 of 1488 stems), with smaller proportions of hophornbeam (263), and beech (202). With time, beech became predominant, due to the pronounced shade-tolerance of beech over maple, and lack of deer browsing on beech.

88. **Quinlan, P.M.** 1996. An Assessment of Wildlife Habitat Characteristics in Adirondack Selection System Stands. M.Sc. thesis. SUNY College of Environment Science and Forestry. Syracuse, NY.

Tree regeneration and abundance of herbs were measured in northern hardwood stands under selection system silviculture, which included understory herbicide treatment. Nine yrs after cutting the richness, diversity and total cover of herbaceous species, and the richness and diversity of non-beech tree regeneration, were negatively correlated to beech stem density. Plots with 10 or more beech stems at yr 9 had dense thickets of beech that shaded out desirable regeneration and reduced the abundance and diversity of herbs.

89. **Richards, N.A., and C.E. Farnsworth.** 1971. Effects of cutting level on regeneration of northern hardwoods. Journal of Forestry 69:230–233.

Prior to treatment, basal area of trees >4 in. dbh averaged 120 ft^2/ac, with 88% in sugar maple, beech and yellow birch. Treatments included: no cutting, leave 70 ft^2/ac, leave 50 ft^2/ac, leave 30 ft^2/ac, and clearcut. Merchantable trees were harvested and understory beech stems ≤3.5 in. dbh were treated with herbicide. Deer browsing hindered growth of sugar maple and yellow birch. At 5 yrs, uncut plots had few seedlings of these species >3 ft tall. Advance beech responded modestly to cutting and was not browsed. Reducing deer densities to 13/sq mi resulted in increased growth of sugar maple and birch, but effects varied near obvious deer paths. Twelve yr after treatment, sugar maple and yellow birch trees >3 ft tall were found on more than two-thirds of plots protected from deer, and having a residual stocking up to 80 ft^2/ac. Seedlings grew slower in plots of 40–80 ft^2/ac than at lower stocking levels. Numbers of beech ≤3 ft tall remained relatively low on all plots, but those >3 ft were high at all cutting levels. Tall beech saplings dominated plots with a residual stocking >80 ft^2/ac and not protected from deer. Strategies that include deer density management and beech understory control may lead to successful regeneration of desirable species.

90. **Trimble, G.R., Jr.** 1973. The regeneration of central Appalachian hardwoods with emphasis on the effects of site quality and harvesting practice. USDA Forest Service Research Paper NE- 282.

A pattern of increasing abundance of shade-intolerant species was observed with decreasing residual stand density (selection cut, to diameter-limit cut, to clearcut).

A reverse pattern was seen for shade-tolerant species. Stump sprouts accounted for 58% of total reproduction on clearcut plots, 18% following diameter-limit, and 18% in the selection cuts. On good sites treated by clearcutting, advance regeneration of shade-tolerant species may hinder establishment of shade-intolerant ones. Similarly, partial cutting in an even-aged stand of diverse species will shift species composition toward to shade-tolerant beech and maple. Shade-tolerant stems ≤15 ft tall can be controlled by a foliar spray a couple of years before harvest.

91. **Walters, R.S., and R.D. Nyland.** 1989. Clearcutting in central New York northern hardwood stands. Northern Journal of Applied Forestry 6:75–78.

Clearcutting of stands with ≥ 5,000 desirable advance seedlings/ac at least 1 ft tall resulted in a well-stocked new cohort. Prior to cutting, the understory had few trees of undesirable interfering species (average of 5,000/ac of beech, compared to 11,000/ac of sugar maple). *Rubus* formed a dense cover across the sties by the second yr, but declined as tree regeneration began to overtop it. Raspberries disappeared by the time of canopy closure at 10–15 yrs after overstory removal. Findings indicate that clearcutting should succeed in similar stands having well-developed advance regeneration of desirable species and a low deer density if logging does little damage to advance reproduction, causes little soil compaction, and does not expose the mineral soil.

2. Chemical and mechanical site preparation

92. **Abrahamson, L.P.** 1983. Control of beech root and stump sprouts by herbicide injection of parent trees. SUNY College Environment Science and Forestry, School of Forestry, Forestry Research Note RN-SOF-83-001.

Three herbicides were applied to pole and sawtimber beech (8 to 20.3 in. dbh) by the chop and squirt method of injection to evaluate success in reducing present root suckers and preventing new stump sprouts or suckers from forming. Herbicides included glyphosate (4 lb active isopropylamine salt of glyphosate per gallon formulation, ratio with water of 1:1); triclopyr (3 lb active Triethylamine salt of triclopyr per gallon formulation, ratio with water 1:1); and a mixture of 2,4-D amine and picloram (1 lb active 2,4-Dichlorophenoxyacetic acid equivalent, plus 0.25 lb active picloram acide equivalent per gallon, used full strength). Trees on control plots were girdled at about 3–5 ft from the ground using a chainsaw. All herbicides effectively killed beech crowns by 1 yr after application. Chainsaw girdling only killed 9% after 1 yr, and triggered stump sprouting. Glyphosate was the only treatment to reduce new root suckering. Both glyphosate and the combined 2,4-D and picloram treatment significantly reduced new sucker production compared to triclopyr.

93. **Barrett, J.W., C.E. Farnsworth, and W. Rutherford, Jr.** 1962. Logging effects on regeneration and certain aspects of microclimate in northern hardwoods. Journal of Forestry 60:630–638.

Beech comprised 50% of stems from 4.5 in. to 9.4 in. dbh before cutting or herbicide treatment. Stems >4.5 in. dbh were poisoned and most had died 2 yr later. Even so, 1–4 in. dbh stems (391 stems/ac) continued to predominate. Beech ≥3 ft tall increased by 70% (549 stems/ac) after clearcutting, indicating that beech had not suffered from exposure. Beech stems in plots cut to 30 ft^2/ac increased by 191 stems/ac, while those in uncut plots decreased by 170 stems/ac. Hobblebush stems increased in the herbicide treated plots and the most heavily cut plots, and may have a harmful effect on regeneration of desirable tree species. Yet this species did not respond as vigorously as *Rubus* in the openings.

94. **Behrend, D.F., and E.F. Patric.** 1969. Influence of site disturbance and removal of shade on regeneration of deer browse. Journal of Wildlife Management 33(2):394–398.

Stands had sugar maple, beech, and yellow birch, with an understory of beech. Treatments included combinations of: partial overstory removal (trees with crowns in the upper half of the crown profile) by poisoning with sodium arsenite in spaced axe cuts; understory removal by mistblowing 2,4,5-T; soil scarification; and fall ground fires. Deer densities approximated 27/sq mi at the time. By 5 yr, the number of yellow birch had increased after both burning and scarification. Little effect was evident where shade had not been partially reduced, but the site was disturbed. Likewise, removal of high or low shade without site disturbance had little effect on numbers of yellow birch seedlings. Control plots varied little in species composition. Results indicate that burning in conjunction with removal of shade regenerates the greatest variety of species.

95. **Carvell, K.L.** 1956. The use of chemicals in controlling forest stand composition in the Duke Forest. Journal of Forestry 54:525–530.

Frilling alone cost nearly as much as frilling plus poisoning. For small trees, frilling cost slightly more than girdling. Frilling plus poisoning was less expensive than girdling for trees >12 in. dbh. Frilling at ground level, and in early spring rather than in mid-summer, was most effective.

96. **Curry, J.R., and F.M. Rushmore.** 1953. Experiments in killing northern hardwoods with sodium arsenite and ammonium sulfamate. Journal of Forestry 53:575–580.

Fifty percent solution of both ammate (5.6 grams of chemical) and sodium arsenite (6.9 grams of chemical) were made by mixing equal weights of water and dry chemicals. Summertime stem injection treatments were considered satisfactory if trees had defoliated by 75–80% in 12 months, or 85–90% at the end of the second yr. Crown kill by 2 yr was successful for all trees treated with 4 ml of sodium arsenite injected into holes placed at 8 in. intervals around the stem (9–28 in. dbh). Injections of ammate at 4 in. intervals were necessary to produce comparable results. Fall and winter injections of aresenite at the 4 in. interval also proved 100% successful. Using 8 in. and 12 in. intervals, respectively, gave 59 and 42% effective kill. Winter and summer injections of ammate gave similar results, and compared favorably with winter treatments of arsenite.

97. **Heiligmann, R.B.** 2004. Controlling undesirable trees, shrubs, and vines in your woodland. Ohio State University Extension. School of Natural Resources, Ohio State University. See URL: http://www.wildlifemanagement.info/publications/forestru_mgt_17.htm

Reviews common methods, time of application, and application rates for currently available herbicides used with stem injection, cut stump treatments, and basal sprays. With stem injection the timing of application and amount injected varies among herbicides, but all can be put into spaced axe cuts that penetrate into the sapwood. Tree size does not appear to limit effectiveness. Basal sprays have proven effective for trees up to 4–6 in. dbh when applied to the lower 12–18 in. of the stem. Since excess herbicide will run down the bark into the soil and may enter adjacent trees through their roots, workers must use care to control the amount applied. That applies to stump treatments as well, where water-soluble the herbicides must be applied to the sapwood area of freshly cut stumps. Oil-soluble herbicides allow more flexibility in timing, but must be applied to the entire stump, the bark, and any exposed roots.

98. **Heiligmann, R.B., and D. Krause.** 2002. Relative effectiveness of herbicides commonly used to control woody vegetation in forest stands. Ohio State University, School of Natural Resources, Extension Fact Sheet F-51-02.

Summarizes the relative effectiveness of currently registered compounds for treating an array of broadleaved trees and woody vines. Most species tested showed susceptibility to triclopyr, picloram, and imazapyr when applied as water solutions into frills or girdles, or sprayed on stumps of cut trees. They rated susceptibility to 2,4-D+2,4-DP and glyphosate as intermediate for most species tested. For oil-soluble herbicides applied as a basal spray or sprayed onto cut stumps, most species had a susceptible or susceptible-to-intermediate rating with respect to triclopyr and imazapyr, and intermediate-level ratings for 2,4-D+2,4-DP. Even with an intermediate ranking, the herbicides killed most of the treated trees or woody vines.

99. **Holt, H.A., and E.H. Reed.** 1981. Controlling beech with injected herbicides. Proceedings of the North Central Weed Control Conference 36:80–91.

Beech trees from 8–12 and 14–18 in. dbh were treated with herbicides in summer and winter. Glyphosate (3 lb/gal), triclopyr (3 lb/gal), picloram (0.67 lb/gal), and dicamba (2lb/gal) all provided >70% control. Triclopyr (0.75 lb.gal) and dicamba plus 2,4-D mecoprop (0.5 plus 2 plus 2 lb/gal, respectively) resulted in 50–70% control. Picloram plus 2,4-D (0.25 plus 1 lb/gal, respectively), glyphosate (0.75 lb/gal), and frilling without herbicide were less than 50% effective.

100. **Horsley, S.B.** 1990. Tank mixing Roundup® with adjuvants and other herbicides for striped maple control. Northern Journal of Applied Forestry 7(1):19–22.

Several formulations of Roundup® were applied in early September to striped maple, using a tractor-mounted mistblower. Two yrs later, the greatest kill was among 10- to 20-ft-tall stems, and the poorest among those <5 ft tall. Roundup® alone killed 81% of striped maple, more successful than any mixture of Roundup® with adjuvants or other herbicides. Adding either Frigate Agricultural Adjuvant or X-77 surfactant did not increase control of striped maple. Sorbicide herbicide adjuvant and 2,4-D reduced Roundup® activity. Height distribution of herbicide was improved by the use of the Friend air blast sprayer. It sprays the herbicide from a series of vertically arranged nozzles, and evenly spreads the chemical over both low and high vegetation. Using 1 qt/ac of Roundup® in 25 gal of water with the Friend sprayer killed nearly all striped maple trees <20 ft tall.

101. **Horsley, S.B.** 1991. Using Roundup® and Oust® to control interfering understories in Allegheny hardwood stands. P. 281–290, in Proceedings of the 8th Central Hardwood Forest Conference. March 4–6, 1991. University Park, PA. McCormick, L.H. and K.W. Gottschalk (Eds). USDA Forest Service General Technical Report NE-GTR-148.

Roundup® controlled >90% of interfering trees less than 1 ft tall when applied between early June and early October. Control of larger trees depended on the time of application. Roundup® applied at 1, 2, or 4 qt/ac in early August or early September controlled ≥95% of 1–5 ft tall striped maple. Use in early June or early July required application of 2–4 qt/ac to achieve the same level of control. The time of leaf senescence marks a practical limit for Roundup® application. For striped maple, optimum results follow application of 1 qt/ac from early August to leaf yellowing. For beech, it is from early August to early October.

Striped maple was not always sufficiently controlled under commercial operating conditions. Increasing the rate of Roundup® to 4 qt/ac resulted in complete kill, but increased the treatment costs. Adding adjuvants to increase Roundup® activity did not improve the results, because of uneven distribution of the herbicide. Applying Roundup® with a Friend air-blast sprayer (uses a vertical stack of nozzles that fills the air space from the ground to about 20 ft elevation) gave good control of both short and tall vegetation, and with only 1 qt/ac in 25 gal of water. When both woody and non-woody interfering plants occupy >15% of the regeneration on sample plots, a tank mix of Roundup® and Oust® will effectively kill all species.

102. **Horsley, S.B.** 1994. Regeneration success and plant species diversity of Allegheny hardwood stands after Roundup® application and shelterwood cutting. Northern Journal of Applied Forestry 11(4):109–116.

Stands were treated in summer with 1 lb/ac active ingredient of Roundup® in 25 gal of herbicide mix using an air-blast sprayer mounted on a tractor. A shelterwood seed cut the following winter left overstory stocking at 60% relative density. Herbicide treatment reduced understory beech and striped maple by 16%, with little increase 7 yr later. This facilitated establishment of desired species. Little change in stocking of beech and striped maple occurred on the control plots.

103. **Horsley, S.B., and J.C. Bjorkbom.** 1983. Herbicide treatment of striped maple and beech in Allegheny hardwood stands. Forest Science 29(1):103–112.

Four herbicides were applied in 60- to 80-yr-old Allegheny hardwood stands to evaluate the effects of rate and time of application in reducing understory American beech and striped maple before overstory cutting.

Glyphosate applied at 1.12 kg/ha active ingredient diluted in 3 liters of water and sprayed onto foliage to a height of 3.0 m effectively killed striped maple and beech. The optimum time of application was August 1 through mid-September for striped maple, and August 1 through October 1 for beech. Applying glyphosate at this rate and time gave the same degree of kill as higher application rates for stems up to 3.0 m tall.

Though 2,4,5-T killed more than 97% of striped maple in all size classes at the lowest rate applied (0.78 kg/ha active ingredient), it also killed desirable advance regeneration of other species. By the third growing season after treatment, the number of desirable seedlings had increased 120% above pretreatment numbers.

Picloram applied to vegetation both at rates of 6.72 kg/ha active ingredient (5% pellets) and 8.96 kg/ha active ingredient (10% pellets) in a 12-yr old clearcut stand killed 83% of striped maple stems by 28 mo after application. Bromocil (80% wettable powder diluted in water to total 3 l) gave no significant difference among application rates, beginning at 8.96 kg/ha active ingredient. When aerial applications are not justified, both root-absorbed herbicides would be useful for treating small areas of brush taller than 3 m.

104. **Jarvis, J.M.** 1957. The effectiveness of ammonium sulphamate for killing defective tolerant hardwoods. Forestry Chronicle 33:51–53.

Beech <12 in. dbh was highly susceptible to treatment by ammonium sulphamate crystals in cups spaced ≤6 in. apart. Closer spacing is required for larger diameter trees. At 2 in. between notches, the treatment cost $3.60/ac. Compared to girdling, reduced labor offset the cost of the poison used with notching technique.

105. **Johnson, K.S.** 2000. Composition of Two Oak-Northern Hardwood Stands 18 Years After Springtime Prescribed Burning. M.Sc. thesis. SUNY College of Environment Science and Forestry. Syracuse, NY.[1]

The relative density of beech stems >1.4 m tall increased significantly by 18 yrs after a single prescribed springtime surface fire, and decreased below unburned levels in the twice-burned plots. Beech stems from 1.5 to 8.9 cm dbh also increased in both burned and unburned plots, but were significantly fewer in twice- than once-burned areas. Beech continued to dominate the tall regeneration in both burned and unburned areas, showing that springtime surface fires did not effectively control understory trees of that species.

[1]This thesis reports long-term findings from a project also documented by

Adams, K.B. 1981. Effects of Prescribed Fire in Transition Oak Stands in New York. PhD. thesis. SUNY College of Environment Science and Forestry. Syracuse, NY.

Shramek, J. 1985. The Status of Red Oak Advance Regeneration Three and Four Years Following Prescribed Burning in Transition Oak Stands of South Central New York. M.Sc. thesis. SUNY College of Environment Science and Forestry. Syracuse, NY.

McGee, G.G. 1993. Some Effects of Frequency and Intensity of Springtime Prescribed Fires on Two New York Oak-Northern Hardwood Forest Understories. M.Sc. thesis. SUNY College of Environment Science and Forestry. Syracuse, NY.

106. **Kelty, M.J., and R.D. Nyland.** 1981. Regenerating Adirondack northern hardwoods by shelterwood cutting and control of deer density. Journal of Forestry 79(1):22–26.

Regenerating desirable species in old-growth northern hardwoods took three treatments. First, controlled hunting reduced white-tailed deer densities from 27 to 14/mi^2 to reduce browsing impacts. Then the stand was mistblown with 2,4,5-T to kill understory beech up to 20 ft tall. Next, shelterwood seed cutting reduced the overstory to 60% crown cover. Stem injection killed other beech trees not removed during logging. Study areas had received this treatment with seed cutting 2, 6, and 10 yr earlier, and the overstory had been removed from one of the 10-yr-old stands. An additional 7-yr-old stand had no stem injection of beech >1 in. dbh, and a 11-yr-old stand had supported a mixedwood rather than northern hardwood stand.

The northern hardwood sites receiving the full set of treatments had 45,200 desirable seedlings (sugar maple, yellow birch, and white ash) at 2 yrs, 47,300 by age 6, and 43,900 at age 10. Further 92% of plots in the 10-yr stand had trees at least 8 ft tall, with the tallest averaging 12.8 ft. Yellow birch and white ash were the tallest, and sugar maple the most abundant species in nearly all stands. Beech occurred in only small numbers, and was tallest on only 20% of regeneration plots. By contrast, the 7-yr-old stand had no control of beech >1 in. dbh, and that species was the tallest tree on 60% of plots. In the 11-yr-old mixedwood site, yellow birch was tallest on 46% of plots, and beech the tallest on 48%.

107. **Kochenderfer, J.D., S.M. Zedaker, J. Johnson, D.W. Smith, and G.W. Miller.** 2001. Herbicide hardwood crop tree release in central West Virginia. Northern Journal of Applied Forestry 18(2):46–54.

Chop-and-squirt injection and low-volume stem bark band methods were used to apply glyphosate (Accord®), imazapyr (Arsenal® or Chopper®), and triclopyr (Garlon™ 3A or Garlon™ 4) to American beech saplings through sawtimber-sized trees as a crop tree release treatment. Either 1.5 ml or 3 ml of solution, respectively, was injected per inch of dbh or applied as a bark treatment. Stem injection with Accord®, Garlon™ 3A, and Arsenal® AC proved effective. Arsenal® AC damaged large numbers of crop trees. Accord® damaged crop trees when applied to nearby trees of the same species. Root sprout mortality was highest after treatment with Arsenal® AC and Accord®.

108. **Kochenderfer, J.D., J.N. Kochenderfer, D.A. Warner, and G.W. Miller.** 2004. Preharvest manual herbicide treatments for controlling American beech in central West Virginia. Northern Journal of Applied Forestry 21(1):40–49.

Tree injection (with Accord®, 50% solution in water for trees ≥6 in. dbh) and basal spraying (with Garlon™ 4, 10% solution in Hy-grade I oil for trees <6 in. dbh) both gave almost complete control of American beech trees. Production rates for basal spraying of trees <1 in. dbh and 1.0–5.9 in dbh were 362 vs. 201 stems/hr, respectively. Workers could inject trees ≥6 in. dbh at the rate of 59 stems/hr. Costs per acre varied with stem density and size, cost of the herbicide, and method of application for the different treatments.

109. **Liptzin, D., and P.M. Ashton.** 1999. Early-successional dynamics of single-aged mixed hardwood stands in a southern New England forest, USA. Forest Ecology and Management 116:141–150.[1]

Following clearcutting, all advance reproduction and stump sprouts were removed manually and treated by basal application of herbicide (2,4,5-D) in June. Temporal and spatial patterns of regeneration stratification were compared 28 yr later. The treatment did not prevent beech root sucker development. Beech reproduction flourished on the swale-till sites. Regardless, shade-intolerant species remained the tallest of all trees.

[1]See also citation #309.

110. **Lyman, G.T., A.E. Gover, L.J. Kuhns, N.L. Hartwig, and T.L. Watschke.** 1990. Dormant stem brush control study. P. 6–15, in Roadside Vegetation Management Research, Fourth Year Report. Pennsylvania State University Report Number PA 90-4620 + 85-08.

Garlon™ 4 at 4 qt plus Clean Cut + Pine (emulsified crop oil) at 8 qt, totaling 75 gal/ac, was applied to roadside beech and striped maple using a Cibolo Jr. spray rig equipped with a Swinglock nozzle. The treatment caused severe injury to contacted stems and also had an effect on stems beyond the contacted area. This formulation proved most cost efficient, at $97.59/ac. Other formulations of the herbicides provided non-significantly better control at a higher cost.

111. **Maass, D.** 1983. Timing-species-herbicide interactions for tree injection treatments. Proceedings Annual Meeting of the Northeastern Weed Science Society 37:268–272.

Treatment of beech by glyphosate (diluted 1:3 with water) resulted in successful control in all seasons of application. Winter application using a combination of glyphosate and triclopyr (diluted 1:1:6 with water) outperformed either herbicide alone for beech control.

112. **Mallett, A.L.** 2001. Management of American Beech by Mechanical and Chemical Control Methods. M.Sc. thesis. SUNY College of Environment Science Forestry. Syracuse, NY.

Four study sites within the Adirondack Mountain and the Southern Tier regions of New York State were treated at two-week intervals from April through October during 2000 by cutting understory hardwoods <5.5 in. dbh, using a brush saw. After 1 growing season, plots treated in July and August had the fewest American beech stump sprouts. Sprouting increased with stump diameter up to 8 in., and decreased with stump height up to 2 ft tall. Eighty-three percent of sprouts initiated from the callus tissue along the rim of the stump, suggesting the probability of low sprout survival. Data from plots treated in mid-summer of 1997 and 1998 support this. Number of sprouts had declined by three and four growing seasons after the felling treatment.

Garlon™ 4, Accord®, or Chopper® all successfully controlled stump sprouting when applied as a cut-stump treatment. Garlon™ 4 and Chopper® also proved effective when applied as a basal spray. At one growing season following treatment, the herbicides had controlled sprouting more effectively than felling treatments.

113. **McCormack, M.L., Jr.** 1981. Chemical weed control in northeastern forests. Weed control in forest management. P. 108–115, in Proceedings of the 1981 Johnathan S. Wright Forest Conference, H.A. Holt and B.C. Fischer (Eds.). Department of Forestry and Natural Resources, Purdue University. W. Lafayette, IN.

Beech and pin cherry can dominate good sites for 15 yr or more. Beech has shown resistance to some understory treatments by producing large numbers of stump sprouts and root suckers. Pin cherry seeds will remain viable for long periods in duff layers, sprouting after canopy removal. Both species were effectively killed when treated by aerial application or stump treatment of triclopyr amine at 2.2 and 4.5 kg/ha in water. Carefully controlled applications of glyphosate at 2.4 to 3.4 l/ha effectively reduced beech and favored sugar maple, which exhibited some tolerance.

114. **McCormack, M.L., Jr., L.B. Lynn, and E.B. Sprague.** 1980. Results with glyphosate for forestry in Maine. Proceedings of the Annual Meeting of the Northeastern Weed Science Society: 304.

Application of glyphosate as Roundup® at 1.68 and 3.36 kg/ha active ingredient successfully controlled pin cherry and beech, releasing established conifers in Maine.

115. **McCormack, M.L., Jr., and M. Newton.** 1980. Aerial application of triclopyr, phenoxies, picloram and glyphosate for conifer release in spruce-fir forests of Maine. Proceedings of the Weed Science Society of America: 47–48.

Glyphosate applied at 2.2 kg/ha gave a 90% kill of beech, pin cherry, and raspberry, with less than 40% kill of sugar maple. Striped maple kill was intermediate. A rate of 4.4 kg/ha successfully controlled all species except sugar maple. Triclopyr amine at 2.2 kg/ha and 4.4 kg/ha resulted in a 90% kill of all species except beech. Glyphosate was the most cost effective for killing beech, and triclopyr for abundant maple.

116. **McGee, G.G., D.J. Leopold, and R.D. Nyland.** 1995. Understory response to springtime prescribed fire in two New York transition oak forests. Forest Ecology and Management 76:149–168.[1]

American beech as root suckers were the most abundant tree regeneration following springtime prescribed fire in transition oak stands. These surpassed the growth of red oak. Numbers of beech stems increased following fire due to root injury or fire-induced injury/mortality of standing beech trees.

[1]See also, McGee, G.G. 1993. Some Effects of Frequency and Intensity of Springtime Prescribed Fire on Two New York Oak-Northern Hardwood Forest Understories. M.Sc. thesis. SUNY College of Environmental Science and Forestry. Syracuse, NY.

117. **Nyland, R.D.** 2003. Simple girdle kills small American beech (*Fagus grandifolia* Ehrh.). Northern Journal of Applied Forestry 21(4):220–221.

A simple girdle at waist high killed understory beech up to ~3 in. dbh in 1 yr, and trees to 5 in. in 3 yrs. Either removing all the bark from within the girdle or just cutting two kerfs into the wood around the circumference using a small hand saw sufficed. The methods should kill small trees of other species as well. It would not prove cost effective for treating large areas, or in stands with understory stem densities >400/ac.

118. **Ostrofsky, W.D., and M.L. McCormack, Jr.** 1986. Silvicultural management of beech and the beech bark disease. Northern Journal of Applied Forestry 3:89–91.

The primary objective was to regenerate a northern hardwood stand with desirable species by reducing the beech. This involved a four-step process, combining herbicide application and shelterwood cutting. Triclopyr

(Garlon™ 3A) was applied by mist blower to understory saplings at a rate of 1.2 lb/ac active ingredient, and full strength in frills on defective beech stems >3.0 in. dbh. The treatment was replicated using glypohosate (Roundup®) at a rate of 1.8 lb/ac active ingredient by mist blown applications, and full strength in frills. Both herbicides effectively reduced the beech. The two-stage shelterwood method initially removed defective beech, leaving desirable species as seed trees. After 2 yr, desirable seedlings increased significantly in all treatment plots, while the number of beech saplings and defective overstory trees decreased.

119. **Pitt, D.G., D.G. Thompson, and N.J. Payne.** 1993. Response of woody eastern Canadian forest weeds to fall foliar treatments of glyphosate and triclopyr herbicides. Canadian Journal of Forest Research 23:2490–2498.

Beech, but not striped maple, was effectively controlled with greater than 0.5 kg /ac active ingredient of glyphosate (VISION, MON14420, Touchdown®) or triclopyr (RELEASE), but more consistently and efficiently with glyphosate.

120. **Sage, R.W., Jr.** 1987. Unwanted vegetation and its effects on regeneration success. P. 298–316, in Managing Northern Hardwoods. R.D. Nyland (Ed.). SUNY College Environment Science and Forestry, Faculty of Forestry Miscellaneous Publication 13 (ESF 87-0002). (Society American Forestry Publication 87-03).

Effectiveness of herbicide applications by a skidder-mounted mistblower (delivery rate and travel speed fixed) was compared to pre-established criteria of 80% control of understory beech 1 ft tall to 3.4 in. dbh. September applications of Krenite® (fosamine) at 0.78 gal/ac, Roundup® (glyphosate) at 0.23 gal/ac and 0.47 gal/ac, and Tordon 101M (picloram) at 0.47 gal/ac met the established standard. Banvel 720 (dicamba) at 0.71 gal/ac provided 77% kill. This treatment had the lowest cost/ac ($24.94). Based upon control rate and treatment cost at hardwood sites, use Roundup® at 0.25 gal/ac (1 lb a.e./ac) applied during July and August, or Krenite® at 0.75 lb/ac (3 lbs a.e./ac) applied in September. Individual stem treatments will prove less costly at sites with <400 stems/ac ≤30 ft tall.

121. **Shipman, R.D.** 1982. Selective herbicide treatment of striped maple. Proceedings of the Annual Meeting of the Northeastern Weed Science Society 36:215–220.

All merchantable trees >12 in. dbh were cut from a stand containing 1840 striped maple stems/ac, ranging from 1 to 3 in. dbh, and 6–26 ft tall. Tests on understory striped maple included: AMS (1 tbs 95% active ingredient crystal/in. dbh); bromacil (1 tsp 10% active ingredient pellets/in. dbh), fenuron TCA (1 tsp 22% active ingredient granules/in. dbh), fenuron (1 tsp 25% active ingredient pellets/in. dbh), picloram (1 tsp 10% active ingredient pellets/in. dbh), picloram plus 2,4-D (1 ml of 50–50 water dilution 10.2% active ingredient picloram plus 30.6% active ingredient 2,4-D), 2,4-D (1 ml of 40.3% active ingredient). Pellets and granules were applied in April to the soil at the base of stems. Crystals were applied in June to "V" notched cut stumps. Liquids were also applied in June with a tree injector into cuts at the base of trees. 2,4-D gave a significantly lower mean kill than any other treatment, but rates for other herbicide treatments did not differ. No significant difference was detected in the number of basal sprouts, and all herbicide treatments resulted in significantly fewer sprouts than the control treatment (cut, no herbicide). Soil application of picloram pellets was the most effective method for controlling sprouting.

122. **Swan, F.R., Jr.** 1970. Post-fire response of four plant communities in south-central New York State. Ecology 51(6):1074–1082.

Thirty-eight percent of beech stems were killed back by wildfire. Striped maple decreased at burned sites. Beech and sugar maple produced the majority of sprouts and root suckers, although many saplings died and did not sprout. Beech remained the dominant species in an area where light ground fire reduced the humus and litter layers, and injured standing beech trees. This promoted the production of root suckers.

123. **Thompson, D.G., D.G. Pitt, T.M. Buscarini, B. Staznik, and D.R. Thomas.** 2000. Comparative fate of glyphosate and triclopyr herbicides in the forest floor and mineral soil of an Acadian forest regeneration site. Canadian Journal of Forest Research 30:1808–1816.[1]

Forest floor and mineral soil layers in Acadian forests were sampled for persistence of the herbicides glyphosate (as Vision, Touchdown®, or Mon14420) and triclopyr (as Release) following September brush treatments. Glyphosate had an average half-life of 12 days and 10 days, respectively, in forest floor and mineral soil layers, regardless of formulation. Triclopyr had an approximate average half-life from 39–69 days, depending on depth in the soil. Neither chemical was mobile in forest terrestrial substrates.

[1]See also Pitt, D.G., D.G. Thompson, and N.J. Payne. 1993. Response of woody eastern Canadian forest weeds to fall foliar treatments of glyphosate and triclopyr herbicides. Canadian Journal of Forest Research 23:2490–2498.

124. **Tierson, W.C.** 1967. Influence of Logging, Beech Control, and Partial Deer Control on Northern Hardwood Reproduction. M.Sc. thesis. SUNY College of Environment Science Forestry. Syracuse, NY.

Logging reduced stand basal area 70 ft^2/ac. Within 10 yr, stand density increased by 10%, primarily due to ingrowth of small sapling beech. Ten yrs later, understory beech (0.5–12 in. dbh) were treated by sodium arsenite; larger beech were also treated. Without this treatment, regeneration of preferred species failed. Control can provide suitable levels of sugar maple and yellow birch stocking, as long as heavy deer browsing is reduced. Otherwise, it may be impossible to regenerate northern hardwoods by light selection cutting, even with beech control. Then even-aged silviculture appears best, and should include deer density control during the reproduction phase of management. Beech control prior to the even-aged reproduction method would improve the establishment of desirable reproduction derived from abundant seed produced on overstory trees.

125. **Tierson, W.C.** 1969. Controlling understory beech by use of mistblowers. The Northern Logger and Timber Processor 17(12):40–41.

To control understory beech before a commercial logging operation, 2,4,5,-T (4 lb acid per gallon, reduced 1:8 with diesel fuel) was applied by back-pack mistblower. By 2 yr, this had effectively defoliated 88% of beech from 1–6 in. dbh, to a height of 20 ft from the ground. Application of 2,4,5-T (substituting water for fuel oil as a carrier) by tractor-mounted mistblower effectively killed taller stems, but gave a less uniform control of beech. It also required extra care to avoid damage to valuable overstory trees. An oil carrier had no advantage over water carrier in controlling beech.

Both treatments proved most effective in killing beech when applied after full leaf flush, and no later than two weeks before the first killing frost. Unlike beech and most other broad-leaved species, sugar maple was considerably tolerant of the treatment. But to assure survival, avoid direct application of herbicide to understory sugar maple.

PART II: HAYSCENTED, NEW YORK, AND BRACKEN FERNS

A. Biologic and Ecologic Considerations

126. **Bowersox, T.W., and L.H. McCormick.** 1987. Herbaceous communities reduce the juvenile growth of northern red oak, white ash, yellow poplar, but not white pine. P. 39–43, in Sixth Central Hardwood Forest Conference; 1987. February 24-26 1987, Knoxville, TN. R.L. Hay, Frank W. Woods, and H.R. DeSelm (Eds). University of Tennessee. Knoxville, TN.

Bare root northern red oak, white ash, yellow-poplar, and white pine seedlings were planted in herbaceous communities dominated by hayscented fern or poverty oat grass, or areas within those communities where the grass or fern had been treated with glyphosate (1.7 kg/ha). Survival of seedlings was not impeded by the herb cover during the first 2 yrs, but height growth was. Yellow-poplar showed the greatest response to release. White pine did not respond.

127. **Brach, A.R., S.J. McNaughton, and D.J. Raynal.** 1993. Photosynthetic adaptability of two fern species of a northern hardwood forest. American Fern Journal 83(3):47–53.

The study evaluated the adaptation of hayscented fern and intermediate wood fern to sun and shade. As hayscented fern is a competitive species, the authors expected its sun- and shade-grown sporophytes to have higher net photosynthetic rates than similarly grown sporophytes of the shade-tolerant intermediate wood fern. Sun-grown plants had significantly higher dry mass per unit leaf area, but not significantly different N concentrations and content. Shade-grown hayscented fern had higher net photosynthesis per unit leaf dry mass than intermediate wood fern. This makes it more efficient in low light beneath the forest canopy and in colonizing beneath canopy gaps.

128. **Chazdon, R.L., and R.W. Pearcy.** 1991. The importance of sunflecks for forest understory plants. BioScience 41(11):760–766.

Sunflecks are brief pulses of generally direct radiation, in contrast to the relatively constant level of background diffuse radiation, and vital in light-limited environments. This paper discusses their significance in the photosynthesis, growth, germination, and reproduction of plants living in restricted light. The size, shape, duration, and peak photon flux depend on the height and arrangement of overtopping vegetation and the position the sun. Variation in daily photon flux density among shaded microsites can be attributed to small-scale differences in sunfleck incidence. Light remains the major environmental factor that limits growth and reproduction in deeply shaded understories. Thus, shade-adapted understory plants have evolved with well-developed physiological mechanisms to efficiently use sunflecks. These adaptations include a low rate of induction loss, a high electron-transport capacity relative to carboxylation capacity, and stomatal opening at low photon flux density. Also, stomatal conductance decreases when evaporative demand is high.

129. **Cody, W.J., and C.W. Crompton.** 1975. The biology of Canadian weeds. 15. *Pteridium aquilinum* (L.) Kuhn. Canadian Journal of Plant Science 55:1059–1072.[1]

Provides a comprehensive summary of information about bracken fern and the two varieties (Eastern and Western) common to Canada. Information includes their description and amount of variation; positive and negative economic importance, geographic distribution (i.e., essentially worldwide); habitat; growth and development; reproduction via sexual and vegetative means; population dynamics; response to chemical and other manipulations (i.e., in 1975, Asulam showed the most promise); and response to parasites (e.g., insects, microorganisms and viruses, and higher plant parasites have been reported, but no fungal surveys conducted).

[1]For additional information about herbicides, see also citation #195.

130. **Conard, H.S.** 1908. The structure and life-history of the hay-scented fern. Carnegie Institute of Washington. Botanical Laboratory of Johns Hopkins University, Contribution No. 7.

The life-history of hayscented fern (*Dennstaedtia punctilobula* (Michx.) Moore) offers insight into its relation to its surroundings. The author meticulously dissected hay-scented ferns to describe the cellular orientation and derivation of the fern's root, leaves, and stem; development of sexual organs of the gametophyte; and growth of young sporophytes. Findings show that the development and structure of the mature tissues are independent of the development and structure of their originating meristem. The mature tissues are shaped out of the meristem in response to stimuli from more mature cells. This fern generally occurs in open woods, clearings, or roadsides on well-drained, stony or sandy soil. The stems are found 5–15 cm below the surface, and its long, slender, much-branching rhizomes spread rapidly to produce densely matted beds. Roots arise plentifully from all parts of the rhizome and ramify through the soil.

131. **Cooper-Driver, G., S. Finch, and T. Swain.** 1977. Seasonal variation in secondary plant compounds in relation to the palatability of *Pteridium aquilum*. Biochemical Systematics and Ecology 5:177–183.

Bracken was sampled throughout the growing season from four sites to determine the relationship between changing levels of secondary compounds and the fern's palatability to herbivores. Deer and sheep browsed only on young acyanogenic fronds. Grazing ceased at the boundary between these and cyanogenic plants. Tannins also likely reduced the palatability of the fronds. Insect (*Schistocera gregaria*) feeding was inhibited during peaks in both cyanogenesis and tannins.

132. **Daniels, R.E.** 1985. Studies in the growth of *Pteridium aquilinum* (L.) Kuhn. (bracken) 1. Regeneration of rhizome segments. Weed Research 25:381–388.

Bracken fern plants were grown from rhizome segments to observe their pattern of regeneration. Rhizomes and all shoot types produced both fronds and extensions of the rhizome. New rhizomes were long, slender shoots with widely spaced branches and buds. As rhizomes extended over the growing season, the distance between lateral buds increased. When the main apex was missing, lateral buds developed either as long shoots or via transitional shoots to long shoots. Thirty-two percent of the rhizome segments died without producing any fronds. Death was attributed to insufficiently developed root systems on the segment, or to damage sustained during transplanting.

133. **Demchik, M.C., and W.E. Sharpe.** 1999. Foliar and root chemistry response of hay-scented fern to liming and fertilization. Northern Journal of Applied Forestry 16(1):33–35.

The study evaluated P, Ca, Mg, and K uptake on the growth of red oak seedlings and competing hay-scented fern. Lime and fertilizer had no effect on fern frond density, frond mass, or root mass. P, Ca, and Mg concentrations were higher in roots and rhizomes. Total uptake by the ferns accounted for <4 kg/ha of the amounts applied. This discounts hayscented fern as an important sink for the fertilizer, and indicated that fern control would not necessarily improve the success of forest soil amendment treatments.

134. **Demchik, M.C., and W.E. Sharpe.** 2001. Forest floor plant response to lime and fertilizer before and after partial cutting of a northern red oak stand on an extremely acidic soil in Pennsylvania, USA. Forest Ecology and Management 144:239–244.

Soil amendments may remedy nutrient deficiencies on acidic, base-poor forest soils. Forest floor communities were monitored for 2 yrs before and 2 yrs after partial removal of the red oak and red maple overstory. Plots received either a combination of 6,600 kg/ha dolomitic lime and 1,100 kg/ha 0-10-20 NPK fertilizer, or no fertilizer. Liming and fertilization had little influence on overall species frequencies, including hayscented fern and cinnamon fern. The number of plants within the established layer of hayscented fern increased after cutting.

135. **Dent, C.H.R.** 1971. Bracken fern: A poisonous weed. The Agricultural Gazette of New South Wales 82(2):103–105.

A popular press article reporting that bracken is readily spread, poisonous, and unpalatable perennial weed. Rhizomes are more toxic than foliage, and toxins break down during decomposition. Thiaminase degrades thiamine in the blood and tissues of horses and pigs. The condition is treatable with repeated conditions of B_1. Nitrosamines are carcinogenic to sheep and cattle.

136. **Dibble, A.C., J.C. Brissette, and M.L. Hunter, Jr.** 1999. Putting community data to work: Some understory plants indicate red spruce regeneration habitat. Forest Ecology and Management 114:275–291.

Paired plots compared harvested and unharvested areas on eight sites across northern, western, and eastern Maine. Cutting treatments included irregular shelterwood, single-tree selection, pre-commercial thinning, salvage clearcuts, and conifer release. Stems greater than or equal to 2.5 cm were tallied, seedlings were counted, and percent cover of each species was scored. In canonical correspondence ordination, the first two axes accounted for 64.6% of the species-environment variation. Bracken fern correlated negatively and *Drypopteris* spp. associated with small red spruce. When bracken fern was present, it tended to dominate the understory. Both species are common in red spruce stands, but have little potential as indicators because of their wide niches. Further, parent trees probably influence seedling density more than ground flora does.

137. **Dolling, A.** 1996. Changes in *Pteridium aquilinum* growth and phytotoxicity following treatments with lime, sulphuric acid, wood ash, glyphosate and ammonium nitrate. Weed Research 36:293–301.

The study used a randomized complete block design with treatments (i.e., sulfuric acid, ammonium nitrate, lime, wood ash, glyphosate, and an untreated control) applied annually for 4 yrs. Shoots were counted prior to treatment and each August thereafter, and frond cover estimated annually. The lengths of 25 randomly selected shoots were recorded and humus samples subjected to pH analysis and aspen seed bioassays 1 yr after the treatments ceased. Glyphosate reduced bracken growth, but other treatments had little effect on fern density or height. Aspen seedling emergence and pH were significantly lower in bracken humus from plots treated with sulfuric acid, glyphosate, ammonium nitrate, and in the control. The low pH seemed to enhance inhibition of phytotoxic compounds. Where glyphosate is not permitted, the author suggests planting shade-tolerant species such as Norway spruce beneath a residual canopy. The study did not elucidate possible compounding of treatment conditions (e.g., bracken response under atmospheric deposition when treated with fertilizer and/or a herbicide).

138. **Dolling, A.** 1999. The vegetative spread of *Pteridium aquilinum* in a hemiboreal forest—invasion or revegetation? Forest Ecology and Management 124:177–184.

The change in bracken fern frond density and cover under a closed canopy and adjacent to clearcut areas was assessed to determine whether the species invades new ground or vegetates previously occupied ground. The two experiments revealed that bracken fern spreads in clearcut areas where it has been previously, but tends not to increase frond density or colonize new ground. However, overstory removals increase its density sufficient to impede forest regeneration.

139. **Dyer, A.F., and S. Lindsay.** 1992. Soil spore banks of temperate ferns. American Fern Journal 82(3):89–122.

Available literature suggests that fern spore banks are widespread, but using them to assess their importance to fern regeneration is limited. The research evaluated spore banks in North Carolina and Scotland, based on soil samples from the surface soil (3 sites) or deeper layers. Generally, five 2.5-cm cores were taken at predetermined depths, with three replicate cultures made from each sample. Viable fern spores were widespread, and detected at every site within each habitat tested. Spore banks usually contained at least two fern species, even though some occurred at low frequencies. The wide variation in size and species composition of the spore banks was attributed to distance to the nearest fern sporophyte. A single-species spore bank can develop where fertile fronds of that species are abundant. Further, spore abundance diminishes with soil depth and the gametophytes from spores at ≥30 cm were smaller than those from surface soil cultures. Soil samples also contained more individual spores than seeds, indicating that spore banks are deeper and wider-spread than associated seed banks. Spores of some species, including *Dryopteris,* persist at least 1 yr; but the 2-yr-old spore bank is significantly reduced. Spore banks survived control burns at the Duke Forest and in Scotland. Results imply that soil acts as a spore tray, containing spores capable of outcrossing, establishing year round, and surviving even when surface vegetation is periodically removed.

140. **Flaccus, E.** 1959. Revegetation of landslides in the White Mountains of New Hampshire. Ecology 40(4):629–703.

This study evaluated 29 landslides that occurred 9–72 yrs prior to sampling in the White Mountains of New Hampshire. The point-centered quarter method was used to select trees at least 1 in. dbh, and a m^2 quadrate was placed at each point to inventory small trees by height class and species, the frequency of shrub species, and presence of herbs. Relative values and summative importance values of tree species were compared to show changes with time and altitude. Herb cover developed from paucity to a terminal-type spectrum, with a high presence of hay-scented fern. Even so, the herb and shrub components were generally minor. Paper birch, yellow birch, pin cherry, and trembling aspen immediately formed thickets on the sites. Soil samples were taken to gauge temporal change in pH, organic matter, and the concentration of exchangeable calcium, magnesium, potassium, and phosphorus. Among the older landslides, spruce and fir increased in relative importance. Within the 72-yr chronosequence, organic matter, exchangeable calcium, magnesium, and potassium increased to levels similar to the surrounding forest. Uniformity in succession across sites was attributed to the common exposure to harsh light, high transpiration stress, temperature extremes, root medium instability, and susceptibility of the surface to erosion.

141. **Frankland, J.C.** 1976. Decomposition of bracken litter. Botanical Journal of the Linnean Society 73:133–143.

Bracken fern is one of the dominant ground flora of the Lake District, and as such its decomposition could contribute significantly to the nutrient balance of the area. Decomposition of purified, senescent bracken petioles was studied over 5 yrs on six soil types. Changes in gross physical features, chemical composition, pH, dry weight, and composition of colonizing fungi were recorded. The sequence of decomposition of the litter layer was similar across sites, with the rate on moder > mull > peat soils. Although readily leached components were removed within a few months, decomposition was generally slow on all sites. Most (95%) of the dry matter is expected to last 11–23 yrs, although fronds that are not yet in contact with soil will decompose more slowly. The initial fungal community is composed of cosmopolitan litter types. They are successively replaced by overlapping waves of less specialized weak parasites, primary saprophytes, secondary saprophytes, and finally common soil fungi. This slow decomposition and associated accumulation can be a major ecosystem-altering influence.

142. **Fraser-Jenkins, C.R.** 1980. Nomenclatural notes on *Dryopteris*: 4. Taxon 29(5/6):607–612.

Nomenclatural disputes are discussed and the results reported. The name *Dryopteris carthusiana* (Vill.) H.P. Fuchs is retained in its current usage.

143. **George, L.O., and F.A. Bazzaz.** 1999a. The fern understory as an ecological filter: Emergence and establishment of canopy-tree seedlings. Ecology 80(3):833–845.

The herb and shrub layer, particularly the fern component, may serve as an important ecological filter that influences the initial composition and structure of the future overstory forest community. To test this proposal, the authors quantified the impact of light levels, litter depths, and soil exposure, moisture, and organic matter content on seedling emergence where the fern layer was undisturbed, partly removed, or completely removed. For partial removal, fern fronds were pinned away to create a shade-free aboveground community. The midsummer light levels beneath ferns were ~32% of that in shade-free or fern-free plots. When the overstory fully leafed out, the light level at 1 m was 3.4% that of full sun, while light below ferns was further reduced to 1.1% of full sun. The understory served to differentially filter tree seedling emergence. Under fern cover, birch, pine, and oak emergence decreased, as did summer emergence of maple and ash and maple spring emergence was unaffected. Summer emergence of maple and emergence of pine appeared related to reduced light levels, while birch was limited by low soil exposure. Oak seedlings were eaten under fern cover. Seedling survival of naturally disturbed seed during the first yr was related to seed size, suggesting that the establishment of smaller-seeded species may be more sensitive to understory cover due to lower resource reserves. The deep litter layer may also stop seeds from falling to the soil, and become a barrier for seedlings emerging through the litter mat. The fern layer does influence the density, species composition, and distribution of the seedling bank.

144. **George, L.O., and F.A. Bazzaz.** 1999b. The fern understory as an ecological filter: Growth and survival of canopy-tree seedlings. Ecology 80(3):846–856.

Seedling growth and survival were studied under understories left undisturbed (i.e., "fern"), partially removed (i.e., "shade-free"), or completely removed (i.e., "fern-free") to explore filtering mechanisms. Oak, birch, and maple seedlings were transplanted into each plot, and tallied at the beginning and end of the next two growing seasons. If applicable, the probable cause of mortality was recorded. In addition, seedling height, basal diameter, and leaf lengths were measured and biomass estimates were obtained from the regression equations of similar measurements on extra seedlings. The presence of a fern understory reduced growth and survival of all tested species. Reduced light levels under fern are the primary cause of reduced total biomass accumulation and mortality. The relative height growth of birch was higher in shade-free and fern-free manipulations. Maple and oak were unaffected. As a result of the fern filter, maple dominated the seedling pool beneath ferns while dominance in the fern-free areas was shared by maple and birch. Predation by insects and rodents was most substantial for oak, but maples in fern-free areas were also consumed. The fern understory protected oak leaves from insect defoliation observed elsewhere. The fern understory did not alter the initial ranking of seedlings by seed size. Thus, oaks were the tallest of each cohort and the only species expected to emerge from beneath ferns in substantial numbers unless a disturbance releases the remainder. Understory ferns affect the spatial distribution of forest species and influence the competition, dynamics, and diversity of the resultant canopy.

145. **Hamilton, R.G., and R.M. Lloyd.** 1991. An experimental study on the effects of earthworms on the ecological success of fern gametophytes. American Fern Journal 81(3):95–99.

Earthworms influence gametophyte habitat by tilling the soil and increasing aeration. To study effects of earthworms on spore germination, gametophyte establishment, and/or reproductive success, 40 5-cm plastic pots were filled with soil mixed with dried fertile silvery glade fern fronds. One-half were inoculated with two *Lubricus terrestris,* a common temperate earthworm. The pots were covered with clear plastic and placed in an east-facing window and checked periodically for 250 days. Pots with earthworms were free of fungi after 48 days. After 22 days, gametophytes germinated in 18 of 20 pots, and sporophytes in 3 pots. Worm-free pots had fungi throughout the experiment, algae appeared by day 62, and arthropods were found after day 113. Gametophytes only germinated in five of the worm-free plots, and no sporophytes were produced. Findings indicate that earthworms improve the habitat for gametophytes by reducing the activity of potential pathogens and competitors.

146. **Hippensteel, T.E, and T.W. Bowersox.** 1995. Effects of hayscented fern density and light on white ash seedling growth. P. 256–270, in 10th Central Hardwood Conference. Mar. 5–8, 1995. Morgantown, WV. USDA Forest Service General Technical Report GTR NE-197.

Two field studies were conducted to determine the effects of light altered by hayscented fern foliage on the growth and development of planted white ash seedlings. Four 8m x 8m areas were selected for their dense fern populations and were randomly assigned for reduction of cover to 100%, 50%, 25%, or 0% by periodically removing fern fronds within 0.25m parallel or parallel and perpendicular strips. Areas 2m x 8m adjacent to these were treated with glyphosate (1.1 ai/ha) 1 yr earlier and subdivided into four 2m x 2m sections, each representative of a different shade treatment (0%, 30%, 60%, and 80%) controlled via shade cloth. A fence excluded deer. Oven dry frond biomass increased with frond density, and was inversely correlated with white ash seedling shoot growth. The use of simulated fern fronds without root competition (i.e., shade cloth) indicated that loss of light is not the only limiting factor.

147. **Hollinger, D.Y.** 1987. Photosynthesis and stomatal conductance patterns of two fern species from different forest understories. Journal of Ecology 75:925–935.

Carbon dioxide and water vapor exchange, photosynthesis and transpiration rates, and active photon flux density were measured on crown fern growing beneath hard beech (*Nothofagus truncata* (Col.) Ckn.), and under bracken fern in a neighboring radiata pine plantation. The bracken fern understory received a higher percentage of the above-canopy photosynthetically active photon flux. Sunflecks were important in both understories, but accounted for more of the light reaching the bracken fern. The ferns' photosynthetic rates corresponded to the light environment of their respective forest communities. Both ferns showed high stomatal conductance relative to photosynthetic capacity and relatively insensitive stomata. The opportunistic stomata make them adapted to a fluctuating light environment. Findings indicate that the photosynthetic characteristics of these two fern understories can be influenced by the overstory.

148. **Horsley, S.B.** 1977. Allelopathic inhibition of black cherry by fern, grass, goldenrod, and aster. Canadian Journal of Forest Research 7(2):205–216.[1]

The continual regeneration failures of "orchard stands" and "savannah" areas within the Allegheny Plateau may result from allelopathic interactions. Investigations eliminated the lack of seed source, lack of advance regeneration, losses to browsing, high soil temperatures, frost injury, low soil moisture, and lack of nutrients as causes of poor regeneration. Seedlings free from herbaceous interference grew well, regardless of shade status. Those under herb cover did not grow, even after the shade was removed. More importantly, after the exhaustion of cotyledonary reserves, seedlings were inhibited by foliage extracts of bracken fern, wild oat grass, goldenrod and flat-topped aster, and root washings from goldenrod and aster. This implicates allelopathic interactions in the regeneration failure.

[1]See citations #154 and #155 for more recent findings.

149. **Horsley, S.B.** 1977. Allelopathic inhibition of black cherry. II. Inhibition by woodland grass, ferns, and club moss. Canadian Journal of Forest Research 7(3):515–519.[1]

Allelopathic effects of herbaceous understory plants may lead to regeneration failures of formerly well-stocked black cherry stands. On the poorly drained Allegheny hardwood sites of this study, the presence or absence of herb cover, and the presence or absence of a particular ground cover, influenced seedling germination and establishment. There were ~80% fewer seedlings on plots having ferns, and ~50% fewer on plots having *Lycopodium*. Reduced numbers of black cherry were associated with New York and hayscented ferns, club moss, and short husk grass. Height reductions were noted only under fern and grass. There were fewer red maple on the fern and grass plots, and fewer sugar maple on the fern plots. A greenhouse pot study investigated the impact of individual root extracts on seedlings that had exhausted cotyledonary reserves. Extracts of all four ground covers inhibited the growth of black cherry seedlings. Ferns and grasses cast dense shade in addition to their allelopathic interference. In field situations, club moss may not present a large enough surface for leachate to be detrimental. It may actually stimulate growth, as its presence is often associated with increases in soluble N, P, K, and Fe. Findings imply that clearcutting and shelterwood seed cutting on poorly drained Allegheny hardwood soils will stimulate existing hayscented and New York ferns and short husk grass. Future research should address the relative importance of allelopathy and shade on regeneration failures, and the proportion of overstory basal area that can be removed without promoting fern and grass development.

[1]See citations #154 and #155 for more recent findings.

150. **Horsley, S.B.** 1977. Allelopathic interference among plants. II. Physiological modes of action. P. 93–136, in Proceedings of the Fourth North American Forest Biology Workshop, 1976. Aug 9–11, 1976. Syracuse, NY. Wilcox, H.E., and A.F. Hamer (Eds.) SUNY College of Environmental Science and Forestry. Syracuse, NY.[1]

A review about the inhibition of one higher plant by another through the direct interference of some essential metabolic process. Allelopathic chemicals are released from plant tissues through root exudates, volatilization, or leaching of living tissue or plant residues. The soil acts as a filter, mediating all non-volatilized inhibitors. The chemicals may be changed qualitatively or quantitatively when adsorbed on soil colloids, fixed in soil humus, and transformed and degraded by soil microorganisms. Accumulated chemicals may directly impact other plants or provide carbon sources for microorganisms that deter competing plants. Depending on the chemical, uptake can be passive or active and may be influenced by pH. Plants appear to control the rate of uptake and may conjugate toxins with sugar or other substances, making them less reactive. Higher plants may also metabolize the chemicals though hydroxylation, methylation, or demethylation. The most commonly observed effect on receiver plants is delayed or prevented germination. Reduced height development, root growth, and dry weight accumulation have also been observed. Death may occur. These result from the inhibition of ion uptake, respiration and oxidative phosphorylation, photosynthetic carbon fixation, enzyme or hormone activity, protein synthesis, cell division and elongation, or hemoglobin synthesis. In temperate systems, the most common secondary chemicals implicated in allelopathic interactions are phenolic compounds, particularly benzoic and cinnamic acids and coumarins.

[1]See citations #154 and #155 for more recent findings.

151. **Horsley, S.B.** 1979. Chemicals from herbaceous plants maintain forest openings. Pennsylvania Forests 68(4):12–13, 24.[1]

Fire, combined with deer browsing, prevents or severely restricts tree regeneration on poorly drained soils of the Allegheny plateau. Instead, herbaceous plants (particularly wild oat grass, rough stemmed goldenrod, flat topped aster, and bracken fern) have flourished. Aspen occurs sporadically, but not longer-lived species. Abundant black cherry seedlings fail to grow well or live long. The dense herbaceous cover interferes with seedling development in ways other than by reducing light, moisture, or nutrients. Foliage extracts of all four plants inhibited growth by up to 75%. Root washings from aster and goldenrod decreased growth. Analyses indicated that the toxins accumulated in the pots, suggesting the need to remove or reduce herb presence before trying to regenerate a stand.

[1]See citations #154 and #155 for more recent findings.

152. **Horsley, S.B.** 1988. Effects of hayscented fern on nitrogen transformations in a shelterwood cut Allegheny hardwood stand (abstract). P. 232, in Proceedings of the Tenth North American Forest Biology Workshop; 1988. July 20–22, 1988, Vancouver, BC. J. Worrall, J. Loo-Dinkins, and D.P. Lester (Eds.). University of British Columbia.[1]

Hayscented fern interferes with establishment of black cherry regeneration after shelterwood method seed cutting in Allegheny hardwood stands. Nitrogen is the most limiting nutrient in these stands and black cherry is a high nitrate demanding species. Thus, interference with nitrate production or availability could account for the hayscented fern interference. Trenching controlled the presence of overstory tree roots. Treatments included: ferns only, tree roots only, fern and tree roots, and no fern or tree roots. The vegetation treatments had little effect on ammonium-nitrogen pool size, but there were differences for nitrate-nitrogen. Plots with no fern or tree roots had the largest nitrate pool size. Those with tree roots only or fern and tree roots had the smallest nitrate pool size. Soil solutions in plots with either tree roots only or fern and tree roots usually did not contain more than 0.5 to 1.0 ppm of nitrate during the growing season. Soil solution nitrate rose steadily from mid-May until late fall on fern only and no fern or tree [sic] root plots in 1986. Nitrate concentration peaked at 15 ppm in early November on fern plots, and at 39 ppm in late October on no fern or tree root plots. In 1987, soil solution nitrate reached only 9 and 16 ppm, respectively. Net mineral production followed a sigmoid curve in both years, with amplitude greater in 1986 than 1987. Nitrogen production was near zero or positive in May, strongly negative in June, strongly positive in July, and then decreased in August and September. The strong negative net nitrogen production in June correlated with negative net ammonium production and little net nitrate production. Strong positive net production in July correlated with high net nitrate production and a small negative net ammonium production. The vegetation treatments did not influence these trends.

[1]Published only as an abstract, as summarized here.

153. **Horsley, S.B.** 1989. Effect of fern groundcover and overstory tree roots on nitrogen transformations in a partially cut *Prunus-Acer* Allegheny hardwood stand (abstract). American Journal of Botany Supplement 76(6):108.[1]

The effect of hayscented fern and overstory tree roots on NH_4- and NO_3-N pool sizes and production was evaluated over a 2-yr period after a shelterwood cut in a stand having a mosaic of patches with and without fern groundcover. Four vegetation treatments were established: ferns only, tree roots only, fern and tree roots, and no fern or tree roots. Mineral N pool sizes (ug/g organic matter) in the upper 7.5 cm of soil were highest in May and June of yr 1, then declined to a lower level by August. It remained unchanged through yr 2. The vegetation treatments had little effect on NH_4-N pool size. Fern and overstory tree roots reduced the NO_3-N pool size. Overstory tree roots had the greatest effect. Net mineral N production followed a sigmoid curve in both years, with amplitude greater in yr 1 than yr 2. N production was near zero or positive in May, strongly negative in June and strongly positive in July, and decreased in August and September. Strong negative net N production in June was correlated with negative net NH_4 production and little net NO_3 production. Strong positive net N production in July was correlated with high net NO_3 production and low negative NH_4 production. The vegetation treatments did not influence these trends.

[1]Published only as an abstract, as summarized here.

154. **Horsley, S.B.** 1993. Role of allelopathy in hay-scented fern interference with black cherry regeneration. Journal of Chemical Ecology 19(11):2737–2755.

The allelopathic effect of hayscented fern on black cherry germination, seedling survival, and growth was evaluated by monitoring response to fern foliage extracts, root washings, and soil transformation products. The seed and seedlings were grown in natural soil cores in addition to semi-sterile sand. Living fern foliage was left intact, but kept away from the seedlings. Fern leachates, root washings, or soil transformation products did not affect black cherry seed germination and seedling growth. Rather, shade cast by fern foliage causes the interference.

155. **Horsley, S.B.** 1993. Mechanisms of interference between hayscented fern and black cherry. Canadian Journal of Forest Research 23:2059–2069.

Germinated black cherry seed fail to develop into established seedlings beneath a dense cover of hayscented fern. The research evaluated effects of this fern on light, soil water, phosphorus, and nitrogen after partial overstory removal. Light was the key mechanism for interference. Dense ferns importantly reduced its quantity and quality. Primarily, withdrawal by overstory trees reduced soil nitrate availability. Hayscented fern had little effect on soil moisture, soil phosphorus or ammonium, nor their availability. Mycorrhizal infections and foliar phosphorus concentrations were similar in fern and fern-less areas. Survival and growth of germinated seedlings will improve only by reducing the shade by ferns.

156. **Hoshizaki, B.J., and K.A. Wilson.** 1999. The cultivated species of the fern genus *Dryopteris* in the United States. American Fern Journal 89(1):1–98.

The 50 species of *Dryopteris* under cultivation in the United States are described. Diagrams, cultural requirements, and dichotomous keys are provided to aid in identification.

157. **MacCammon, G.W.** 1938. Bracken Fern: Its Silvicultural Aspects in the Northeastern Forest. M.For. thesis. SUNY College of Forestry. Syracuse, NY.

Bracken fern has been widely studied in term of agriculture, particularly in the British Isles. However, it is unknown whether the resultant information can help foresters in the Adirondack Mountains of New York. This study addressed bracken succession, destructive effects, and potential control. Bracken was conspicuously absent from areas with frequent low growing season temperatures. In uncut stands, bracken occurred only in the openings on spruce flats. It was absent from both boggy areas and in old-growth northern hardwood stands. High water tables or rapid regeneration of hardwood seedlings kept bracken fern in check on cut-over lands. Cut areas subject to fire had abundant fern cover 3–5 yrs later. Regeneration failures were attributed to smothering or breakage by heavy, snow-laden fronds, dense shade, and competition for water. Of the species observed, red pine suffered the least ill effects due to its strong bole and stocky growth habit. Norway, white, and red spruce appeared to recover with only slight difficulty. White pine and Scots pine are not recommended. Within one month after a control treatment in June by breaking the fern with sticks, bracken recovered to the height and vigor of unbroken control areas. After a second treatment in July, the ferns did not regrow by September. Plowing and removal of rhizomes also successfully reduced fern cover.

158. **Maguire, D.A., and R.T.T. Forman.** 1983. Herb cover effects on tree seedling patterns in a mature hemlock-hardwood forest. Ecology 64:1367–1380.

Herb distribution may importantly control tree seedling density and distribution in Cathedral State Park, WV. This hemlock-fern community has pockets of birch-maple. The herb layer had previously been composed of primarily hayscented fern and spinulose shield fern, with lesser amounts of cinnamon fern. Living and dead spinulose shield fern still had a high frequency and cover. Herb cover accounted for most of the variation in tree seedling density and distribution, with a negative relationship between red maple seedling abundance and that of spinulose shield fern. Similarly, red maple, birch, cherry, hemlock, and total seedling density were much lower inside patches of hayscented fern. As species of all shade tolerances were affected, allelopathic interactions rather than light may affect tree seedling distribution and density. The distribution of herb patches is also influenced by tree canopy foliage and by other herb patches.

159. **McCormick, L.H., and T.W. Bowersox.** 1997. Grass or fern competition reduce growth and survival of planted tree seedlings. P. 286–93, in 11th Central Hardwood Forest Conference; Mar 23–26, 1997. University of Missouri, Columbia, MO. S.G. Pallardy, R.A. Cecich, H.G. Garrett, and P.S. Johnson (Eds.). USDA Forest Service General Technical Report GTR-NC-188.

Bare-root northern red oak, white ash, yellow-poplar, and white pine seedlings were planted in herbaceous communities dominated by hayscented fern, poverty oat grass, or areas within those communities where the grass or fern had been treated with glyphosate (1.7 kg/ha). Average survival 4 yrs post planting was equally good in grass-free and fern-free treatments. However, survival of the hardwood species was lower under weedy conditions. White ash and yellow-popular showed the greatest height growth when released from competition, and more so when released from fern than grass.

160. **Milberg, P.** 1991. Fern spores in a grassland soil. Canadian Journal of Botany 69:831–834.

A soil diaspore bank was assessed after 35 yrs of grazing, biannual mowing, and free succession, each with and without yearly fertilizer application. Spore banks contained spinulose wood fern, two unidentified species of *Dryopteris*, and bracken fern even in grasslands lacking ferns. This likely resulted from long-distance dispersal. Spores may have also accumulated over a long period of time. Such dispersal could be an important source for the regeneration of ferns in later successional stages. A large spore bank also offers the potential for prothallia from different sporophytes to develop at the same time in a limited space.

161. **Page, C.N.** 1979. Experimental aspects of fern ecology. P. 552–589, in The experimental biology of ferns. Dyer, A.F. (Ed.). Academic Press, London.

Habitats for individual species are broadly defined by the interplay of a wide assortment of physical conditions including aspect, slope, soil depth, pH, parent material, drainage and aeration, light, and moisture availability. Rarely do two or more species occupy identical habitats. Occasionally, two or more species will form an association, but ferns tend to occur in single-species stands, even over a very small area, within a uniform habitat.

162. **Page, C.N.** 1985. The strategies of bracken as a permanent ecological opportunist. P. 173–181, in Bracken: Ecology, Land Use and Control Technology. Proceedings of the International Conference—Bracken '85. Smith, R.T., and J.A. Taylor (Eds.). Parthenon Publishing.

"Bracken fern is either one of the world's worst weeds or one of the most successful pteridophytes ever." It has high disease resistance, low palatability, allelopathic effects on competing species, high propagule mobility, wide climatic and edaphic tolerance, adaptation to fire, association with ants, and cytrological and genetic polymorphism.

163. **Penrod, K.A., and L.H. McCormick.** 1996. Abundance of viable hay-scented fern spores germinated from hardwood forest soils at various distances from a source. American Fern Journal 86(3):69–79.

Spore-origin hayscented fern can colonize forest stands and subsequently interfere with hardwood regeneration. This study sought to determine where and how many spores exist in relation to the spore source in undisturbed mixed oak stands of central Pennsylvania along roadsides or in clearcuts adjacent to undisturbed stands. Intact soil samples were taken at 0, 2, 4, 5, 8, 10, 20, 30, 40, and 50 m from within large hay-scented fern communities before and after spore dispersal. After 10–12 weeks in the greenhouse, counts of gametophytes from the top 1 cm were used as an indication of spore abundance. Hayscented fern spores occurred up to 50 m from the source, but the abundance generally decreased with distance. Most viable spores were in soil samples taken within 2 m of the source, and the highest numbers were always within 4 m. Viable spores persist at least 1 yr.

164. **Poel, L.W.** 1961. Soil aeration as a limiting factor in the growth of *Pteridium aquilinum* (L.) Kuhn. Journal of Ecology 49(1):107–111.

Bracken fern generally does not grow on poorly drained soils, and is often replaced on such sites by *Juncetum acutiflori*. Oxygen diffusion was measured at 5-ft intervals along two 100-ft transects through the transition zone between these species. The mean rate of oxygen diffusion corresponded with topography and vegetation. However, the evidence was insufficient to show a clear relationship between soil aeration and the presence of bracken fern on poorly drained soil.

165. **Raynor, G.S., E.C. Ogden, and J.V. Hayes.** 1976. Dispersion of fern spores into and within a forest. Rhodora 78:473–487.

Controlled release of fern (*Osmunda* and *Dryopteris*) spores demonstrated that atmospheric motion disperses fern spores similar to smaller pollen. The larger size and greater settling velocity of spores cause them to fall closer to the source. Spores are carried greater distances in the open than under forest cover. Spores are carried long distances only by strong winds and with good atmospheric mixing.

166. **Siccama, T.G, F.H. Bormann, and G.E. Likens.** 1970. The Hubbard Brook Ecosystem Study: Productivity, nutrients, and phytosociology of the herbaceous layer. Ecological Monographs 40(4):389–402.

Within the control watershed of the Hubbard Brook Ecosystem Study, herb cover was higher (27.8 g/m^2 vs. 7.7 g/m^2) and included more species (7.8 species/m^2 vs. 6.1 species/m^2) on plots with a tree canopy cover of <75%. Spinulose wood fern had the greatest importance (sum of relative weight of current growth and relative cover) on 46% of the plots. It comprised 85% of the weight of current growth among the cryptogam group and about 70% of the total weight of all herbs, but generally had lower nutrient concentrations in its tissues. This suggests that its success is due in part to its lower nutrient requirements. Hayscented fern occurred less frequently, and was positively correlated with indicators of past disturbance (especially pit and mound topography).

167. **Stromayer, K.A.K., and R.J. Warren.** 1997. Are overabundant deer herds in the eastern United States creating alternate stable states in forest plant communities? Wildlife Society Bulletin 25(2):227–234.

This literature review discusses ways that white-tailed deer create alternate stable states in woody communities. Most critically, deer suppress advance tree regeneration that would normally restock a site following overstory cutting or fire. Large amounts of edge communities and deer avoidance of several problem herbaceous species (most notably ferns) compound the direct effects of browsing.

168. **Underwood, L.M.** 1881. Our Native Ferns and How to Study Them with Synoptica Descriptions of the North American Species. Leader Publishing Co. Bloomington, IL.

Describes the "haunts, habits, and distribution of ferns," as well as the morphology of growing ferns, fructification, germination, structure, classification, and a description of how to study ferns. In general, fern growth depends on appropriate warmth, moisture, and shade specific to each species. Common bracken fern is most common on uncultivated places and rocky hillsides.

169. **Watt, A.S.** 1950. Contributions to the ecology of bracken (*Pteridium aquilinum*). V. Bracken and frost. New Phytology 49:308–327.

The susceptibility of bracken fern to frost was quantified over a 15-yr period. Initial observations showed that the plants have a large reserve of buds and differentiated fronds, with only a small portion of the frond potential expressed as mature fronds. A high proportion of fronds and buds near surface rhizome pieces are lost during serious winter frosts. Killing or damaging current fronds seemed either to stimulate or remove the inhibition of new frond development. New growth was more effectively stimulated by removing the fronds than by their loss to frost. Replacement fronds grew more rapidly, particularly when frost killed the current frond. Winter frost reduced the length of petioles during the following growing season, either due to reduced reserves or a selective effect on fronds originating from buds of different depths. An adequate snow or litter cover can moderate frost damage.

170. **Werth, C.R., and M.I. Cousens.** 1990. Summary: The contributions of population studies of ferns. American Fern Journal 80:183–190.

The authors summarize findings in papers the American Fern Journal's special issue on the population studies of ferns. They discuss the need for further research into fern life history. They arrange questions into eight categories: taxa variability; spore dispersal; gametophyte establishment; mating systems, sporophyte recruitment; and the genetic polymorphism and long-term demographic studies of sporophyte populations.

B. Uses and Cultural Importance

171. **Anderson, J., D. Blahna, and D.J. Chavez.** 2000. Fern gathering on the San Bernardino National Forest: Cultural versus commercial values among Korean and Japanese participants. Society and Natural Resources 13(8):747–762.

Contrary to the expectations of the San Bernardino National Forest staff, permit holders who gather ferns generally do it to enjoy this time spent outdoors with family and friends, and not for commercial purposes. Japanese respondents rated the environmental aspects as most important, while Korean respondents cited the social aspects. Respondents also simply like the taste of ferns, and want to teach children or others about their cultural background. Many respondents also said they take care to ensure a future supply. Harvesters were dissatisfied with the cost of permits, particularly as they picked less than they paid for, and did not pick for profit. Managers accustomed to considering the economic value of special forest products might consider the interests of multicultural recreational users in their pricing structure, advertising, and signage.

172. **Callaghan, T.V., G.J. Lawson, and R. Scott.** 1982. Bracken as an energy crop? P. 1239–1247, in Solar World Forum. Hall, D.H., and J. Morton (Eds.). Pergamon Press. Oxford.

Bracken's widespread distribution, high yield on poor soils, and ability to be harvested without reducing usage, value, or landscape quality make it an attractive option for biomass energy. The authors use average yields from previous studies to demonstrate that the Scottish bracken resource (8 t/ha/yr x 2,000 km^2 = 33.6 PJ) can meet 4.5% of the country's energy consumption, or if converted to methane could offset 25% of its petrol and petroleum product imports. Further, bracken is a noxious weed that the Government has paid to eradicate. Bracken could be harvested successively or periodically during the growing season and digested, or harvested when senescent and gasified or pelletized and combusted.

173. **Chavez, D.J., and C. Gill.** 1999. Bracken fern harvesting. Forestry Research West: 5–10.

After determining that bracken fern is a forest product in 1981, the Arrowhead Ranger District of the San Bernardino National Forest began offering harvesting permits. The Forest Service wants to know who harvests and why so it can recommend means to protect the quality and diversity of neighboring resources. In-depth interviews and on-site observations indicate that Japanese and Korean Americans harvest the ferns primarily for personal consumption, rather than for sale. Many gatherers emphasized social and environmental values of the gathering experience, with the cultural aspects particularly important for those of Korean descent. Ferns are eaten fresh seasonally, or parboiled and dried for later consumption. Picking, processing, and eating bracken evoked fond memories for older harvesters. Some pickers knew of the toxic and carcinogenic nature of bracken, but chose to ignore it. Conversely, some young men avoided consumption, believing that it causes impotence. As most users of the program are older and have limited English skills, customer service is the key means to enhance this program.

174. **Dalgity, A.C.** 1907. The common brake as food. The Fern Bulletin 15:41–43.

Taste trials indicated that cleaned of their bitter scales, bracken stalks have a unique flavor and readily cooked like asparagus. They are nutritionally similar to cabbage. A historic preparation is to dry and finely pound the rhizome into a flour, but its use has been discontinued with the ready availability of wheat flour.

175. **Callaghan, T.V., R. Scott, G.J. Lawson, and A.M. Mainwaring.** 1985. An experimental assessment of native and naturalized species of plants as renewable sources of energy in Great-Britain: Natural Environment Research Council. Contract No. ESE-R-015-UK.

Bracken fern's widespread and productive nature make it a candidate for use as a biofuel. A 3-yr experimental program examined the effect of weather, time of harvesting, frequency of harvesting, and addition of fertilizers on its management. An annual fall harvest is feasible for more than 3 yrs, but then a rest year may be necessary for long-term management. Fall harvested bracken can be pelletized to 760 kg m^{-3}. An annual summer harvest can be maintained for only 4 yrs to produce biogas in an anaerobic digester at 40% conversion efficiency. Weather and repeated cutting affect the yields, but fertilizer application does not. The digester residues are a potential source of fertilizer, and this deserves further investigation.

176. **Evans, I.A., J.H. Prorok, R.C. Cole, M.H. Al-Salmani, A.M.H. Al-Samarrai, M.C. Patel, and R.M.M. Smith.** 1982. The carcinogenic, mutagenic and teratogenic toxicity of bracken. Proceedings of the Royal Society of Edinburgh 81B:65–77.

A review of the literature pertaining to health problems associated with the consumption of bracken fern. Animals raised on a diet of bracken suffer from a variety of gastro-intestinal cancers, possibly a result of quercetin rather than shikimic acid. Japan has one of the highest rates of gastric cancers, possibly attributed to consumption of either bracken fern or tea.

177. **Gliessman, S.R., and C.H. Muller.** 1972. The phytotoxic potential of bracken, *Pteridium aquilinum* (L.) Kuhn. Madrono 21:299–304.

Extracts from live and dead bracken fronds were used as a bioassay for toxicity to *Bromus rigidus*. Extracts of green fronds proved insignificantly toxic even when concentrated. Those from dead fronds proved highly toxic. Toxicity was reduced after one winter season, and completely removed by leaching rains after 2–3 seasons. Transfer of inhibitors of other plants occurs through leachate from bracken fronds washed into the soil by rain, fog, or dew drip, even from unbroken fronds. The toxin involved in this interaction was tentatively identified as cinnamic acid.

178. **Lawson, G.J., T.V. Callaghan, and R. Scott.** 1984. Renewable energy from plants: Bypassing fossilization. Advances in Ecological Research 14:57–114.

The land required for dedicated biofuel production has the potential to compete with food and fiber production. However, such opportunity energy crops can be collected without significant disruption to agriculture or forestry production, and can provide independence from fluctuations in oil availability. Bracken fern is widespread and productive enough to justify harvesting. Bracken pellets can be produced at an energy price less than coal. Fresh bracken can also be either anaerobically digested (at four times the cost) or thermally converted (marginally cost effective) to methane. A financial analysis indicated that costs were less than coal in 1984, but the level of sophistication and cost of desification need to decrease. The article only briefly discusses harvesting, where logistically possible, as an alternative to chemical control of the fern.

179. **Rymer, L.** 1976. The history and ethnobotany of bracken. Botanical Journal of the Linnean Society 73:151–176.

Bracken spread in Scotland contemporaneously with the change from cattle- to sheep-farming in the 18th century. Bracken provided an important source of potash for glass, soap, and bleach. Fronds mixed with grasses fed livestock and cushioned packed fruit and other items. It has been burned for fuel in brick-making, brewing, and for domestic use.

C. Fern Responses to Overstory Disturbance

180. **Collins, B.S., and S.T.A. Pickett.** 1988. Demograhic responses of herb layer species to experimental canopy gaps in a northern hardwoods forest. Journal of Ecology 76(2):437–450.

Foresters have long valued canopy gaps for recruitment of less shade-tolerant species. This research examined the demographic response of forest plants in the herb layer when exposed to either average or small gaps in a 70-yr-old even-aged Alleghany hardwood stand. These included single- or multiple-tree gaps representative of the mean size of smaller gaps in the region. Trees were cut to mimic tree snaps, rather than uprooting, although both disturbances commonly produce canopy gaps in the region. Comparisons between the man-made gaps and beneath the adjacent intact canopy showed that fern leaf size and number generally increased over the study period. Growth was not statistically different between treatments. Hayscented fern became readily established in the transitional area, and New York fern encroachment was more variable.

181. **Daniels, R.E.** 1986. Studies in the growth of *Pteridium aquilinum* (L.) Kuhn (bracken). 2. Effects of shading and nutrient application. Weed Research 26:121–126.

Bracken fern plants receiving no nutrients, nitrogen, phosphate, or a balanced fertilizer were grown in shaded and unshaded environments. The number of fronds on unshaded plants increased significantly, as they also did on plants treated by NP and NPK fertilizer. Single applications of either N or P had little effect. Shaded plants had much greater leaf area on their fewer fronds. NP and NPK additions were also associated with longer rhizomes. Findings suggest that an adaptable growth and frond morphology may facilitate colonization of open areas. In addition, since the more favorable nutrient and light environments result in more fronds, that may make the plants more susceptible to foliar herbicides.

182. **de la Cretaz, A.L., and M.J. Kelty.** 1999. Establishment and control of hay-scented fern: A native invasive species. Biological Invasions 1(2/3):223–236.

With increased light and removal of competing plants by herbivores, hayscented fern may develop into a dense, monospecific understory that inhibits the regeneration of desirable tree species. Analysis of 28 red and white pine plantations representing six thinning regimes and two levels of browsing pressure indicated that during 15 yrs of intensive browsing after thinning, ferns formed dense thickets. But neither thinning nor intensive herbivory alone is sufficient to trigger such a response. Herbivory must be controlled in high-browse areas to facilitate tree regeneration. A second study assessed the relative importance of the fern's canopy, dense root mat, and dead fronds on the germination of sown black birch seed. Complete removal of the rhizome mat and associated litter greatly increased the germination of woody and herbaceous species. Mixing this organic mat into the mineral soil increased germination, but the resulting seedlings did not survive the regrowth of ferns. In the repeatedly clipped area, fewer black birch, white pine, and *Rubus* germinated, but they thrived despite the intact rhizomes and litter layer. The fern control treatments significantly influenced fern density, frond length, and percent grass cover in the first and second yrs. Treatments mimicking scalping and root-raking resulted in fern regrowth indistinguishable from untreated areas. Results indicate that the interception of light by ferns is more limiting than the presence of a fern root mat for successful establishment of black birch, although both are important. The authors suggest mowing as a control mechanism.

183. **Gilliam, F.S., N.L. Turrill, and M.B. Adams.** 1995. Herbaceous-layer and overstory species in clear-cut and mature central Appalachian hardwood forests. Ecological Applications 5(4):947–955.

Ecosystem management necessitates a better understanding of the response of the herb layer to overstory manipulation, as well as knowing how the herb layer interferes with seedlings and sprouts of the future overstory. This paper focuses on the effect of clearcutting on species composition of the central Appalachian hardwoods. Cover of vascular plants ≤1 m was estimated within ten 1-m^2 subplots and stems ≤2.5 cm dbh were measured on 15 0.04-ha circular plots per watershed. Canonical correlation loadings suggested a successional sequence whereby shade-intolerant black cherry and yellow poplar were replaced by shade-tolerant sugar maple and northern red oak after ~ 20 yrs. Shield fern and Christmas fern were among the important herb species, regardless of stand age. The particularly high frequency of these species on one watershed was attributed to its north-facing slope. Young sites were dominated by allogenic factors (e.g., soil characteristics) while the older sites were influenced more by autogenic factors (e.g., stand characteristics). However, richness and diversity were not altered significantly over the ~60 yrs after clearcutting.

184. **Groninger, J.W., and L.H. McCormick.** 1992. Effects of soil disturbance on hayscented fern establishment. Northern Journal of Applied Forestry 9(1):29–31.

A dense cover of hayscented fern can interfere with the establishment and growth of desirable hardwood tree regeneration through regeneration delays and failures. Spread of fern beds into adjacent areas is facilitated by asexual reproduction from the perennial invasive rhizome system. The degree that spores contribute to this invasion is not known. The study reports on the influence of logging-related soil disturbance on establishment via spores. Cutting during the spring and summer reduced the stand basal area from 100 to 80 ft^2/ac, and gypsy moth related mortality further reduced live basal area by 10–15%. Presence or absence of newly established ferns and the presence or absence of logging-related soil disturbance were recorded on plots along line transects through spring- and summer-cut areas. Disturbance, particularly during spring harvests, facilitates the establishment of spore-origin hayscented fern. Restricting logging to dry periods or following the cutting treatment with a broadcast herbicide application should reduce spread of ferns via spores.

185. **Hall, I.V.** 1955. Floristic changes following the cutting and burning of a woodlot for blueberry production. Canadian Journal of Agricultural Science 35:143–152.

Wild blueberry stands in New Brunswick have been converted to commercially productive fields by a planned program of burning every third spring. This study considered whether woodlands bordering such fields could be similarly converted, and documented plant succession during the conversion. The experimental area was harvested and suckers were pruned prior to burning 2 and 3 yrs later. Floristic changes were recorded each June. Hayscented fern and bracken fern increased after the treatment. These commonly occur in clearings and were present prior to the conversion treatment. They survived the burning via rhizomes buried 2–4 in. below the surface. Clearing and burning removed other competition, insured full sunlight, and increased available nutrients. Established fern rhizomes responded more rapidly than seedlings from neighboring blueberry fields. Hayscented fern produced spores under 50% full sunlight, had moderate vegetative growth at only 10% light, and survived with minimum growth under only 1% of full sunlight. Managers should not expect seedlings to succeed in areas with an established fern rhizome system.

186. **Horsley, S.B., and D.A. Marquis.** 1983. Interference by weeds and deer with Allegheny hardwood reproduction. Canadian Journal of Forest Research 13:61–69.

A dense layer of hayscented fern, New York fern, and short husk grass will reduce the development of advance regeneration after a shelterwood seed cutting, particularly in areas under high browsing pressure. These herbs also impede seedling growth after the removal cutting. Over 4 yrs in fenced and fenced plus hand-weeded areas, compared to an unfenced and unweeded control, ferns significantly interfered with seedlings following both cuttings. Pin cherry, yellow birch, black birch, and raspberries all grew through the fern layer, but were extensively browsed once visible. Deer did not directly affect seedlings that did not emerge through the dense herb layer. Areas with raspberry had substantially less fern and grass cover, so browsing of the raspberries would indirectly compound regeneration problems. In ferny regions with inadequate deer density control, use of shelterwood method cutting will encourage fern and grass, and fail to successfully regenerate desirable tree seedlings.

187. **Hughes, J.W., and T.J. Fahey.** 1991. Colonization dynamics of herbs and shrubs in a disturbed northern hardwood forest. Journal of Ecology 79:605–616.

The study area was sampled prior to removing all stems greater than 2 cm dbh, and again each August–September for an additional 3 yrs. The seed rain and predation were also sampled for 2 yrs after overstory removal. Seedling emergence from soil samples was quantified by species. The spatial distribution of species was similar before and after cutting. Colonization occurred primarily from existing stems and expansion of existing patches, rather than by establishment of new seedlings. By contrast, the first yr recruitment of raspberries occurred through germination of buried seed. Populations of whorled wood aster and hayscented fern increased steadily after the overstory removal, respectively, to overall frequencies of 12.6 and 4.7 times higher than prior to overstory cutting. Rapidly colonizing species (e.g., *Rubus idaeus*) did not affect the spatial distribution of herbs present in the undisturbed forest prior to overstory removal (e.g., spinulose shield fern). Results suggest an important distinction between disturbances that do not disturb the forest floor, and those that affect the forest floor and destroy the preexisting plants understory.

188. **Marquis, D.A.** 1978. The effect of environmental factors on the natural regeneration of cherry-ash-maple forests in the Allegheny Plateau region of the eastern United States. P. 90–99, in Proceedings: Establishment and Treatment of High-quality Hardwood Forests in the Temperate Climatic Region. September 11–15, 1978. Fevillus Precieux; Nancy-Champenoux, France. International Union of Forest Research Organizations, Division 1. Nancy-Champenoux, France.

Cherry-maple communities are generally managed under an even-aged silvicultural system and are ineffectively regenerated by clearcutting unless advance regeneration is sufficiently dense. The quantity of light reaching regeneration was controlled experimentally by varying the density of shade cloth in tents over the seedlings. Light was controlled under forested conditions by removing varying proportions of overstory basal area. Supplementary treatments allowed light effects to be separated from those of soil moisture, temperature, and nutrient composition. Soil conditions and herbaceous competition were also considered. Light exposure affected all species, as it influenced soil moisture and surface soil temperature. All species germinated and survived best under partial shade, but low light impeded root development of some shade-intolerant species. A dense fern and grass cover reduced establishment and growth of these species. Maintaining an overstory density of 60–70% for a shelterwood seed cutting will minimize spreading of the ferns. Overstory removal can follow in 5–10 yrs.

189. **McGee, G.G., D.J. Leopold, and R.D. Nyland.** 1995. Understory response to springtime prescribed fire in two New York transition oak forests. Forest Ecology and Management 76:149–168.

Eight to 12 yrs after 0 to 2 springtime prescribed fires in transition oak stands in south-central New York, forb richness, forb and shrub cover, and the importance values of forbs relative to shrubs had increased in burned areas. Yet the community composition remained relatively unchanged. Hayscented fern increased in importance after the fires, and was among the species responsible for separating 1- and 2-burn-areas in the canonical correlation analysis. Rhizome depth related to post-fire competitiveness of dominant perennial forbs and shrubs.

190. **Ristau, T.E., S.B. Horsley, and L.H. McCormick.** 2001. Sampling to assess species diversity of herbaceous layer vegetation in Allegheny hardwood forests. Journal of the Torrey Botanical Society 128(2):150–164.

The study evaluated the optimum frequency and time of sampling to produce diversity indices of the herbaceous layer beneath Allegheny hardwood forests. Sampling occurred monthly from May through August of 1992 and 1993, within four 8-ha sites with a recent history of partial overstory removal. In both years, hayscented fern, New York fern, and spinulose wood fern were the most abundant species. All three emerge in the spring and expand over the growing season; sampling for their abundance and cover should occur in July or August. To get total herb abundance and diversity data, do an additional sampling in May to capture spring ephemerals.

191. **Sage, R.W., Jr., W.F. Porter, and H.B. Underwood.** 2003. Windows of opportunity: White-tailed deer and the dynamics of northern hardwood forests of the northeastern US. Journal for Nature Conservation 10:213–220.

More than 50 yrs of study of northern hardwood regeneration in the central Adirondacks indicates that individually and together, herbivory, lighting regimes, and site conditions determine regeneration success. Weather, predation, human exploitation, pathogens, wind, and fire temper the outcome. Regeneration succeeded during periods of low deer density (<2 deer km^{-2}) and significant forest disturbance. Managers can manipulate the key variables to successfully regenerate diverse species in a stand. Localized deer density and beech understory control should accompany shelterwood regeneration method

192. **Thomson, J.A., C. Willoughby, and C.M. Shearer.** 1985. Factors affecting the distribution, abundance and economic status of bracken (*Pteridium aquilinum*) in New South Wales. P. 109–119, in Bracken: Ecology, Land Use and Control Technology Proceedings of the International Conference—Bracken '85. Smith, R.T., and J.A. Taylor (Eds.). Parthenon Publishing.

Questionnaires and surveys were coupled with aerial photos to follow changes in bracken's distribution and determine its rate of spread in Australia. Annual rainfall was the single most important factor correlated with bracken fern abundance on cleared land and woodland communities. Other factors likely to contribute to bracken's spread were recent clearing, decline in fertility, older pastures, low stocking rates, seasonal influences like drought, and increasing cost of labor and fuel for control measures.

193. **Tilghman, N.G.** 1984. Deer browse and forest regeneration. Pennsylvania Forests 74(3):6–8.

This popular press article reports on initial results from 160-ac enclosures stocked with non-reproductive deer at densities of 10, 20, 40, and 80 deer mi^2. Enclosures included cutting treatments with 10% clearcut, 30% thinned, and 60% uncut. At 2 yrs, the clearcut subjected to 10 deer mi^2 had dense stump sprouts and seedlings that averaged 7 ft tall. At 80 deer mi^2, growth was slower and stump sprouts had been preferentially browsed (averaged 4 ft tall). Average seedlings height in areas unprotected by slash was only 2 ft. Ferns covered nearly 18% of the clearcut area under high deer pressure, but less than 5% at low deer densities.

D. Control Methods

194. **Biggin, P.** 1982. Forestry and bracken. Proceedings of the Royal Society of Edinburgh 81B:19–27.

Afforestation in Scotland often occurred on steep or rocky slopes at low elevation or in soils too poor for other uses. The vigorously growing bracken on these sites indicated deep and well drained soil suitable for planting to a wide range of timber species. Yet bracken itself poses a threat to planted seedlings. Hand and mechanical control are still limited in use. Most control is by chemical means, preferably with a single application of a selective herbicide. Past studies indicate that dicamba (3, 6-dichloro-oanisic acid) should only be used prior to planting, and only on sites infertile enough to slow reinvasion. Picloram (4-amino-3,5,6-trichloropyridine-2-carboxylic acid) and chlorthiamid (2,6-dichloro(thiobenzamide)) have provided good bracken control, but severely damaged young Sitka spruce. When bracken fern is the primary weed problem, Asulam (methyl-4-amino-phylsuphonyl carbamate) can be applied pre-planting at 2.8 kg/a.e./ha or post-planting at 2 kg/a.e./ha. Glyphosate (N-(phosphonomethyl) glycine) is best for controlling a wider spectrum of weeds, but causes more damage to the conifers.

195. **Cody, W.J., I.V. Hall, and C.W. Crompton.** 1977. The biology of Canadian weeds. 26. *Dennstaedtia punctilobula* (Michx.) Moore. Canadian Journal of Plant Science 57:1159–1168.

This report provides a thorough review of the biological characteristics of hayscented fern, a native perennial herb with a center of distribution in the Appalachian region. Persistent underground rhizomes allow it to densely colonize lowbush blueberry fields, upland pastures, and roadsides. This characteristic makes it a desirable colonizer after fires, because it prevents soil erosion and accumulates soil organic matter. Both 2,4,5-T and 2,4-D-2,4,5-T mixtures were ineffective in controlling hayscented fern. And while amitrol (3-amino-5-triazole) prevented fern competition during blueberry establishment, it also rendered nearby berries inedible. Cutting must be done prior to spore maturation. However, mowing is often impractical.

196. **Cox, H.R.** 1915. Eradication of ferns from pasture lands in the eastern United States. US Department of Agriculture Farmer's Bulletin 687:1–8.

Cutting or mowing prior to spore maturation and again in mid-August greatly reduces sporing and weakens rootstocks, and has reduced the number of hay-scented fern. Best results came after repeating the treatment a second yr. Controlled burning after cutting may further injure rootstocks, as can seeding to grass and clover and maintaining the pasture by cultivation. Salting fern patches encourages livestock to trample the plants. Applying salt and arsenate of soda in conjunction with seeding, liming, and fertilization successfully controlled hayscented fern. However, this treatment cost more than just mowing, and required an investment in specialized equipment.

197. **Fletcher, W.W., and R.C. Kirkwood.** 1979. The bracken fern (*Pteridium aquilinum* L. (Kuhn); its biology and control. P. 591–636, in The Experimental Biology of Ferns. Dyer, A.F.(Ed.). Academic Press. London.

Bracken fern commonly occurs on marginal and hill land that would be otherwise suitable for grazing. The fern is carcinogenic and consumption is associated with a deadly thiamin-deficiency in certain animals. The paper reviews literature pertaining to bracken's taxonomy and phytogeography, life cycle, historical uses, ecology, and toxicity to livestock. Biological control has been largely unsuccessful, although cattle trample young fronds and pigs root out and consume the rhizomes. Repeated mowing over consecutive growing seasons will reduce frond density and height. Asulam is the most effective herbicide.

198. **Gray, T.** 1984. Goats curb weed problem. The New Zealand Farmer 105(8):13–14.

Goats moved monthly from paddock to paddock reduced blackberry, thistles, broom, and young scrubby trees that were inaccessible to sheep and cattle. The goats only ate bracken fern when short of other feed, reducing it to small clumps. Then sheep ate the new shoots. The goats and sheep held the bracken fern in check, but did not eliminate it.

199. **Horsley, S.B.** 1981. Control of herbaceous weeds in Allegheny hardwood forests with herbicides. Weed Science 29:655–662.

Allegheny hardwood forest openings dominated by bracken fern and its associates fail to regenerate to trees. Hand weeding around natural seedlings resulted in better growth, but is impractical on a large scale. Bromacil, glyphosate, picloram, simazine and hexazinone at four rates and five application dates were assessed for effects on hayscented fern, New York fern, bracken fern, short husk grass, wild oat grass, goldenrod, and flat-topped aster without detrimental effect to black cherry. Control was influenced by date and rate of application, as well as pH. No herbicide interfered with germination and establishment from stored seed. Bromacil at 22.4 kg/ha, picloram at 9 kg/ha, and hexazinone at 13.4 kg/ha adversely affected tree seedling survival or growth. Glyphosate at 1.1 kg/ha proved the most economical for treating these herbs, in either forest stands or openings. July 1 to September 1 application is appropriate for hayscented and New York ferns, and short husk grass. Delaying treatment until August 1 to September 1 is necessary for effective control of bracken fern.

200. **Horsley, S.B.** 1982. Development of reproduction in Allegheny hardwood stands after herbicide-clearcuts and herbicide-shelterwood cuts. USDA Forest Service Research Note NE-308.

Regeneration responses were evaluated 3 yrs after a shelterwood seed cut or clearcut in a single Allegheny hardwood stand treated with Roundup® (glyphosate). Roundup® reduced fern cover from 75–80% of the area, to 1% or less. Reinvasion occurred on 10% of the area in clearcuts, and 3% in the shelterwood areas. Roundup® eliminated short husk grass. Dormant wild oat grass was stimulated by logging, with highest germination in clearcut areas. Desirable hardwood seedlings increased from 5–11% of stand-wide stocking to 95% and 100%, respectively, at 1 and 3 yrs after shelterwood cutting, and 44% and 64% after clearcutting. Black cherry dominated the clearcuts, while red maple and black cherry shared dominance in the shelterwood areas. The response was more variable in clearcut blocks, making the herbicide-shelterwood sequence more reliable in regenerating black cherry and red maple.

201 **Horsley, S.B.** 1984. Ferns: Shapers of tomorrow's northern hardwood forests? Adirondac 48(9):20–23.[1]

Hayscented and New York ferns affect the composition of future forests in New York. Even small numbers proliferate after thinning. The new large population may persist many years, responding again after additional overstory cutting. Black cherry, red maple, and sugar maple rarely grow through dense fern cover, apparently inhibited by allelopathic interactions. Pin cherry, yellow birch, black birch, blackberry, and red raspberry can grow though ferns. *Rubus* can interfere with fern, albeit the time for renovating a dense stand is unknown. Deer impede this transition as they preferentially browse whatever grows through the ferns. Cutting in stands with both dense fern and heavy deer pressure often promotes beech and striped maple, or fails to regenerate any woody species. The shift to beech has additional implications as beech bark disease promotes beech suckers, regardless of fern or deer pressure. Effective fern control will reduce existing ferns and minimize their spread. Mowing the ferns 2–3 times annually, or breaking the fronds biweekly, has effectively stunted bracken and hayscented fern development. Difficulty of access through a site and cumulative costs of the operations make these techniques impractical on a large-scale. Repeated burns have oppressed the ferns in pine and oak stands, but environmental conditions in northern New York often make burning impractical. Shelterwood seed cutting following chemical site preparation with Roundup® (glyphosate) will enhance conditions for development of new seedlings.

[1]See citations #154 and #155 for more recent findings.

202. **Horsley, S.B.** 1988. Control of understory vegetation in Allegheny hardwood stands with Oust®. Northern Journal of Applied Forestry 5(4):261–262.

The herbicide Oust® was evaluated in a small plot experiment for control of hayscented fern, New York fern, short husk grass, striped maple, and American beech. It was applied at 0, 2, 4, or 8 oz of product/ac monthly from May to November. Control was assessed after 1 and 2 yrs. Applications to ferns prior to frond maturation (May 1 and June 1) or after frond senescence (November 1) resulted in significantly less control. Poor control after senescence implicates root uptake as a significant mode of entry, making Oust® superior to Roundup®. The best control of short husk grass occurred with late season application at the highest rate (September 1 to November 1). Oust® did not affect striped maple and beech, has no apparent effect on germination of red maple or black cherry seeds.

203 **Horsley, S.B.** 1991. Using Roundup® and Oust® to control interfering understories in Allegheny hardwood stands. P. 281–290, in Proceedings of the Central Hardwood Forest Conference, 1991. L.H. McCormick, and K.W. Gottschalk (Eds.). USDA Forest Service. General Technical Report NE-GTE-148.

Roundup® controlled the undesirable species that often interfere with successful regeneration in Allegheny hardwood stands of Pennsylvania. Large-scale commercial application sometimes gave less control than observed with small-plot experiments. Ferns regenerated from segments of fern rhizome broken off under the vehicle tracks. Logging stimulated germination of grass and sedge seed. Many striped maple trees survived the herbicide treatment. Simply applying 1 qt/ac Roundup® during large-scale application did not give adequate control. Fern, grass, and sedge were better controlled with 2 oz/ac Oust®, either alone or in a tank mixture with Roundup®, plus 0.5% of a non-ionic surfactant.

Effects on striped maple improved only after increasing the uniformity of coverage across striped maple crowns, using Roundup®. Current recommendations suggest using Oust® alone to control ferns, grass, and sedge. Oust® will not control mature short husk grass, striped maple, or beech. Roundup® is recommended for control of striped maple and beech. If more than 15% of the regeneration plots contain species unresponsive to either of these herbicides alone, use a tank mix of Roundup® and Oust®.

204. **Horsley, S.B., L.H. McCormick, and J.W. Groninger.** 1992. Effects of timing of Oust® application on survival of hardwood seedlings. Northern Journal of Applied Forestry 9(1):22–27.

Oust® (2 oz/ac) was applied at four intervals to three sizes of black cherry, white ash, and red maple. Black cherry and white ash were sensitive to Oust®, particularly if a surfactant was used. Red maple was much less susceptible. Early October treatments caused less damage and mortality to black cherry and white ash. Delaying application until late August will insure reasonable seedling survival without compromising control of hayscented and New York ferns.

205. **Kirkwood, R.C., P. Veerasekaran, and W.W. Fletcher.** 1982. Studies on the mode of action of asulam in bracken (*Pteridium aquilinum* L. Kuhn). Proceedings of the Royal Society of Edinburgh 81B:85–96.

Any herbicide applied to bracken foliage must translocate in sufficient amounts through the rhizome to the buds in order to efficiently control the fern. Autoradiograph and liquid scintillation counting studies traced the movement of [^{14}C] asulam through plants grown from sporelings or rhizome fragments. Translocation from young fronds tended to be upward to immature pinnae, while translocation from mature fronds became progressively more downward to rhizomes. Absorption and translocation increase with temperature and humidity. Uptake is greater through the lower than the upper frond surface, perhaps due to cuticle thickness or stomatal incidence. Asulam is efficiently absorbed and moderately translocated to actively metabolizing buds. There it inhibits ATP, RNA, and protein synthesis. Dormant buds may not receive a lethal dose. The optimum time to spray is just prior to full-frond expansion.

206. **Martin, D.J.** 1976. Control of bracken. Botanical Journal of the Linnean Society 73:241–246.

This paper summarizes experiences in Scotland during the shift from mechanical control and harvesting of bracken fern, toward the use of selective herbicides. Asulam was most effective when applied from late July through early August. Rain after its application does not diminish efficacy. Asulam is also less sensitive than other herbicides to altitude and aspect. Glyphosate applications reduced frond numbers and killed rhizomes. Liming, applying phosphate, reseeding, and fencing are also needed to insure full benefit to the herbage. Research must still determine if these herbicides translocate into the plants through the inert rhizome mass.

207. **McDonald, P.M., C.S. Abbott, and G.O. Fiddler.** 1999. Development of a shrub-fern-ponderosa pine community eleven years after site preparation and release. Western Journal of Applied Forestry 14(4):194–199.

The composition, density, and development of a northern California shrub-fern-Ponderosa pine community were tracked for 11 yrs after chemical release. The experiment has a randomized complete block design with four replicates of the four treatments. These included Velpar® L (hexazinone), Garlon™ 4 (triclopyr ester), Escort® (metsulfuron), and an untreated control. Each 1/7 ac plot had 30–35 ponderosa pine of crop tree potential. After site preparation and planting, woody shrubs and bracken fern quickly recolonized the site. Even overtopped bracken grew taller into sunflecks. Ponderosa pine with scattered chinqapin, green manzanita, and occasional bracken (9,000 fronds/ac and 0% cover) seem likely to dominate the Velpar® plots. Garlon™ plots have more shrubs and bracken (27,800 fronds/ac and 4% cover). Escort® plots have wider and taller shrubs and bracken (15, 467 fronds/ac with 3% cover), similar to the control area (11,400 fronds/ac with 1% cover). To minimize bracken in this community type, managers should use Velpar® for release treatments.

208. **Miller, J.H.** 1987. The use of herbicides in hardwood forestry. P. 31–52, in Proceedings of the Fifteenth Annual Hardwood Symposium of the Hardwood Research Council: Applying the Latest Research to Hardwood Problems. May 11–13, 1987. Memphis, TN. USDA Forest Service, Northeastern Area State and Private Forestry. Broomall, PA.

Unlike clearing or cutting treatments, herbicides can eliminate undesirable stand components with minimal resprouting. This reduces competition and channels resources to desirable plants to improve their emergence, establishment, or growth. Removing the herbaceous competition can also reduce rodent predation and the risk of fire. This tutorial discusses the benefits and application techniques for individual stem and broadcast methods to control herbaceous and woody weeds in forests, as well as the current recommendation for each species group. It references Horsely's (1981) recommendation (citation #199) for using Roundup® at

1 qt/ac between August 1 and September 1 to control bracken fern, rough goldenrod, and flat-topped aster in Allegheny hardwoods. The long-term growth gain and economic return has not been established, although increases in seedling survival and establishment have. The paper warns that users must follow label instructions to ensure safety of workers and to the site.

209. **Radosevich, S.R., W.H. Brooks, D.R. Adams, and W.B. McHenry.** 1979. Bracken fern control with several herbicides. International Pest Control (May/June):67.

Four experiments tested the effectiveness of glyphosate, asulam, and dicamba in reducing density and fresh weight of bracken fern. Dicamba at 1 or 2 lb/ac reduced stand and fresh weight by <31%. Glyphosphate (rate unknown) caused 96–100% stand reduction and 98-100% decrease in fresh weight. Asulam (rate also unknown) resulted in 88–92% stand reduction and 83-93% decrease in fresh weight, but with death occurring over several months. No new growth occurred within 25 mo after the glyphosate or asulam treatments.

210. **Stewart, R.E., A.W. Cooley, and A. Guardigli.** 1979. Asulam controls western bracken (*Pteridium aquilinum*) on forest land in Western Oregon. Weed Science 27(6):589–594.

Douglas-fir plots covering 2, 4, or 8 ha were left untreated or treated with 3.4 or 6.7 kg/ha of asulam. Asulam was also applied at 3.7 kg/ha with or without 0.2% (v/v) Spreader-Activator to two 2-ha plots in a Noble fir plantation. Application in mid to late August insured full frond emergence on the bracken fern, but not more than 5% of the cover had yellowed. Cover, stem height, and number of stems were assessed prior to treatment, and after 12 and 24 mo. The treatments controlled the dense bracken stands for at least 2 yrs. They did not damage the Douglas-fir seedlings. Noble fir showed reduced height growth, increased defoliation, and higher bud damage after application of the asulam plus surfactant. Analysis of soil residues indicated that asulam degraded rapidly (i.e., half-life of <7–18 days), with minimal vertical movement and transport in overland flow. The authors recommend releasing Noble fir and Douglas-fir seedlings using 3.4–3.7 kg/ha of asulam without surfactant, applied from late July through early August.

211. **Veerasekaran, P., R.C. Kirkwood, and W.W. Fletcher.** 1977. Studies on the mode of action of asulam in bracken (*Pteridium aquilinum* L. Kuhn). I. Absorption and translocation of [^{14}C] asulam. Weed Research 17:33–39.

Although asulam [methyl (4-aminobenzenesulphonyl) carbamate] effectively controls bracken fern, the mode of action or its efficiency of movement through rhizomes to associated buds remains unclear. Uptake and translocation, as well as the physiological and environmental impacts, were studied using [^{14}C] ring labeled asulam on field- and greenhouse-grown plants. The total uptake, retention in treated pinnae, and total translocation decreased as the fronds matured. Yet uptake and distribution after the rapid initial uptake continued in even fully expanded fronds. Translocation was basipetal from treated pinnae to rhizome apices, frond buds, root tips, and young frond tissue. Translocation and distribution in field-grown bracken was extensive in the rhizome system. Both active and dormant buds on non-frond bearing and storage rhizomes accumulated ^{14}C. High humidity (95%) and high temp (30ºC) were associated with higher uptake. Uptake was greater through the stomatal-bearing abaxial surface than through the adaxial surface. Adding a surfactant facilitated cuticle penetration, but more information is needed about the ideal compound and its dosage. Optimum uptake and distribution occurred in the rhizome and buds following asulam applications to almost fully expanded fronds.

212. **Veerasekaran, P., R.C. Kirkwood, and W.W. Fletcher.** 1978. Studies on the mode of action of asulam in bracken (*Pteridium aquilinum* L. Kuhn). III. Longterm control of field bracken. Weed Research 18:315–319.

The experiment applied asulam to plots on 5 or 26 July, 16 August, 6 September, or 11 October in 1972. Rates were 0, 2.2, 4.4, or 8.8 kg a.i./ha. One yr later, two additional plots received 4.4 kg a.i./ha at the end of July, with or without surfactant (1% ethylan CP). All combinations provided good control for 1 yr. Only the 4.4 and 8.8 kg/ha rates sprayed late July and mid-August provided satisfactory control through 5 yrs. Other treatment combinations killed fewer frond buds and apices, resulting in increased frond density and spreading of the ferns over the 5-yr study period. The surfactant did not immediately or significantly improve control. The added 10% reduction in frond density on surfactant plots did not become apparent until the fourth yr.

213. **Yarborough, D.E., and A.A. Ismail.** 1984. Treatment of bracken fern with asulam in lowbush blueberry fields. Proceedings of the Northeastern Weed Science Society 38:168–171.

Hexazinone has only partially controlled bracken in Maine's lowbush blueberry fields. An alternate post-emergent spray of asulam at 1.7 or 3.4 kg/ha was applied to more fully opened fern fronds, using a backpack sprayer equipped with a field jet nozzle. Findings suggest effective control of bracken fern with application of 1.8 kg/ha. The treatments had no phytotoxic effects to the blueberries, and significantly increased the number of blueberry stems and flower buds.

PART III. RASPBERRIES

A. Biologic and Ecologic Considerations

214. **Klinka, K., A.M. Scagel, and P.J. Courtin.** 1985. Vegetation relationships among some seral ecosystems in southwestern British Columbia. Canadian Journal of Forest Research 15:561–569.

Rubus spp. were found most frequently (81–100% of sites) in young stands of the *Tsuga-Rhytidiadelphus* site association under conditions of a humid cool mesothermal climate. *Rubus spectabilis* frequency peaked during the early immature stage of stand development, while *Rubus ursinus* peaked during the regeneration stage. Both occurred at all stand ages. *Rubus parviflorous* was present in greatest abundance at the initial stage, but gradually declined until dying out during the early immature stage. *Rubus lacinaiatus* had the same developmental pattern, but its frequency was never >40%. As tree regeneration is stimulated and available nitrogen begins to decrease (2–5 yr after clearcutting), so will percent cover of *Rubus*.

215. **Lautenschlager, R.A.** 1997. Effects of perturbations and stimulants on red raspberry (*Rubus idaeus* L.) seed germination. Forestry Chronicle 73(4):453–457.

Raspberries commonly form an extensive cover across open sites following major disturbances in eastern boreal and northern hardwood ecosystems. Buried seeds germinate after a long period of stratification and degradation of seed coat. In laboratory experiments, raspberry seed germination was not enhanced by short-term intermittent soaking in dilute hydrochloric acid; passage through the digestive tract of bears, coyotes, or birds; physical perturbations; increased light and/or temperatures; nor the addition of nitrogen to the soil.

216. **Marks, P.L.** 1974. The role of pin cherry (*Prunus pensylvanica* L.) in the maintenance of stability in northern hardwood ecosystems. Ecological Monographs 44:73–88.

Rubus idaeus, and to lesser extents *R. hispidus* and *R. alleghensis* become important codominant species to pin cherry during the first 2–3 yr following disturbance. *Rubus* spp. may persist for 5 yr, but will decline in abundance after 3 yr when pin cherry becomes dense.

217. **Oleskevich, C., S.F. Shamoun, and Z.K. Punja.** 1996. The biology of Canadian weeds. 105. *Rubus strigosus* Michx., *Rubus parviflorus* Nutt., and *Rubus spectabilis* Pursh. Canadian Journal of Plant Science 76:187–201.[1]

Rubus strigosus occurs from Alaska, south to California, Arizona, and New Mexico, and east to North Carolina. It is found from valley bottoms to timberline. *Rubus parviflorus* has a similar range, but only along coastal California. It also occurs in the Great Lakes region. Rubus spectabilis occurs in low subarctic-high temperate regions in the Aleutian Islands and southern Alaska, and southward to northwestern California. It is most abundant below 800 m. These species occupy disturbed sites after fire, logging, or silvicultural activities. They are shade intolerant and grow best on moist sites. They are nitrophytic and indicators of nitrogen rich soils. *R. strigosus* reaches 2 m tall, often arched. It does not root from shoot tips, has white flowers, numerous prickles, and a red mature fruit that falls from the intact receptacle. The plants fruit and senesce in a 2-yr period, but stools may produce shoots for up to 2 decades. It can produce >26,000 seeds/m^2 over a 4 yr period. *R. parviflorus* reaches 0.5–2.5 m tall. The stems are unarmed. It may produce >75 seeds/m^2 with 60% constancy, and up to 84 seeds/m^2 with 75% constancy. *R. spectabilis* reaches 0.5–5 m tall. It has deep-pink solitary flowers and produces more than 300,000 seed/kg. It often reaches heights greater than 2 m. The latter two species produce annual shoots and maintain extensive bud banks and rhizome systems, with clones surviving for up to 45 yr.

Seeds of all species drop directly below the plant. Burrowing animals, other mammals and birds disperse the seeds. Seeds survive for 50 to 100 yr (species dependent). Increased light and temperature (ie: after harvesting and scarification) stimulate germination. Once established, raspberries spread primarily by root suckers or rhizomes. They colonize disturbed sites, forming monospecific shrub communities. These species of *Rubus* interfere with conifer regeneration by controlling site resources (light, nutrients, moisture, space.). Yet they provide important habitat and food sources for wildlife, play a role in nutrient cycling and conservation, reduce soil erosion, and prevent establishment of longer-lived competitive tree species following disturbance.

Late season application of glyphosate at 2.14 kg a.e./ha caused light to moderate control of *R. strigosus* (Haeussler et al. 1990), but Pitt et al. (1992) demonstrated >60% cover reduction with aerial applications of 0.5 kg ae/ha. August applications (after full leaf flush) of 1.4 kg/ha gave the most effective control of *R. parviflorus* (LePage et al. 1991). Light to moderate injury occurred among R. spectabilis treated with 1.4–2 kg/ha glyphosate in July–September (Newton et al. 1986, William 1994). Summer aerial applications of 2 kg ai/ha of hexazinone effectively reduced *R. strigosus* (Reynolds and Roden 1995). Application of 4 kg ai/ha caused 25–60% injury to 4-yr-old *R. parviflorus* and *R. spectabilis* (D'Anjou 1990). Spring applications of 0.3 and 0.45 kg ai/ha of sulfometuron reduced *R. strigosus* cover by 35 and 30%, respectively (Reynolds and Roden 1995). Spring broadcast spraying at 0.6 kg ai/ha gave good control of *R. parviflorus* and *R. spectabilis* (D'Anjou 1990), as did a combined picloram and 2,4-D (0.25 g ai + 0.9 kg ai/ha) (William 1994). Metsulfuron applied as a spot spray at 0.6 kg ai/ha or as an aerial spray at 0.03 kg ai/100 l/ha may control *R. spectabilis* (Cole et al. 1988). Sixty to 90% injury of *R. parviflorus* and *R. spectabilis* were observed after summer treatment of 2.9 kg ae/ha of triclopyr esters.

Though scarification most often stimulates germination of buried seed and/or fragments of roots, increasing stool shoots, scarification with brush blade, flex-track forwarder with blade, or dip and dive often successfully reduced *R. strigosus* in spruce plantations (Oswald and Brown 1992). Biocontrol involving bacterial and fungal pathogens have given successful preliminary results. In addition, raspberry regeneration has been diminished by seeding recently scarified sites with legumes, bunch grasses, and sod-forming grasses (Coates et al. 1993). Likewise, decomposing straw of barley, oat, or wheat reduced spring seed germination of raspberries (Jobidon et al. 1989). Low intensity prescribed burns create optimal seedbed conditions for germination and resprouting of remaining stems. Cutting also stimulates resprouting. *R. parviflorus* and *R. spectabilis* can regrow 60-90% of pretreatment height within 1 yr. Likewise, fertilization also stimulates growth.

[1]Citations within this article include

Coates, K.D., M.J. Douglas, J.W. Schwab, and W.A. Bergerud. 1993. Grass and legume seeding on a scarified coastal alluvial site in northwestern British Columbia: response of non-crop vegetation and planted Sitka spruce seedlings. New Forestry 7:193–211.

Cole, E.C., M. Newton, and D.E. White. 1988. Efficacy of imazapyr and metsulfuron methyl for site preparation and conifer release in the Oregon Coast Range. Oregon State University, Forest Research Laboratory Research Note 81.

D'Anjou, B. 1990. Growth response of several vegetation species to herbicides and manual cutting in the Vancouver Forest Region. Canadian Forest Service and British Columbia Ministry of Forestry, Victoria. BCFRDA Report 135.

Haeussler, S.D. Coates, and H. Mather. 1990. Autecology of common plants in British Columbia: a literature review. Canadian Forest Service and British Columbia Ministry of Forestry, Victoria. BCFRDA Report 158.

Citation #250.

Newton, M., E.C. Cole, and D.E. White. 1986. What influences control of coastal deciduous brush with glyphosate. Proc. West. Soc. Weed Sci. 39:86-92.

Oswald, E.T., and R.N Brown. 1992. Vegetation and seedling development following site preparation in the ESSFwm subzone of Glenogle Creek, Nelson Forest Region, British Columbia: a case study. Canadian Forest Service and British Columbia Ministry of Forestry, Victoria. BCFRDA Rep. 188.

Pitt, D.G., R.A. Fleming, and D.G. Thompson. 1992. Glyphosate efficacy on eastern Canadian forest weeds. Part II: Deposit-response relationships and crop tolerance. Canadian Journal of Forest Research 22:1160–1171.

Citation #255.

William, R.D. (Comp). 1994. Pacific Northwest Weed Control Handbook. Oregon State University. Corvallis, OR.

218. **Tilman, D.** 1987. Secondary succession and the pattern of plant dominance along experimental nitrogen gradients. Ecological Monographs 57:189–214.

Measurements in fields of native oak savannah in Minnesota indicated that the cover of raspberry increased from ~1% to ~18% as total soil nitrogen increased along a gradient from 400 to 1400 mg N/kg of soil.

219. **USDA Forest Service.** 2000. *Rubus spectabilis*. Botanical and ecological characteristics. FEIS (Fire Effects Information System). URL: http://www.fs.fed.us/database/feis

Salmonberry grows 7 to 13 ft tall. It is prevalent on mesic sites, in barren, acidic, and infertile soils. This nitrogen demanding species persists for up to 30 yr after disturbance, but begins to decline after 2 to 5 yrs if available nutrients decline. It ranges from shade-tolerant to intermediate in shade tolerance. Sexual reproduction occurs in the second yr, generally producing 30 "berries" (aggregates of drupelets) per shrub. Seeds have a hard impermeable coat. Germination requires scarification, followed by warm, then cold stratification. Seedlings require mineral soil for successful establishment. Salmonberry sprouts vigorously from the stump (greatest potential for regrowth), root crown, stem base or rootstock. It can form a dense network of clonal rhizomes that average 0.2 to 2.0 in. in diameter and lay 1–2 in. below the mineral soil. Some may extend to depths of >6 ft. Salmonberry spreads by layering.

220. **Wagner, R.G., and J.C. Zasada.** 1991. Integrating plant autecology and silvicultural activities to prevent forest vegetation management problems. Forestry Chronicle 67(5):506–513.

Seed germination and clonal development from rhizomes ensure the rapid spread of red raspberry in newly disturbed sites. Control strategies must accommodate both sexual and asexual modes of reproduction like the timing of seed production, seed dispersal patterns, distribution and longevity of buds, and bud recovery after disturbance. Raspberries have beneficial effects to balance against the potential cost of its presence.

221. **Whitney, G.G.** 1982. The productivity and carbohydrate economy of a developing stand of *Rubus idaeus*. Canadian Journal of Botany 60:2697–2703.

Growth and development of *Rubus idaeus* were studied in clearcut sites up to 5 yr old. It covered 90% or more of the area, except in 1-yr-old stands, where it was only 30%. Raspberry developed in a two-phase process. During the first 2 yr (the building phase), many seedlings (primocanes, then floricanes) became established. Thereafter, raspberry proliferated via root suckers that developed into independent functioning stools. Suckering declined after the second yr, to 4/m^2. During Phase 2 (the self-thinning phase) raspberry biomass accumulated, with high net productivity. Stool density declined as larger stools grew and replaced smaller stools. Seed production peaked by yr 4.

222. **Whitney, G.G.** 1984. The reproductive biology of raspberries and plant pollinator community structure. American Journal Botany 71:887–894.

Rubus idaeus produced abundant flowers over several months, beginning in early June and decreasing to an occasional flower/m^2 in late summer. Plants produced 4.29 mg of dilute sugar/flower/day. Bumblebees with long tongues and high energy requirements pollinated the flowers. Comparatively, *R. pubescens* flowered for a 1- to 2-week period in late May, coinciding with canopy closure. Daily sugar production was only 0.12 mg/flower.

223. **Whitney, G.G.** 1986. A demographic analysis of *Rubus idaeus* and *Rubus pubescens*. Canadian Journal of Botany 64:2916–2921.

The seed bank for shade-tolerant *Rubus pubescens* includes a limited transient seed bank below ground, and long-lived seeds (10 to 20 yr) above ground. Flowering is sporadic with a small percentage of flowers producing seeds. Birds and mammals readily disperse the seed. Seed germination initiates a slow increase in *Rubus* through production of trailing primocanes (offsets). Seventy percent of primocanes formed offsets, and 92% of these developed into an active photosynthetic system during the second yr. By contrast, shade-intolerant *Rubus idaeus* has a long-lived seed bank (~100 yr) that germinates after an increase of solar radiation (ratio of red/far red radiation, and increased light intensity) and soil water nitrate levels. These conditions occur in the first yr following a disturbance. During the second and third yr, root suckers fill the canopy gaps and develop independent systems. Thereafter, *R. idaeus* produces seeds, depositing a large seed bank in the fourth yr (+14,000 seeds/m^2), and reinitiating the cycle.

B. Interference with Conifers

224. **Balisky, A.C., and P.J. Burton.** 1993. Distinction of soil thermal regimes under various experimental vegetation covers. Canadian Journal of Soil Science 73:411–420.

Temperatures at 10 cm below in the soil (June in British Columbia) differed as follows: bare soil (8.8°C); cover of fireweed (4.6°); cover of salmonberry (2.7°). The daily mean temperatures were significantly lower (2–3°C) beneath fireweed and salmonberry, and about 4°C lower under alder or mixed species. Temperatures at 8 AM did not differ significantly between bare soil and soil covered by either fireweed or salmonberry (about 15°C). Temperatures at 6 PM were 5–7°C lower under these species (18°C). The mitigating effect of fireweed or salmonberry did not prevent conifer seedling growth. Lower temperatures beneath vegetation created unsuitable microsites at higher latitudes or elevations. They may reduce shoot growth and net photosynthesis of tree species. Ideally, pioneer non-tree species would favorably temper temperatures at the germination and early seedling stages, but die after tree seedling establishment so conditions for growth improve.

225. **Fox, T.R.** 1986. Raspberry (*Rubus idaeus* L.) competition effects on balsam fir (*Abies balsamea* (L.) Mill.) seedlings in northern Maine. Tree Planters' Notes 37(2):20–23.

Strip clearcuts were created in 60-yr-old red spruce-balsam fir stands with overstory basal area of 28 m^2/ha and abundant advance regeneration. Strips were 30 m wide and separated by uncut strips of 45–60 m. After five growing seasons, raspberries overtopped 50% of balsam fir seedlings and retarded their growth, most significantly in root collar diameter. Differences in P (greater in open-grown) and K (greater in overtopped) concentrations were not biologically significant.

226. **Lautenschlager, R.A.** 1995. Competition between forest brush and planted white spruce in north-central Maine. Northern Journal of Applied Forestry 12(4):163–167.

Woody vegetation and raspberry that developed after clearcut in a spruce-fir forest significantly reduced the height growth of naturally occurring spruce regeneration. By yr 3, growth reductions attributed to hardwoods were nearly twice due to raspberry. Interfering vegetation was more abundant (raspberry cover of 6–43 times greater) on the well-drained site than the somewhat poorly drained to well drained site, but with reduced spruce growth on both soils.

227. **Lautenschlager, R.A.** 1999. Environmental resources interactions affect raspberry growth and its competition with white spruce. Canadian Journal of Forest Research 29:906–916.

The study evaluated effects of light, moisture and nutrients on the growth of 1- and 2-yr-old *Rubus idaeus* seedlings and planted white spruce on northwest facing slopes in Maine. Raspberry biomass production and root/shoot ratio increased as moisture and nutrients increased or nitrogen was added. White spruce production decreased beneath 73% shade, while shoot/root ratio increased. Production did not change as light level increased with decreasing *Rubus* cover below 30%. Raspberry interference did not affect spruce height growth. Yet the diameter and biomass production decreased. Low-nitrogen shaded plots supported few raspberry plants, while spruce had greater diameters and biomass production on these sites.

C. Regeneration Following Harvesting and Silvicultural Activities

228. **Archambault, L., J. Morissette, and M. Bernier-Cardou.** 1998. Forest succession over a 20-year period following clearcutting in balsam fir-yellow birch ecosystems of eastern Quebec, Canada. Forest Ecology and Management 102(1):61–74.

Coverage of *Rubus ideaus* (0.5–1.0 m tall) decreased from 60% at 5 yr after harvest, to 2% after 20 yr following clearcutting with whole-tree harvesting in a balsam fir-yellow birch ecosystem. Raspberry was virtually absent in mature stands (simulated pre-harvest conditions). *Rubus* height increased between 5 (0.88 m) and 10 yr (0.95 m), but declined to 0.46 m by 20 yr.

229. **Barrett, J.W., C.E. Farnsworth, and W. Rutherford, Jr.** 1962. Logging effects on regeneration and certain aspects of microclimate in northern hardwoods. Journal of Forestry 60:630–639.

Harvesting reduced an old-growth northern hardwood stand (sugar maple-yellow birch) to six different residual basal area levels: no cutting; 70 ft^2/ac; 50 ft^2/ac; 30 ft^2/ac; clearcut of trees >4.5 in. dbh; clearcut of all stems >3 ft tall. Other treatments included poisoning of small trees, scarification, and erection of deer exclosures. Raspberries averaged 1310 stems/ac during the first growing season after logging. They regenerated most vigorously with stand density <50% of full stocking (basal area below 70 ft^2/ac), where soil temperatures exceeded 45°C. Heavy raspberry cover remained on a clearcut site for up to 22 yr.

230. **Crawford, H.S.** 1976. Relationship between forest cutting and understory vegetation. USDA Forest Service Research Paper NE-349.

Three yrs after clearcutting in an Ozark oak-hickory stand, raspberry cover varied with site quality (black oak site index) from 33% to 83% cover. Herbaceous plants initially grew more rapidly than the woody vegetation. On the better sites, woody species should form a complete canopy and reduce the herbaceous cover.

231. **Halpern, C.B.** 1988. Early successional pathways and the resistance and resilience of forest communities. Ecology 69:1703–1715.

Vegetation changes following clearcut and slash burning were studied for 21 yr in a New Hampshire hemlock forest. Study sites were classified by level of soil disturbance (undisturbed, disturbed-unburned, lightly burned, and heavily burned). In all areas, species composition changed gradually from annual to woody perennials (*Rubus parviflorus*), then to forest herbs. Sub-shrubs (*R. ursinus*) showed persistent release. *R. parviflorus* characterized disturbed-unburned sites. Annuals initially dominated heavily burned sites, followed later by small perennials (*R. leucodermis*), and subsequently by tall woody perennials (*R. parviflorous*). The character of vegetation colonizing a site depended on the level of disturbance, the traits of the flora in the region, the species in the cut forest, and stochastic events.

232. **Halpern, C.B.** 1989. Early successional patterns of forest species: interactions of life history traits and disturbance. Ecology 70:704–720.[1]

Rubus ursinus characterized above-ground vegetation of undisturbed forest communities, regardless of its initial abundance or mode of recovery. Following clearcutting and slash burning, *R. ursinus* spread vigorously by trailing and climbing stems, even reaching the crowns of tall shrubs and trees. It appeared highly competitive following canopy removal and tolerant of fire. While its abundance peaked early (0–4 yr), *R. ursinus* persisted throughout the 20-yr study period, exhibiting >5% canopy cover during the growing season. Suppression of *R. ursinus* was not expected until canopy closure. *R. parviflorous* was characterized as a "late" invading perennial, with the greatest longevity of any colonizer noted in this study. It was prominent in disturbed microsites. *R. parviflorous* originated from buried seed and animal-dispersed seed. Rhizomatous growth was slow, but constant.

[1]For detailed information regarding research methods, refer to citation #231.

233. **Harvey, B.D., A. Leduc, and Y. Bergeron.** 1995. Early postharvest succession in relation to site type in the southern boreal forest of Quebec. Canadian Journal of Forest Research 25:1658–1672.

Sites within a boreal forest (ranging from 10 to 1300 ha) dominated by balsam fir, black spruce, and white birch where mechanically and manually whole-tree harvested over 7 yrs, with no effort to minimize disturbance. Mesic clay sites had the least broadleaf and high shrub regeneration, but a high cover of *Rubus idaeus*. That species was also abundant on mesic sands and deep tills. Long-term persistence was observed on nutrient rich sites, where it appeared to displace other species, including *R. pubescens*. The later species was found more frequently at sites with little impact from harvesting.

234. **Hornbeck, J.W., C.W. Martin, R.S. Pierce, F.H. Bormann, G.E. Likens, and J.S. Eaton.** 1987. The northern hardwood forest ecosystem: Ten years of recovery from clearcutting. USDA Forest Service Northeastern Forest Experiment Station NE-RP-596.

Ground vegetation formed a dense tangle averaging about 1.5 m in height by 2 yr after block and strip clearcutting.[1] Areas under dense slash, or those severely disturbed during logging, did not regenerate. Raspberries rapidly dominated the shrub layer and played a key role in nutrient uptake from the system. Between 2 and 10 yr, raspberry stem density declined (varied with elevation and treatment) as it became overtopped by tree species. Death of the *Rubus* released nutrients for uptake by the emerging tree community. Streamflow returned to pre-disturbance levels within a decade.

[1]The strip cutting applied in this study is described in
Marquis, D.A. 1969. Silvical requirements for natural birch regeneration. P. 40–49, in Birch Symposium Proceedings. Aug. 19–21; Durham, NH. USDA Forest Service Northeastern Forest Experiment Station. Upper Darby, PA.
Stafford, L.O. 1983. Silvicultural guide for paper birch in the northeast (revised). USDA Forest Service Northeastern Forest Experiment Station NE-RP-535.

235. **Horsley, S.B., and D.A. Marquis.** 1983. Interference by weeds and deer with Allegheny hardwood reproduction. Canadian Journal of Forest Research 13:61–69.

Three treatments in two separate Pennsylvania cherry-maple stands followed a shelterwood seed cutting and removal cutting: fenced; fenced and hand weeded throughout the study period; and unfenced and unweeded (control). Raspberry cover increased significantly after the seed cutting in fenced areas, but not in the control plots. Weeding removed all raspberry cover. After the removal cut, raspberries increased significantly from 5% ground cover to 70%–75% on plots with fern cover, and to 80%–85% on plots with grass cover (unweeded). Grass and fern cover declined as *Rubus* increased. Thus, the growth of raspberry indirectly prepared the site for establishment of longer-lived trees that were inhibited by the fern or grass. Though deer browsed heavily on raspberry that grew above herbaceous cover, they had little effect on raspberry growth. After 4 yrs, the amount of raspberry did not differ between fenced and unfenced areas.[1]

[1]See citation #83 for report that deer browsing will prevent *Rubus* development.

236. **Hughes, J.W., and T.J. Fahey.** 1991. Colonization dynamics of herbs and shrubs in a disturbed northern hardwood forest. Journal of Ecology 79:605–616.

Rubus ideaus was not present on Watershed 5 at the Hubbard Brook Experimental Forest prior to whole-tree harvesting. Soil disturbance after cutting was patchy and irregular, simulating that of natural tree falls. *R. idaeus* increased in frequency to 59% by 2 yr, initially from buried seed (44.4/m^2), but later by sprouting and rhizomatous growth. After 10–20 yrs, species characteristic of the original forest dominated the site.

237. **Jobidon, R.** 1993. Nitrate fertilization stimulates emergence of red raspberry (*Rubus idaeus* L.) under forest canopy. Fertilizer Research 36:91–94.

The effect of soil nitrate concentrations on the germination and growth of *Rubus idaeus* was tested in undisturbed mature balsam fir-spruce stands in eastern Quebec. Fertilization was carried out in October, and repeated the following year to verify that raspberry emergence continued over 2 consecutive growing seasons. *Rubus* germination increased with increased nitrate levels. Emergence ranged from 12.2 (112 kg N/ha) to 41.3 (336 kg N/ha) during yr 1, and 17.2 (112 kg N/ha) to 80.4 (336 kg N/ha) seedlings during yr 2. New germinates failed under low light. Raspberry emergence would be significant in disturbed conditions having greater light and an enhanced nitrate-nitrogen soil content.

238. **Marquis, D.A.** 1965. Regeneration of birch and associated hardwoods after patch cutting. USDA Forest Service Research Paper RP-NE-32.

The study evaluated regeneration in several cut patches ($^1/_{10}$th ac to $^2/_3$rd ac) within old-growth and second-growth stands. At 3 yrs, raspberry dominated nearly all sites, and averaged 3 ft tall. Raspberry stems averaged 49.5/ac in the second-growth stands, and 42.1/ac in the old growth. Stocking was highest on skid roads, and progressively less on disturbed areas, on undisturbed areas, and beneath slash piles.

239. **Marquis, D.A.** 1967. Clearcutting in northern hardwoods: Results after 30 years. USDA Forest Service Northeastern Forest Experiment Station Research Paper NE-RP-085.

Winter clearcuts of 5 ac blocks were made in a stand having a basal area of 122 ft^2/ac in trees ≥4.6 in. dbh. Immediately after cutting, raspberries covered the area, along with advance regeneration of shade-tolerant species, hardwood stump sprouts and root suckers, and trees like pin cherry. Early thinning or weeding was recommended to enhance the growth of valuable shade-intolerant and shade-intermediate species.

240. **Ricard, J.P., and C. Messier.** 1996. Abundance, growth and allometry of red raspberry (*Rubus idaeus* L.) along a natural light gradient in a northern hardwood forest. Forest Ecology and Management 81:153–160.

The effects of natural light gradients on abundance and growth of red raspberry were measured in gaps ranging in size from 10 to 300 m^2 created by partial cuts that removed 30% of the basal area. Raspberry occurred in all plots where photosynthetic photon flux density (PPFD) values exceeded 25%, but was frequently present in gaps with PPFD values of 8%–40%. Light below 8% of above canopy PPFD limits raspberry establishment. Biomass allocation did not change along the light gradient, suggesting that raspberry has a low allocation plasticity-light relationship.

241. **Roberts, M.R., and H. Dong.** 1993. Effects of soil organic layer removal on regeneration after clearcutting a northern hardwood stand in New Brunswick. Canadian Journal of Forest Research 23:2093–2100.

Yellow birch and raspberry predominated clearcut sites 4 yr after clearcutting 1.25 ac of a sugar maple-yellow birch-fir stand. Soil scarification or presence of a thin forest floor favored the colonization of species adapted to mineral microsites, including raspberries, and minimized the chances of lethal temperatures. Despite the presence of raspberry (24.5 stems/m^2, 83% freq), advance birch regeneration (5.8 stems/m^2, 90% freq) was tallest on 40% of plots. Adjacent undisturbed sites also had raspberry, but advance regeneration and new germinants of sugar maple and pin cherry dominated 57% of the plots.

242. **Truax, B., D. Gagnon, F. Lambert, and N. Chevrier.** 1994. Nitrate assimilation of raspberry and pin cherry in a recent clearcut. Canadian Journal of Botany 72:1343–1348.

After spring clearcutting of a 15-ha maple-birch forest in Quebec, post-harvest utilization of soil nitrate was evaluated using leaf nitrate reductase activity (NRA) as an indicator. Over 2 yr, raspberry had high enzymatic activity values (2.52 and 2.32 mmol NO_2/(g dry wt.ht), while pin cherry had extremely low activity (0.8 and 0.7 mmol NO_2/(g dry wt.ht). By yr 3, nitrate became less abundant and ammonium became the major form of inorganic nitrogen in the soil. Raspberry cover decreased in favor of more ammonium-nitrogen demanding species (i.e., pin cherry).

243. **Walters, R.S., and R.D. Nyland.** 1989. Clearcutting central New York northern hardwood stands. Northern Journal of Applied Forestry 6:75–78.

Clearcutting of stands with advance regeneration (≥ 5,000 seedlings/ac at least 1 ft tall) resulted in a well-stocked new cohort. At yr 3, more than 90% of regeneration plots contained raspberry. By yr 10, a new closed tree canopy had formed in all stands and raspberry remained on <10% of plots. The abundance of raspberry may indicate a low deer density.

D. Relationships to Biomass and Nutrients

244. **Crowell, M., and B. Freedman.** 1994. Vegetation development in a hardwood-forest chronosequence in Nova Scotia. Canadian Journal of Forest Research 24:260–271.

Secondary succession involves changes in plant species composition and other ecosystem characteristics after a disturbance that does not destroy the regenerative potential at a site. The level of disturbance, the life history traits of flora in the region, the species in the cut forest, and stochastic events determine what colonizes a site. This was examined in 22 stands ranging from 0 to 75 yr old. Ground vegetation, especially raspberries (*R. strigosus* and *R. canadensis*), was most prominent in the initial recovery of stands (87% of total foliage biomass). Foliage biomass of *Rubus* increased from 0.02 t/ha 1 yr after clearcutting, to 0.7 t/ha by age 3, and then declined to trace amounts by age 13. By yr 3, ground vegetation had higher nutrient concentrations than woody plants: 4.3 times larger in N; 4.4 for P; 1.9 for Ca; 11.8 for K; and 6.6 for Mg. These nutrients were released after trees and shrubs overtopped and killed the ground vegetation. Findings suggest that rapid development of ground vegetation makes these systems resilient to disturbance.

245. **Hendrickson, O.Q.** 1988. Biomass and nutrients in regenerating woody vegetation following whole-tree and conventional harvest in a northern mixed forest. Canadian Journal of Forest Research 18:1427–1436.

Sites within an Ontario northern mixed conifer-hardwood forest had all above-ground woody biomass (WTH) or only trees exceeding 9 cm dbh (CH) removed. Raspberries dominated the shrub layer in both cases, increasing from 2.5% before harvest to 32.5% after one season. Shrub biomass (all species) increased from 0.3% of the total in the uncut stand to 11.6 and 20.3% in the WTH and CH stands, respectively. After four growing seasons, no significant difference was found in the amount of above-ground woody material between treatments, with raspberries the highest of components measured.

246. **Hooper, D.U., and P.M. Vitousek.** 1998. Effects of plant composition and diversity on nutrient cycling. Ecological Monographs 68(1):121–149.

Establishment of vegetation immediately after clearcutting reduced organic matter decomposition substantially. A diverse plant community will likely shade the soil faster, and enhance nutrient uptake.

247. **Iseman, T.M., D.R. Zak, W.E. Holmes, and A.G. Merril.** 1999. Revegetation and nitrate leaching from Lake States Northern Hardwood forests following harvest. Soil Science Society of America Journal 63:1424–1429.

Five yr after clearcutting, nitrate leaching (0.56 g N/m^2/yr) was significantly greater in an upper Michigan sugar maple-red oak hardwood stand on sandy soils than on uncut control plots (0.05 g N/m^2/yr). At a sugar maple-basswood site, nitrate leaching (0.02 g N/m^2/yr) did not differ from control plots (0.41 g N/m^2/yr). Red raspberries evenly colonized that site (100% of above ground biomass), whereas the sugar maple-red oak stands had only 55% in raspberry. The forest floor of the latter site had thick Oi and Oe horizons. This may have limited the germination and establishment of raspberry, when compared to that on the thin, well-mixed mineral soil of the former site. The lower rates of nitrate leaching in the sugar maple-basswood stand probably resulted from the high uptake of nitrate by the dense raspberry.

E. Chemical and Biological Control Methods

248. **Campbell, R.A.** 1990. Herbicide use for forest management in Canada: where we are and where we are going. Forestry Chronicle 66:355–360.

Several herbicides successfully control raspberry, as follows:

- Glyphosate—Vision; differs from Roundup® only in its label.
- Hexazinone—Velpar® L—a liquid formulation diluted with water is registered in Canada for ground broadcast application, not aerially. Pronone®; a granular formulation, appears to cause less conifer damage than observed with Velpar® L.
- Triclopyr—Garlon™ 3A (amine), Garlon™ 4 (ester), registered for release treatments by foliar or stem applications.
- Metsulfuron methyl—Ally® or Escort®. Conifers are not tolerant to release treatments, but spruce shows some tolerance to site preparation treatments.
- Fluroxypyr—No trade name. Is less effective than triclopyr for control of raspberry. However, conifers suffered less damage from fluroxypyr release treatments applied in summer, than from triclopyr release treatments.

249. **Jobidon, R.** 1991. Potential use of bialaphos, a microbially produced phytotoxin, to control red raspberry in forest plantations and its effect on black spruce. Canadian Journal of Forest Research 21:489–497.

Bialaphos (a non-chemical, microbial toxin) was applied using a backpack sprayer at 4 rates (1.0, 1.5, 2.0, and 2.5 kg a.i./ha, dissolved in 3.5 L of water) in mid-July, August, and September to clearcut plots in Quebec. Mortality occurred within 3 weeks, regardless of the application rate. June and September applications proved far less effective than the others. Rates of 2.0 and 2.5 kg a.i./ha applied from mid-July to late August gave the best control of raspberry resurgence and height growth. After 15 mo following mid-summer applications, the seedlings had only minor to no signs of foliar injury, even though current year foliage of planted black spruce seedlings appeared more sensitive than older foliage.

250. **Jobidon, R., J.R. Thibault, and J.A. Fortin.** 1989. Phytotoxic effect of barley, oat and wheat-straw mulches in eastern Quebec forest plantations 1. Effects on red raspberry (*Rubus idaeus*). Forest Ecology and Management 29:277–294.

In clearcut and site-prepared stands, red raspberry seed germination and growth were inhibited by 9 cm thick cover-mulches of oat, wheat, or barley straws, or a mixture of all three. Oat straws, followed by wheat and barley, most successfully inhibited the raspberries. Germination failed due to toxic substances released by decomposition of the straws. Established seedlings grew poorly. Since absence of raspberry did not stimulate other interfering species, the treatments decreased overall competition.

251. **Jobidon, R., J.R. Thibault, and J.A. Fortin.** 1989. Phytotoxic effect of barley, oat and wheat-straw mulches in eastern Quebec forest plantations 2. Effects on nitrification and black spruce (*Picea mariana*) seedling growth. Forest Ecology and Management 29:95–310.

Straw mulching and the associated release of phytotoxins during decomposition inhibited the production of NO_3-N. That, to some extent, limited the establishment of *Rubus idaeus* during the 2-yr period of this study. Other abiotic and biotic factors could have affected raspberry germination and growth. Foliar analyses revealed a reduction in N content of raspberry seedlings, compared to control seedlings. Treatments did not affect growth of planted black spruce seedlings. In fact, the spruce had a greater basal diameter but not greater height on treated plots.

252. **Newton, M., E.C. Cole, D.E. White, and M.L. McCormack, Jr.** 1992. Young spruce-fir forests released by herbicides I. Response of hardwoods and shrubs. Northern Journal of Applied Forestry 9(4):126–130.[1]

Helicopter applications of 2,4,5-T2 (2.2 and 3.3 kg/ha), 2,4-D + 2,4,5-T esters (1.1 + 1.1 kg/ha and 2.2 + 2.2 kg/ha), triclopyr amine (2.2 and 4.4 kg/ha), triclopyr amine + 2,4-D ester (2.2 kg/ha + 2.2 kg/ha), and glyphosate (1.7 and 3.3 kg/ha) were delivered with D-6-46 nozzles spraying 37.4 l/ha in four swaths of

16.7 m net coverage to control interfering deciduous cover in conifer stands. Weed species were reduced in stature by phenoxy herbicides, but recovered enough to maintain significant presence and competitive stature. Glyphosate and triclopyr were more efficient, though some raspberries remained. Raspberry died in untreated control stands by yr 16 due to interspecific competition. If substantial conifer release and greater species diversity is sought in the stand, a phenoxy herbicide is recommended.

[1]For specific information regarding growth and development of conifers in this study see Newton, M., E.C. Cole, M.L. McCormack, Jr., and D.E. White. 1992. Young spruce-fir forests released by herbicides II. Conifer response to residual hardwoods and overstocking. Northern Journal of Applied Forestry 9:130–35.
[2]2,4,5-T is no longer licensed for application in forestry practices.

253. **Pitt, D.G., R.A. Fleming, and D.G. Thompson.** 1992. Glyphosate efficacy on eastern Canadian forest weeds. Part II: Deposit-response relationships and crop tolerance. Canadian Journal of Forest Research 22(8):1160–1171.

Nine treatments of glyphosate (one control and 4 rates ranging from 0.25 to 1.00 kg ae/ha) were applied in September by two dispersal systems (AU5000 Micronairs and conventional hydraulic nozzles) to four cutover areas planted to black spruce. Raspberry cover was reduced at deposit levels ≤0.5 kg a.e./ha, regardless of dispersal system without posing a threat to planted black spruce. Seedlings on untreated plots exhibited signs of stress, emphasizing the importance for raspberry control.

254. **Reynolds, P.E., and M.J. Roden.** 1995. Short term performance of two hexazinone formulations: Efficacy, seedling survival and growth. Forestry Chronicle 71:228–232.

Liquid hexazinone (Velpar® L, 2 kg ai/ha) was aerially applied in 55 L/ha water to a clearcut to reduce *Rubus idaeus* interference with planted black spruce seedlings. Dry-flowable hexazinone (Velpar® ULW, 2 kg ai/ha) was applied to another site. After 5 growing seasons, mean raspberry cover had increased to 82% in the untreated plots, compared to 64% on V-L plots and 56% on V-ULW plots. Spruce diameter growth decreased as raspberry cover increased. Optimal spruce growth occurred on sites planted 2 months after treatment with V-ULW. This was also operationally the least expensive (no water was required).

255. **Reynolds, P.E., and M.J. Roden.** 1995. Hexazinone site preparation improves black spruce seedling survival and growth. Forestry Chronicle 71:426–433.

Granular hexazinone at 10% (Pronone® 10G, 1, 2, and 4 kg ai/ha) and 5% (Pronone® 5G, 2 kg ai/ha) were applied in May and September, followed by planting of black spruce seedlings 1 yr later. After 6 growing seasons, raspberry cover was significantly less on treated sites. In the controls it increased to 92%. No difference was detected in raspberry cover or height attributable to formulation (5% or 10%). Seedling height and diameter were negatively correlated with raspberry height. Optimal spruce survival and growth followed spring application of Pronone® 10G (2 kg ai/ha).

256. **Reynolds, P.E., and M.J. Roden.** 1996. Site preparation with sulfonylurea herbicides improves black spruce seedling growth. Forestry Chronicle 72:80–85.[1]

A mixed conifer and hardwood stand in New Brunswick was clearcut in the fall and site prepared the following summer using a Letourneau crusher to fell snags and break residual logging slash. Application of metsulfuron (Ally® or Escort® at 36 and 72 g ai/ha) and sulfometuron (Oust® at 150, 300 and 450 g ai/ha) 1 yr after the cutting successfully reduced raspberry interference and enhanced black spruce survival and growth. Spring-applied sulfometuron at 34.9 and 30.1%, and summer-applied metsulfuron at 58.6 and 44.8%, reduced the sixth yr mean raspberry cover (%) with no significant difference in cover or height between formulations. The less expensive herbicides and those permitting planting sooner after chemical site preparation seem preferable for weed control.

[1]This article also published as Reynolds, P.E., and M.J. Roden. 1995. Short term performance of two sulfonylurea herbicides: efficacy, seedling survival and growth. Northern Journal of Applied Forestry 12:80–85.

F. Western Species of *Rubus*

257. **Coates, K.D., M. Douglas, J.W. Schwab, and W.A. Bergerud.** 1993. Grass and legume seeding on a scarified coastal alluvial site in northwestern British Columbia: response of native non-crop vegetation and planted Sitka spruce (*Picea sitchensis* (Bong.) Carr.) seedlings. New Forestry 7:193–211.

Reestablishment and height growth of thimbleberry decreased from 18% cover to 6% following seeding of sod-forming grasses. Blading also dramatically reduced salmonberry cover and slowed reestablishment. After 5 growing seasons, it averaged 9% cover in all treatments. Height growth averaged 19 cm in plots with sod-forming grass and legumes, but varied between 26 and 32 cm in all other plots. Sitka spruce survived best in plots with sod-forming grasses (91%), and poorest in the legume plots (76%).

258. **LePage, P., J.C. Pollack, and K.D. Coates.** 1991. Chemical and manual control of thimbleberry (*Rubus parviflorus*) in northwestern Brit-

ish Columbia: A rate and timing trial. Western Journal of Applied Forestry 6(4):99–102.

Brushsaw cutting at the time of full leaf development (mid-July at the study site) successfully controlled thimbleberry for 2 yr, but cover was not significantly different from the untreated plots. Mid- and late summer application of glyphosate at 1.4 kg ai/ha or 2.1kg ai/ha successfully controlled thimbleberry cover. The mid-July application was most effective beyond three growing seasons.

259. **Miller, R.E., W.I. Stein, R.L. Heninger, W. Scott, S.N. Little, and D.J. Goheen.** 1989. Maintaining and improving site productivity in the Douglas-fir region, P. 98–136, in Maintaining the Long-term Site Productivity of Pacific Northwest Forest Ecosystems. D.A. Perry, R. Meurisse, B. Thomas, R. Miller, J. Boyle, J. Means, C.R. Perry, and R.F. Powers. (Eds). Timber Press, Portland.

Release treatments are applied in the Douglas-fir region when species such as salmonberry forms a solid stand. Those treatments foster forest growth and increase species diversity.

260. **Stein, W.I.** 1995. Ten-year development of Douglas-fir and associated vegetation after different site preparation on Coast Range clearcuts. USDA Forest Service Pacific Northwest Research Station Research Paper PNW-RP-473.

The following treatments were applied to sites planted with Douglas-fir and dominated by salmonberry: no site preparation; spot-clearing (cutting woody vegetation to 15-cm height for 1.2-m radius around each tree); aerial spraying (glyphosate application in fall at 2.52.kg/ha); summer broadcast burning; slashing and burning; spraying and burning (application of picloram and 2,4-D at 1.49+5.97 kg/ha, followed by a broadcast burn during the same summer). Spot-clearing temporarily reduced salmonberry to 6.6%, but the Rubus returned to ~1/3 of the cover. Other treatments reduced the cover to <1%, with the highest recovery <25% (spot-cleared sites). Spraying kept salmonberry cover to <8%, and height less than in any other treatments. Even so, average height of salmonberry increased nearly threefold over the 10-yr study period, averaging 500 cm tall. The plots also had trailing blackberry. Broadcast burning drastically reduced its presence. Spot-clearing, glyphosate spraying, or no site preparation had no effect. Its dominance peaked after 5 yr, and then declined as taller-growing species dominated the site.

261. **Tappeiner, J.C., and J.C. Zasada.** 1993. Establishment of salmonberry, salal, vine maple and bigleaf maple seedlings in the coastal forests of Oregon. Canadian Journal of Forest Research 23:1775–1780.

Three 40- to 50-yr-old conifer stands in the stem initiation (2-yr-old clearcut), stem exclusion (50–58 m^2/ha basal area and less than 5% understory cover) and understory reinitiation (thinned 3–5 yr prior to 30–36 m^2/ha with 10–15% understory cover) stages of development were evaluated in a study of seed predation, seedling emergence, survival and plant height growth of salmonberry. Emergence was greater on sites with exposed mineral soil compared to undisturbed soil, and more abundant during the second yr of the study. After 4 yr, no significant difference was detected in seedling survival related to soil disturbance, though disturbed sites had consistently better salmonberry survival and height growth, averaging 23 cm in the clearcut and 16 cm in the thinned stand.

262. **Tappeiner, J.C., J.C. Zasada, P. Ryan, and M. Newton.** 1991. Salmonberry clonal and population structure: the basis for a persistent cover. Ecology 72:609–618.

Salmonberry remains stable through the production of aerial stems (25–50 stems/m^2). These develop from the bud bank in the rhizomes and at the base of stems, from rhizome extension (1.0–2.5 m/m^2), and through production of new rhizomes. As a consequence, even severe disturbance will not necessarily affect salmonberry populations. Once stand density increases, clones of salmonberry may die, or persist as small linear clones. As the trees self-thin and understory conditions become more favorable, the clones expand.

263. **Zasada, J.C., J.C. Tappeiner, B.D. Maxwell, and M.A. Radwan.** 1994. Seasonal changes in shoot and root production and in carbohydrate content of salmonberry rhizome segments from the central Oregon Coast Range. Canadian Journal of Forest Research 24:272–277.

Salmonberry rhizome segments were collected and incubated in a growth chamber to study shoot and root production. Thirty-seven to 58% of active buds elongated into shoots; lowest percentages were in July to October. Maximum root[1] production occurred in samples harvested between August and October, and the fewest roots from samples gathered during February to July. About 90% of root segments showed some growth activity regardless of the time of collection.

[1]Only adventitious roots were produced, with point of origin unrelated to position of nodes or the location of roots clipped before incubation.

PART IV. PIN CHERRY

A. Range, Distribution, and Ecologic Characteristics

264. **Amthor, J.S., D.S. Gill, and F.H. Bormann.** 1990. Autumnal leaf conductance and apparent photosynthesis by saplings and sprouts in a recently disturbed northern hardwood forest. Oecologia 84:93–98.

Leaf surface conductance and apparent photosynthesis were measured on green and senescing leaves of pin cherry in a northern hardwood forest 5 yr after a whole tree harvest. During late summer, pin cherry leaf conductance exceeded that of sugar maple by four times, of American beech by three times, and of yellow birch by 1.5 times. By October, conductance of pin cherry leaves remained higher than overall values of sugar maple. Pin cherry had greater green LAI, conductance of water, rates of photosynthesis, and CO_2 assimilation per unit leaf area than the other species. Pin cherry leaf production continued throughout August and it retained green, active leaves later into autumn than both sugar maple and American beech.

265. **Borland, J.** 1994. Field Notes: *Prunus pensylvanica*. American Nurseryman 180(5):106.

This species (often called fire cherry) quickly colonizes recently burned forests. A small, arching shrub form found in the Rocky Mountains (called western fire cherry) has a narrow, upright, single-stemmed form that reaches a height of 5 to 15 ft at maturity. The crown may spread 5 to 10 ft across. Reportedly, more than 20 bird species and many mammals use the fruits of western fire cherry. It tolerates poor soil and dry conditions, and propagates primarily from seed. It will hybridize with *P. emarginata* where the geographic ranges overlap. Pin cherry has no commercial value, but is used for landscaping in the western part of its range.

266. **Hall, I.V., C.O. Gourley, and G.W. Wood.** 1981. Biology of *Prunus pensylvanica* L.f. Proceedings N.S. Institute of Science 31:101–108.

The northern distribution of pin cherry ends at the southern limit of the permafrost. It grows with western serviceberry, beaked hazelnut, choke cherry, jack pine, white spruce, paper birch, and quaking aspen. It succeeds on humo-ferric podzols, organic and cryic fibrisol, and the luvisolic gray luvisol. Soil pH is strongly to quite acidic. Pin cherry readily regenerates in old fields and on cleared sites. A red fruit with a stony endocarp enclose the seed. Seeds mature in summer and germinate following a dormancy and cold period. Seedlings emerge after fire when intense heat destroys the seed coat and increased soil nutrients stimulate germination. The trees may grow to 15 m tall, and often serve as a nurse crop to conifers. Since shoots can arise from pieces of root in the soil, eradication must be extensive and thorough. Though no longer available, 2,4,5-T will kill pin cherry, as will ammonium sulfamate and dichhlorprop.

267. **Hay, R.** 1978. Conditions for optimum growth of a species can be fragile and fleeting, as this discovery proves. American Forests 84(4):14, 62–63.

Pin cherry grows rapidly and in pure stands on sites where logging exposes the soil. However, it will not remain abundant in a forest without periodic disturbance (i.e., fire, blowdowns, rock slides, logging).

268. **Hough, A.F., and R.D. Forbes.** 1943. The ecology and silvics of forests in the high plateaus of Pennsylvania. Ecological Monographs 13:299–320.

Aspen-pin cherry stands form following repeated burning of logged-over second-growth stands. In those stands, pin cherry accounts for 28% of all trees ≥1 in. dbh. After clearcutting following short rotations, pin cherry and other weedy species flourish to the detriment of the desirable commercial species.

269. **Leak, W.B.** 1991. Secondary forest succession in New Hampshire. Forest Ecology and Management 43:69–86.

Pin cherry, an early successional species that regenerates after heavy cutting, has a short life (peaking at 30 yrs), and then its abundance declines rapidly. Even when absent from stands older than 50 yrs, its reproductive potential is maintained through buried seeds.

270. **Wendel, G.W.** 1990. Pin cherry (*Prunus pensylvanica* L.f.). In: Silvics of North America. Volume 2. Hardwoods. Burns, R.M., and B.H Honkala (Eds.). USDA Forest Service. URL: http://www.na.fs.fed.us/spfo/pubs/silvics_manual/

Commonly called northern pin cherry, bird cherry, wild red cherry, and pigeon cherry. It grows on rocky ledges, sandy plains, moist loamy soils and rich loams. Soils supporting pin cherry stands in New England vary widely, but are mostly shallow, well-drained Spodosols ranging from very stony to extremely stony sandy loams to loams. Pin cherry grows from Newfoundland west to British Columbia, south into the Rocky Mountains to Montana and Colorado. It follows the Appalachian Mountains from New England to New Jersey and south to Georgia and Tennessee. Associated northern tree species include quaking aspen, paper and yellow birch, striped maple, red and sugar maple, American beech, northern red oak, balsam fir, and red spruce. Associated shrubs include blackberry, raspberry, hobblebush, American yew and red elderberry. Pin cherry regenerates naturally from buried seed and may form pure stands following disturbance (e.g., wind throw, light fires and/or harvesting). It usually dominates all other vegetation. Seedlings are very shade intolerant and survive best in large openings having good light and moisture. Pin cherry reaches 20–25 cm dbh in 25 yrs, but rarely persists for more than 35 yrs. Seeds of shade-tolerant species will germinate beneath clumps of pin cherry and grow into the canopy after the pin cherry die. The leaf disease black knot (*Apiosporina morbosa*) most commonly attacks pin cherry, as do leaf feeding insects like the uglynest caterpillar (*Archips cerasivoranus*) and the eastern tent caterpillar (*Malacosoma americanum*). They are considered unimportant.

B. Reproductive Character

271. **Ahlgren, C.E.** 1966. Small mammals and reforestation following prescribed burning. Journal of Forestry 64:614–618.

Pin cherry commonly regenerates from buried seed left by trees that previously occupied the site. Birds often disseminate the seed far from its source, and small mammals cache the seeds on site and elsewhere.

272. **Auchmoody, L.R.** 1979. Nitrogen fertilization stimulates germination of dormant pin cherry seed. Canadian Journal of Forest Research 9:514–516.

Nitrogen applied as urea successfully stimulated germination of pin cherry seed without any significant difference between formulations, except 56 kg/ha N from ammonium sulfate. It induced no germinants. New seedlings survived for 3 mo under the closed canopy. Germination occurred after addition of nitrate, and a chilling period. N fertilizer applied to maturing stands should trigger germination prior to overstory removal, and will reduce the number of pin cherry that germinate after the cutting.

273. **Graber, R.E., and D.F. Thompson.** 1978. Seeds in the organic layers and soil of four beech-birch-maple stands. USDA Forest Service Northeastern Forest Experiment Station NE-401.

Litter and soil samples were placed in a greenhouse to compare germination rates among the seed banks under four beech-birch-maple stands in the White Mountain National Forest. Samples from the 38-yr-old stand produced 111 germinants/m^2. Half as many seeds germinated in samples from the 95-yr-old stand. Findings indicate at least some pin cherry seeds stored in the humus layer remain viable for 75–150 yr. Few seeds germinated from litter and soil under the 5-yr-old and 200+ yr-old stands. Seed fall during 6 yrs beneath the two oldest stands included no new pin cherry seeds. Most likely, using rotations of 60 yr or less would perpetuate pin cherry in a stand and require intensive cultural treatments to insure adequate stocking of high value species.

274. **Jobidon, R.** 1997. Pin cherry sucker regeneration after cutting. Northern Journal of Applied Forestry 14(3):117–119.

Among 10-yr-old stems in 4 clones, suckers emerged from established root systems 1 to 2 yr after the parent stem was cut. They averaged 11–32 suckers/root system and covered a relatively small area. Apparently competition from surrounding stems restricted clonal expansion. No correlation was found between sucker age and distance from the parent stem, or between sucker age and parent root diameter. Four- to 5-yr-old suckers had not initiated roots. Manual or mechanical methods would not control young pin cherry due to root suckering.

275. **Jobidon, R.** 1997. Stump height effects on sprouting of mountain maple, paper birch and pin cherry—10 year results. Forestry Chronicle 73:590–595.

Two yr after late June cutting of 1- to 4-cm dbh trees, pin cherry had a higher percentage of stumps with sprouts than observed for mountain maple or paper birch. Initially, the taller stumps (0- to 75-cm high) had more sprouts, but sprout numbers did not vary with stump height after 10 yr. Numbers of sprouts decreased between the first and second growing seasons, particularly among stumps ≤15-cm tall. During the first yr, sprouts off the shorter stumps grew best, but differences related to stump height became non-significant over time. Sprout vigor was not related to stump height. However, throughout the study the total height of the sprout plus stump combined was significantly greater among the 75-cm stumps.

276. **Marks, P.L.** 1974. The role of pin cherry (*Prunus pensylvanica* L.) in the maintenance of stability in northern hardwood ecosystems. Ecological Monographs 44:73-88.[1]

Pin cherry colonizes disturbed sites larger than 0.25 ac. Once established, it grows rapidly, matures sexually by the fourth growing season, has a 2- to 3-yr seed production cycle, has a high root to shoot ratio and a high leaf area index, and the crown canopy closes early. Pin cherry develops from buried seed that remain viable for up to 50 yrs. Their numbers depends upon the frequency of disturbance in a stand. Soil samples in New Hampshire forests have contained 180,000 seeds/ac. Their abundance determines pin cherry stem density after overstory disturbance. If present underneath dense stands of pin cherry, sugar maple and beech will become the dominant species after 25–35 yrs. With intermediate densities of pin cherry, species like yellow and paper birch and quaking aspen will eventually co-dominate the stand. At low pin cherry densities after clearcutting or fire, the canopy closes more slowly. Rubus, striped maple, aspen, birches and stump sprouts of cut trees may be present. Beech and sugar maple may gain dominance more rapidly than in stands with a high density of pin cherry.

[1]See also: Marks, P.L. 1971. The Role of *Prunus pensylvanica* L. in the Rapid Revegetation of Disturbed Sites. Ph.D. dissertation. Yale University. New Haven, CT.

277. **Marks, P.L.** 1975. On the relation between extension growth and successional status of deciduous trees of the Northeastern United States. Bulletin of the Torrey Botanical Club 102:172–177.

Pin cherry has indeterminant growth, with shoot extension continuing through much of the frost-free season.

278. **Olmstead, N.W., and J. Curtis.** 1947. Seeds of the forest floor. Ecology 28:49–52.

Soil samples from several forest types in Maine were examined for pin cherry seed and its viability. Those from a 24-yr-old red pine plantation had one cherry seed/ac, and it germinated. A 50-yr-old beech-birch-sugar maple stand had 21 seeds/ac, with none viable. The 110-yr-old beech-birch-sugar maple stand had 11 seeds/ac, and 45% germinated. Whether pin cherry was present or absent from the stand, its seed remained viable in the humus layer.

279. **Peterson, C.J., and W.P. Carson.** 1996. Generalizing forest regeneration models: The dependence on disturbance history and stand size. Canadian Journal of Forest Research 26:45–52.

Based upon a general conceptual model for forest regeneration in the northeast, abundance of pin cherry depends upon propagule availability, as determined by area and age of the forest. Pin cherry seed density was low after a disturbance, increased to peak density in the third and fourth decade afterward, and then declined to a low abundance at ages >120 yr. At the Allegheny National Forest, old forests that lacked pin cherry had a limited seed bank. Smaller areas of old growth stands surrounded by agricultural land had sources of seed in close proximity.

280. **Thurston, S.W., M.E. Krasny, C.W. Martin, and T.J. Fahey.** 1992. Effect of site characteristics and 1st- and 2nd-year seedling densities on forest development in a northern hardwood forest. Canadian Journal of Forest Research 22:1860–1868.

Percent scarification, percent slash, and basal area of coarse woody debris in two New Hampshire clearcuts (12 ha and 36 ha) were used to develop density models and determine the importance of initial and long-term abundance of early and late-successional species. All trees >2.5 cm dbh had been cut and saplings and larger seedlings were crushed by felling and skidding. That left only scattered seedlings and sprouts <0.5 m tall. Variability of pin cherry density (2.0–90.2 seedlings/m^2) at yr 2 may result from low seed availability, especially where heavy scarification removed the humus layer. Though nearly all plots had high initial pin cherry densities, stems nearly doubled from yr 1 to yr 2 on plots with little scarification. At 1 and 18 yrs, pin cherry density was negatively correlated with coarse woody debris basal area. These may be associated, but may also reflect the lower pin cherry mortality rates on sites with little coarse woody debris.

281. **Tierney, G.L., and T.J. Fahey.** 1998. Soil seed bank dynamics of pin cherry in a northern hardwood forest, New Hampshire, U.S.A. Canadian Journal of Forest Research 28:1471–1480.

Young stands (23 yrs of age) with a high and low density of standing pin cherry had, respectively, 440 and 1900 viable seed per pin cherry stem present. A 23-yr-old stand had 83% viable seed, compared with 27–30% viability in older ones (60+ yrs). Samples showed a high degree of variability from place to place within any stand. Between 40 and 60 yrs after clearcutting a stand had similar densities of viable seed in the litter. Between 90 and 115 yrs, the seed density decreased by 30%. Findings from this and other research suggest that using rotations shorter than 60 yrs may result in abundant pin cherry due to the quantity of viable seed in the litter layer. For rotations in excess of 100 yrs, viable seed density will have decreased to a fairly low level. With rotations of 120 yrs or longer, pin cherry should not have adverse effects on the regeneration of desirable long-lived tree species.

C. Impact of Deer

282. **Jordan, J.** 1967. Deer browsing in northern hardwoods after clearcutting. Effect on height, density, and stocking of regeneration of commercial species. USDA Forest Service Northeastern Forest Experiment Station Research Paper NE-57.

Heavy browsing by white-tailed deer on new shoots of pin cherry seedlings evidently reduced competition between commercial and noncommercial species and served as a "biological control" of the species. Pin cherry density was greater in every height class inside fenced plots compared to unfenced plots.

283. **Marquis, D.A.** 1974. The impact of deer browsing on Allegheny hardwood regeneration. USDA Forest Service Research Paper NE-RP-308.[1]

Number of stems in 16-yr-old clearcuts did not differ significantly between fenced and unfenced areas. However, selective browsing by deer left increased proportions of beech, black birch, and striped maple. Browsing virtually eliminated pin cherry and sugar maple from the unfenced areas.

[1]Continuation of the study in citation #282.

284. **Marquis, D.A.** 1981. Effect of deer browsing on timber production in Allegheny hardwood forests of northwestern Pennsylvania. USDA Forest Service Research Paper NE-RP-475.[1]

Total regeneration at 9 to 22 yr after clearcutting in stands with approximately 25 deer/sq mi did not differ significantly between fenced and unfenced areas. Yet species composition and number of stems >5 ft tall differed importantly. Less than one-third of unfenced clearcuts had satisfactory stocking of preferred species (i.e., 70% of plots with at least two stems >5 ft tall). Beech, birch and striped maple were the only species more abundant in unfenced areas, showing the effect of preferential browsing by deer. Deer virtually eliminated pin cherry from unfenced areas.

[1]Continuation of study presented in citation #283.

285. **Tilghman, N.G.** 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. Journal of Wildlife Management 53(3):524–532.

Deer densities >40 per 260 ha in thinned and clearcut stands, and >80 per 260 ha in uncut stands, had a detrimental impact on advance tree regeneration and seedling height growth. Deer browsing strongly affected the density of sugar maple, pin cherry, and yellow birch, while beech, striped maple, and black cherry flourished. The latter group dominated sites once stocked by other species.

D. Regeneration Following Silvicultural Treatments

286. **Bicknell, S.H.** 1982. Development of canopy stratification during early succession in northern hardwoods. Forest Ecology and Management 4:41–51.

Pin cherry had the slowest initial growth, but growth improved with each successive growing season. It dominated the upper canopy by yr 6. Beech and sugar maple have a determinate growth form and slower growth rates. Yellow birch and pin cherry were indeterminate in growth. These traits may explain why shade-tolerant species show increased growth upon release and shade-intolerant species initially develop more rapidly than shade-tolerant ones.

287. **Bjorkbom, J.C., and R.S. Walters.** 1986. Allegheny hardwood regeneration response to even-age harvesting methods. USDA Forest Service Northeastern Forest Experiment Station RP-NE-581.

The survival and growth of advance and post-cutting regeneration were studied in a 26-ac block clearcut, 32-ac strip clearcut, 6-ac shelterwood, and a 6-ac uncut control area on the Kane Experimental Forest in Pennsylvania. The block clearcut had the greatest number of pin cherry seedlings at 1 yr after treatment. The heavy cutting caused disturbance of the humus layer, higher light levels near the forest floor, and an increase of soluble nitrogen in the soil. All help to stimulate seed germination. Few pin cherry seeds germinated in the shelterwood stand and the cut and uncut alternate strips. Not many survived in those plots, and none was found in the uncut control stand. The shelterwood treatment best minimized the effect of deer browsing. The seed cutting established new slow growing shade-tolerant seedlings (less succulent than rapidly elongating pin cherry).

288. **Crow, T.R., and F.T. Metzger.** 1987. Regeneration under selection cutting. P. 81–94, in Managing Northern Hardwoods. R.D. Nyland (Ed.). SUNY College of Environmental Science and Forestry, Faculty of Forestry Miscellaneous Publication Number 13 (ESF 87-002). (Society of American Foresters Publication Number 87-03).

Three yrs after patch cutting (1/5 to 2/3 ac) in northern hardwood stands in New Hampshire, pin cherry dominated along with other interfering species, reaching heights of 10–12 ft and >1 in. dbh. Though an early weeding of pin cherry may not be necessary to establish shade-tolerant species, it will benefit species of intermediate shade tolerance.

289. **Hannah, P.R.** 1991. Regeneration of northern hardwoods in the northeast with the shelterwood method. Northern Journal of Applied Forestry 8(3):99–104.

Shelterwood method was applied to northern hardwood stands in Vermont to evaluate subsequent regeneration of preferred and less desirable species.

With overhead cover <60% (residual density < 80 ft2/ac) pin cherry became abundant and interfered with yellow birch growth and development. While birch abundance was not significantly different than less desirable species, the author recommends control by site preparation before or at the time of the shelterwood cutting if undesirable species like pin cherry comprise >50% of advance regeneration.

290. **Heitzman, E., and R.D. Nyland.** 1994. Influences of pin cherry (*Prunus pensylvanica* L.f.) on growth and development of young even-aged northern hardwoods. Forest Ecology and Management 67:39–48.

The study compared areas of high pin cherry stem density (≥3 stems on a 0.0004 ha plot) and low stem density (<3 /plot) in a central New York clearcut.[1] The stand lacked pin cherry prior to clearcutting, but it became established by the third growing season. By yr 20, plots that had a high pin cherry stem density at yr 3 had significantly more total stems, due to the overwhelming presence of pin cherry. Though initially abundant, black cherry declined from 53% of total stems to only 9% at yr 20 on plots with a high density of pin cherry. At yr 20, pin cherry accounted for 56% of basal area on high-density plots, and 33% on low-density plots. High-density plots had only 420 dominant trees/ha (excluding pin cherry), whereas the low-density plots had 1148/ha. The low-density plots had more dominant pin cherry trees, but more codominant and dominant trees of other species. This will assure that shade-intolerant and intermediate species remain as long-term components of the stand. Removing all pin cherry stems with foliage touching the crowns of selected trees in stands with moderate to high stocking of pin cherry would likely maintain desirable stems and stimulate diameter growth among the released trees. However, a cleaning would not benefit stands where pin cherry has overtopped commercially valuable trees, reduced their vigor, and led to mortality of the more desirable species.

[1]The threshold set for this study as a high density of pin cherry was fairly low compared to other reports (e.g., citations #216, #306). See also: Heitzman, E.F. 1991. Influences of Pin Cherry (*Prunus pensylvanica* L.f.) on Growth and Development of Young, Even-aged Northern Hardwoods. M.Sc. thesis. SUNY College of Environmental Science Forestry. Syracuse, NY.

291. **Horsley, S.B., and D.A. Marquis.** 1983. Interference by weeds and deer with Allegheny hardwood reproduction. Canadian Journal of Forest Research 13:61–69.

A shelterwood seed cutting reduced an Allegheny hardwood stand to 75% of full stocking. Pin cherry germinated on all plots, but none survived more than 4 yr. In a separate stand, the second entry of a two-cut shelterwood treatment removed all stems >2.5 cm dbh, following an earlier 50% reduction in stocking. Some areas were fenced and/or weeded. After 2 yr, pin cherry was present on all plots, with significantly more stems after 4 yr on fenced-weeded plots. Both weeding and deer browsing affected the growth of pin cherry. The former stimulated germination by increasing available nitrate in the soil, and the latter limited height development through heavy browsing.

292. **Jensen, V.S.** 1943. Suggestions for the management of northern hardwood stands in the northeast. Journal of Forestry 41:180–185.

Five yr after clearcutting a 15-ac tract, advance reproduction of desirable timber species had grown more rapidly than beech and striped maple. Overall, advance regeneration grew taller in small openings with little interference from shade-intolerant species. After clearcutting, pin cherry (not present as advance regeneration) outnumbered all other stems >4 ft tall. Yet due to its shade intolerance and short life span, pin cherry species should not survive beyond 20-30 yr.

293. **Leak, W.B.** 1988. Effects of weed species on northern hardwood regeneration in New Hampshire. Northern Journal of Applied Forestry 5:235–237.

Four cutting methods in uneven-aged northern hardwoods (initial basal area from 120 to 130 ft^2/ac included clearcut (complete removal in some areas, and a residual overstory of 34 ft^2/ac in others); diameter-limit cutting 64 ft^2/ac; moderate selection cutting to 83 ft^2/ac; and light selection cutting to 95 ft^2/ac. Tallies of post-logging regeneration (1 yr and 8 yr) evaluated the influence of weed species on growth. Pin cherry increased in dominance with the heavier cutting, ranging from 1 to 8.4 % of the dominant stems. A low percentage of commercial species occurred on sites dominated by pin cherry (residual densities <83 ft^2/ac). Pin cherry did not cause a significant reduction in stocking of any species, except for yellow birch at the partial clearcut sites (stocking reduced by one-third).[1] Stocking of sugar maple and white ash showed little to no negative effect from the presence of weed species following any of the cutting treatments.

[1]For more details see citation #306.

294. **Leak, W.B., and M.L. Smith.** 1997. Long-term species and structural changes after cleaning young even aged northern hardwoods in New Hampshire, USA. Forest Ecology and Management 95:11–20.

Three different crop-tree release treatments of varying intensities were applied at stand age 25 to promote valuable timber species. Fifty-six yrs later, species composition did not differ among the stands (including the control). The stands had no pin cherry or striped maple, and beech and sugar maple dominated the stem numbers. The release treatment resulted in substantial short-term changes in density, structure and species composition. Yet crop tree release had only a minor effect on overall stand development.

295. **Leak, W.B., and D.S. Solomon.** 1975. Influence of residual stand density on regeneration of northern hardwoods. USDA Forest Service Research Paper NE-RP-310.

This study examined effects of residual stand density (100, 80, 60, 40 and 0 ft^2/ac in trees $\geq$4.5 in. dbh) and structure (60, 45, and 30% sawtimber) on understory development. Unwanted trees were frilled or chemically treated. Nine growing seasons after cutting, pin cherry accounted for 30–39% of hardwood stems in the clearcuts, but only 0–9% of stems in plots of all other residual densities.

296. **Leak, W.B., D.S. Solomon, and S.M. Filip.** 1969. A silvicultural guide for northern hardwoods in the northeast. USDA Forest Service Northeastern Forest Experiment Station RP-NE-143.

Clearcutting will result in regeneration with two-fifths shade-intolerant, one-fifth intermediate, and two-fifths shade-tolerant species. A greater proportion of shade-intolerant Rubus spp. and pin cherry will retard birch regeneration.

297. **Mallik, A.U., F.W. Bell, and Y. Gong.** 1997. Regeneration behavior of competing plants after clear cutting: Implications for vegetation management. Forest Ecology and Management 95:1–10.

Regeneration of interfering woody species was observed in a 7-yr-old clearcut in a mid-Canadian boreal forest. Pin cherry initially had a density of 3600 stems/ha, but that decreased by 69% and 47%, respectively, over the next 2 yrs. Pin cherry was significantly taller than green alder and beaked hazel. Shoot height correlated positively with shoot and root biomass, and crown diameter. Because pin cherry tends to overtop associated species, the author described it as having a vertical competition strategy (VCS). Other species may exhibit a horizontal competition strategy (HCS). If plants of both kinds are present in high densities, crop trees may suffer long-term interference, and an understory treatment is necessary. It should reflect stem density and the proportion of VCS to HCS plants, as well as their population dynamics, height growth, stem mortality, and recruitment. All these characteristics directly influence the survival and growth of planted seedlings. Stands dominated by interfering plants that self-thin early and/or have a short life span (i.e., pin cherry) may not require any release treatment.

298. **Marks, P.L., and F.H. Bormann.** 1972. Revegetation following forest cutting: Mechanisms for return to steady-state nutrient cycling. Science 176:914–915.

Net annual production and nutrient accumulation were observed in four New Hampshire stands 1, 4, 6, and 14 yr after clearcutting. Pin cherry grew and developed rapidly, and this increased transpiration, accretion of biomass, and nutrient uptake in each stand. This may reflect the adaptive capacity of pin cherry to utilize the greater availability of water and nutrients on disturbed sites. Decisions to use clearcutting may be ecologically unsound if they ignore the recovery role of pin cherry.

299. **Marquis, D.A.** 1965. Regeneration of birch and associated hardwoods after patch cutting. USDA Forest Service Research Paper NE-RP-32.

Amount and size of reproduction was surveyed in several 3-yr-old patch cuttings (one-tenth to two-thirds ac in size) in old-growth and second-growth stands. Patches in the second-growth stand had abundant pin cherry. It became dominant on two-thirds of the plots, reaching 10–12 ft tall, and 1 in. dbh. Patches in the old-growth stands had minimal amounts of pin cherry. Striped maple and beech root suckers dominated the regeneration, with some sugar maple and yellow birch also present. The poor status of regeneration in the second-growth stand appears related to interference by pin cherry, and the absence of more desirable species as advance regeneration.

300. **Marquis, D.A.** 1967. Clearcutting in northern hardwoods: Results after 30 years. USDA Forest Service Northeastern Forest Experiment Station Research Paper NE-RP-085.

The stand had a basal area of 122 ft^2/ac in trees $\geq$4.6 in. dbh, with advance regeneration dominated by shade-tolerant species (26% beech, 56% sugar maple, 16% striped maple, 1% conifers). Immediately after winter clearcutting, raspberries covered the area, along with hardwood stump sprouts, hardwood root suckers, and weed trees like pin cherry. By yr 5, aspen, pin cherry, and paper birch were dominant, but pin cherry began to die out by yr 15. Of the total basal area at yr 25, 56% (55.9 ft^2/ac) was aspen, paper birch and white ash and 26% (25.4 ft^2/ac) beech and sugar maple. The latter occurred as co-dominants, and shade-tolerant species accounted for 63% of all stems.

301. **Martin, C.W., and J.W. Hornbeck.** 1990. Regeneration after strip cutting and block clearcutting in northern hardwoods. Northern Journal of Applied Forestry 7:65–68.

A 12-ha block clearcut and 36-ha progressive strip cut (a series of 3 cuts, 25 m wide, with 50 m wide uncut strips between them, cut at 2 yr intervals) removed all trees and snags >2.5 cm dbh on two sites in New Hampshire. After 10 yrs, the block clearcut had a greater regeneration density than in the strips. Of the strips, the first one had the densest regeneration, particularly at the lower elevations. Yellow birch predominated on both the block clearcut and the first strip cut, but yellow birch and sugar maple biomass was greater on the strips cut later. Pin cherry accounted for 11% of stems in the block clearcut, and <5% of stems in the strip cuts. Yellow birch, sugar maple, and beech will likely dominate when the pin cherry declines. Strip cutting failed to increase the percentage of yellow birch, but did increase the proportion of yellow birch in the larger size classes. The strip cuts also had lower stem densities, resulting in better individual tree diameter growth and biomass production on the crop trees.

302. **McClure, J.W., and T.D. Lee.** 1993. Small-scale disturbance in a northern hardwoods forest: Effects on tree species abundance and distribution. Canadian Journal of Forest Research 23:1347–1360.

Species abundance was evaluated in relation to gap size and location within a gap by sampling 24-, 33-, and 44-yr-old patch cuts that ranged in size from 3,500 ft^2 to 25,600 ft^2. Gap age had a stronger effect than gap size on species relative abundance. Young, large gaps had high basal areas and densities of pin cherry and striped maple. Pin cherry stocking increased with gap size. The low abundance of pin cherry in 44-yr-old gaps of all sizes reflects its disappearance as the community ages.

303. **Merrens, E.J., and D.R. Peart.** 1992. Effects of hurricane damage on individual growth and stand structure in a hardwood forest in New Hampshire, USA. Journal of Ecology 80:787–795.

Forty-nine yr after a hurricane damaged a site within the Hubbard Brook Experimental Forest, there were 85 dead pin cherry trees/ha (>5cm dbh). Pin cherry was replaced by yellow birch, sugar maple, American beech and white ash. This reflects a successional sequence identical to that following clearcutting.

304. **Mou, P., T.J. Fahey, and J.W. Hughes.** 1993. Effects of soil disturbance on vegetation recovery and nutrient accumulation following whole-tree harvest of a northern hardwood ecosystem. Journal of Applied Ecology 30:661–675.

After clearcutting and its associated soil disturbance in the Hubbard Brook Experimental Forest, pin cherry initially had the highest tissue N, P, and K concentrations. By the second yr, concentrations in American beech, sugar maple and striped maple were comparable. Pin cherry had a germination rate of 297 stems/m^2, with the greatest density, fastest growth, and the highest rate of biomass accumulation on scarified sites. Biomass accumulation on undisturbed sites exceeded those of disturbed sites, because pin cherry roots had extended into fertile locations. Total accumulation of macronutrients exceeded outflow from the site, indicating that pin cherry uptake helped to limit nutrient losses following clearcutting.

305. **Ristau, T.E., and S.B. Horsley.** 1999. Pin cherry effects on Allegheny hardwood stand development. Canadian Journal of Forest Research 29:73–84.

Pin cherry was present 1 yr after overstory removal (3500 to 195 stems/ha), but <1.5 m tall. By yr 3, stands had nearly 17,000/ha of pin cherry stems >1.5 m tall. As the density of 3-yr-old pin cherry increased beyond 1.5 m tall, that of 15-yr-old black cherry, red maple, and sugar maple decreased. By yr 15, pin cherry had become the tallest species, reaching >12 m. But the density had decreased to 4000 stems/ha. Pin cherry remains about 30 yr in stands with low pin cherry density, and 40–45 yr where it occurs at a high density. As a consequence, the latter stands have a lower species diversity and slower stand development and lower yields. Landowners should consider the implications for stands where milacre plots have >1 pin cherry stem >1.5 m tall by age 3.

306. **Safford, L.O., and S.M. Filip.** 1974. Biomass and nutrient content of 4-year-old fertilized and unfertilized northern hardwood stands. Canadian Journal of Forest Research 4:549–554.

Growth and development of hardwood regeneration was evaluated following clearcut, scarification, and herbicide treatment of a 20-ha old-growth forest, followed by the application of fertilizer on some stands. Four yrs following treatment, pin cherry regeneration in all areas was much larger than other species. It dominated the regeneration (72% of stems and 94% of the biomass) in fertilized stands. Likewise, pin cherry accounted for more than half of the stems and the biomass in the unfertilized stands, but grew mostly in clumps. This left space for substantial numbers of stems of desirable species. The moderately dense stand of pin cherry permitted early rapid growth of birch with straight stems. When the pin cherry begins to die out of the unfertilized stands, well-formed trees of desirable species will dominate. Though regeneration of desired stems was abundant in fertilized stands (35,000 stems/ha of birches), that may prove insufficient for adequate stocking of desirable trees following early suppression by the dense pin cherry. A cleaning around good trees of other species would reduce the interference and enhance birch growth and development.

307. **Shabel, A.B., and D.R. Peart.** 1994. Effects of competition, herbivory and substrate disturbance on growth and size structure in pin cherry (*Prunus pensylvanica* L.) seedlings. Oecologia 98:150–158.

Two seasons after clearcutting in a New Hampshire forest, the height of pin cherry was significantly shorter where plant densities exceeded 30/m^2. Browsed trees in areas with a density of <30/m^2 grew better in height than unbrowsed ones, and regained height dominance. Such compensatory growth was not significant for pin cherry growing at the highest stand density, and those trees did not regain dominance. Considering the combined effects of density, browsing, and compensatory growth, large initial tree size proved clearly advantageous. Disturbance caused by logging did not significantly affect pin cherry height growth or lead to size inequality.

308. **Smalley, F.E.** 1987. Regeneration hardwood stands in the Northeast. Northern Journal of Applied Forestry 4:5–6.

Nine growing seasons after seed tree cutting in a 16-ac stand with basal area of 84 ft^2, pin cherry stems had grown to about 9–12 ft tall. Other desirable regeneration was less than 5 ft high.

309. **Smith, D.M., and P.M. Ashton.** 1993. Early dominance of pioneer hardwoods after clearcutting and removal of advanced regeneration. Northern Journal of Applied Forestry 10(1):14–19.

Long, 80-ft wide strips and 150-ft diameter circular openings simulated clearcuts in mixed hardwood stands of Connecticut and New Hampshire. All stands were treated by basal spray of herbicide and areas subject to heavy deer browse were fenced. After 2 yrs, few hardwoods had become established except those present as advance regeneration. Later, pin cherry in centers of the openings had overtopped the birches and red oak, limiting their height growth. Other species grew faster than pin cherry only in the side-shade zones along the southern and northern edges of the openings. At one site, deer browsing nearly eliminated the pin cherry and birch succeeded. By the 18th yr, the few pin cherry that remained were small-crowned and moribund. Black, yellow, gray, and paper birch eventually became established. Their height depended on position in the openings, and their interaction with each other and with pin cherry.

310. **Wang, Z., and R.D. Nyland.** 1993. Tree species richness increased by clearcutting of northern hardwoods in central New York. Forest Ecology and Management 57:71–84.

Clearcutting removed trees ≥5 cm dbh from five previously uneven-aged northern hardwood stands, leaving a dense cover of logging slash on site. After 1 yr, the regeneration included more than 10 species. Shade-intolerant pin cherry averaged 0.6 m tall and 0.52 cm dbh. It had grown more rapidly than the shade-tolerant species, and had a ratio of relative basal area to relative density of >1.0. Since pin cherry was absent from the canopy and as advance regeneration, germination likely occurred from buried seeds that had accumulated over long periods prior to clearcutting.

311. **Wang, Z., and R.D. Nyland.** 1996. Changes in the condition and species composition of developing even-aged northern hardwood stands in central New York. Northern Journal of Applied Forestry 13(4):189–194.

During 20 yr following clearcutting, species composition and relative importance of each differed appreciably among five previously uneven-aged northern hardwood stands. Short-lived species had died or grown into dominant positions within the upper canopy. Pin cherry comprised 32% of dominating trees, 25% of the relative density, and 35% of the relative basal area at 18 yr after clearcutting.

E. Pin Cherry in Conifer Stands

312. **Beland, M., and Y. Bergeron.** 1993. Ecological factors affecting abundance of advanced growth in jack pine (*Pinus banksiana* Lamb.) stands of the boreal forest of northwestern Quebec. Forestry Chronicle 69:561–568.

Pin cherry accounted for 0.1 m^2/ha of stems >5cm dbh in a 65-yr-old jack pine-white birch-aspen stand. Pin cherry had a positive correlation with advance growth of balsam fir and white spruce, presumably due to better light conditions beneath the small canopy openings in these stands.

313. **Elliott, K.J., and A.S. White.** 1993. Effects of competition from young northern hardwoods on red pine seedling growth, nutrient use efficiency, and leaf morphology. Forest Ecology and Management 57:233–255.[1]

The study evaluated interference by pin cherry with red pine in two clearcut stands in New Hampshire. One stand was fertilized with 224 g/m^2 of 10-10-10 NPK commercial fertilizer. After 3 yr, total above-ground pin cherry biomass nearly doubled in the fertilized area, with a leaf area index (4.38) three times greater than of other species. The presence of dense pin cherry increased significantly and reduced red pine total biomass by ~60%. Though red pine survived for 3 yrs, its longevity beneath dense pin cherry canopies remains unclear.

[1]See also Elliott, K.J. 1991. Competitive Effects of Northern Hardwoods on Red Pine Seedling Growth, Nutrient Use Efficiency, and Leaf Morphology (*Acer pensylvanicum, Acer rubrum, Prunus pensylvanica, Pinus resinosa*). Ph.D. dissertation. University of Maine. Orono, ME.

314. **Osawa, A.** 1994. Seedling responses to forest canopy disturbances following a spruce budworm outbreak in Maine. Canadian Journal of Forest Research 24:850–859.

Pin cherry became abundant in heavily disturbed stands and where ~10 m^2/ha of balsam fir basal area had died after a spruce budworm outbreak. Pin cherry grew tallest (mean height of 247 cm) where basal area of dead balsam fir was greatest. Regeneration was primarily from seed, with recruitment lasting 8–9 yr after disturbance.

315. **White, A.S. and K.J. Elliott.** 1992. Predicting the effects of hardwood competition on red pine seedling growth. Canadian Journal of Forest Research 22:1510–1515.

Two clearcut sites in Maine were chosen to quantify competition intensity of interfering pin cherry and striped maple on 2-yr growth of planted red pine seedlings. Due to its higher leaf area index and biomass, pin cherry had a greater negative impact.

F. Control Methods—Biological, Chemical, and Mechanical

316. **Church, T.W.** 1955. Weeding - an effective treatment for stimulating growth of northern hardwoods. Journal of Forestry 53:717–719.

Cleaning released crowded and overtopped sugar maple in stands dominated by undesirable pioneer species. Black cherry did not require release. Heavy and silvicultural cleaning[1] resulted in significantly better 16-yr crop tree diameter growth than after a lighter degree of release. Diameter growth increased most among intermediate and overtopped trees. Spacing should range between 12 and 15 ft in 12- to 18-yr-old stands. For black cherry, use silvicultural grade cleaning around crop trees, and heavy release around intermediate and overtopped trees. Use a heavy release around sugar maple, regardless of crown class. For other species use either silvicultural or heavy release.

[1]A flexible treatment based on individual species' requirements for best future growth.

317. **Jobidon, R.** 1998. Comparative efficacy of biological and chemical control of the vegetative reproduction in *Betula papyrifera* and *Prunus pensylvanica*. Biological Control 11:22–28.

Both mechanical and biological treatments successfully controlled the frequency and degree of stump sprouting in pin cherry. Four treatments applied to cut stumps (averaging 50 mm dbh) within 30 minutes following felling included: 2 isolates of the fungus *Chondrostereum purpureum* (Cp1, collected in N. Quebec; Cp2, collected in S. Quebec); bialaphos; and glyphosate. After 1 and 2 yr, sprouts off stumps treated with the more virulent Cp2 were shorter, less vigorous, fewer in number, and had a lower survival rate than those on stumps treated by Cp1. Bialaphos reduced sprout production, but the control only lasted 2 yr. Glyphosate completely controlled sprouting.

318. **Liptzin, D., and P.M. Ashton.** 1999. Early-successional dynamics of single-aged mixed hardwood stands in a southern New England forest, USA. Forest Ecology and Management 116:141–150.[1]

During June following clearcutting, all advance reproduction and stump sprouts were cut and treated with 2,4,5-D. After 28 yr, shade-intolerant pin cherry, paper birch and gray birch dominated the upper canopy, with shade-intermediate black cherry and black birch also prevalent. Pioneer species grew better on swale-till sites than on thin till sites.

[1]See also citation #309.

319. **Longwood, F.R.** 1951. Why release young maple from pin cherry? USDA Forest Service Technical Note. LS-TN-360.

Thirty-yr old pin cherry (25% of the stand) were cut or girdled to release 15- to 20-yr-old overtopped sugar and red maple (80% of the stand). Some areas were left untreated. Fourteen yrs later, the uncut plot had fewer 1-2 in. dbh pin cherry than on the released plots. The release treatment created suitable conditions for new pin cherry seedlings and sprouts, and reduced mortality among pin cherry seedlings and saplings.

320. **McCormack, M.L., Jr.** 1981. Chemical weed control in Northeastern forests. Weed control in forest management. P. 108–115, in Proceedings of the John S. Wright Forestry Conference. Purdue University. Lafeyette, IN.

Pin cherry may dominate good sites for 15 yr or more. Its seeds will remain viable in duff layers for long periods, sprouting after canopy removal. Aerial application or stump treatment of triclopyr amine at 2.2 and 4.5 kg/ha in water will effectively kill pin cherry.

321. **McCormack, M.L., Jr., and M. Newton.** 1980. Aerial application of triclopyr, phenoxies, picloram and glyphosate for conifer release in spruce-fir forests of Maine. Proceedings of the Weed Science Society of America: 47–48

Glyphosate applied at 2.2 kg/ha killed 90% of beech, pin cherry, and raspberry, with less than 40 % mortality among sugar maple.

322. **Newton, M., E.C. Cole, D.E. White, and M.L. McCormack, Jr.** 1992. Young spruce-fir forests released by herbicides I. Response of hardwoods and shrubs. Northern Journal of Applied Forestry 9(4):126–130.[1]

Applications of 2,4,5-T[2] (2.2 and 3.3 kg/ha); 2,4-D + 2,4,5-T esters (1.1 + 1.1kg/ha and 2.2 + 2.2 kg/ha), triclopyr amine (2.2 and 4.4 kg/ha), triclopyr amine + 2,4-D ester (2.2kg/ha + 2.2 kg/ha), and glyphosate (1.7 and 3.3 kg/ha) were delivered by helicopter equipped with D-6-46 nozzles spraying 37.4 l/ha in four swaths of 16.7 m net coverage to control interfering deciduous cover in conifer stands. Seven-yr-old pin cherry was controlled by all treatments. But it died out of stands by yr 16, whether sprayed or not. Glyphosate and triclopyr reduced the hardwoods the most. Using a phenoxy herbicide will leave a stand of greater species diversity.

[1]Specific information regarding growth and development of conifers in this study also in Newton, M., E.C. Cole., M.L. McCormack, and D.E. White. 1992. Young spruce-fir forests released by herbicides. II. Conifer response to residual hardwoods and overstocking. Northern Journal of Applied Forestry 9:130–135.
[2]2,4,5-T and 2,4-D are no longer licensed for application in forestry practices.

323. **Ostrom, C.E., and A.F. Hough.** 1944. Early weeding in northern hardwoods. Journal of Forestry 42:138–140.

Release treatments in second- and third-growth hardwood stands included: light, 70% residual; moderate, 60% residual; heavy, 50% residual; and untreated. Five-yr observations indicated that heavy release increases the proportion of free-to-grow crop trees from 30 to 85%. One-third to one-fourth of the pin cherry died, thereby freeing smaller sugar maple and beech. By yr 18, death of the pin cherry and removal of other weed species had increased stand basal area growth by an average of 6 ft^2/ac/yr.

324. **Pitt, D.G., R.A. Fleming, and D.G. Thompson.** 1992. Glyphosate efficacy on eastern Canadian forest weeds. Part II: deposit-response relationships and crop tolerance. Canadian Journal of Forest Research 22:1160–1171.

Derivative-free nonlinear regression was used to model post-treatment crown area as a function of chemical deposit of glyphosate (as Vision) and pretreatment crown area for pin cherry. Aerial application ≥0.5 kg a.e./ha resulted in acceptable control (>60% cover reduction). Post-treatment crown area declined progressively toward 0 with increasing rate of deposit. The greater the crown area, the greater the deposit needed to reduce post-treatment crown area to any given threshold level. The models developed by the study help users to estimate deposit required for a given level of control.

325. **Stasiak, M.A., G. Hofstra, N.J. Payne, R. Prasad, and R.A. Fletcher.** 1991. Alterations of growth and shikimic acid levels by sublethal glyphosate applications on pin cherry and trembling aspen. Canadian Journal of Forest Research 21:1086–1090.

Glyphosate doses between 0.04 and 2.1 kg/ha were applied during late July to pin cherry growing in a 5-yr-old conifer stand, and repeated twice over a 2-yr period. Four weeks after application of 2.1 kg/ha, pin cherry displayed complete leaf necrosis. The 0.5 kg/ha application also had injurious effects that continued to develop over the study period. Applications of 0.2 kg/ha resulted in a 94% kill. In the first yr it also reduced pin cherry stem length by 45%, and leaf length by 23%. By the second yr, the growth reduction lessened and leaf lengths were similar to the controls, suggesting that pin cherry had recovered.

326. **Wall, R.E.** 1985. The role of disease in removal of weed species from developing forest stands. P. 673–676, in Proceedings of the VI International Symposium on Biological Control of Weeds. August 19-25, 1984. Vancouver, Canada. E.S. Delfosse (Ed.). L'Agriculture canadienne.

Pin cherry in large 3-yr-old clearcuts and burned stands were inoculated with stromata of the black knot fungus in spring prior to bud break. All trees had become infected within 1 yr, and dominance by pin cherry was reduced by the fifth yr after disturbance. Inoculation is best done at yr 2, when branching allows a greater number of infection courts close to the stem and the base of the tree. This leads to higher mortality than following inoculation at 1 yr. Minimizing the area of clearcuts, strip cuts, and roads, and controlling fires that destroy the disease, will provide a natural reservoir of inoculum, making intervention unnecessary.

327. **Wall, R.E.** 1986. Effects of black knot disease on pin cherry. Canadian Journal of Plant Pathology 8:71–77.

The black knot disease occurs naturally in pin cherry within 2–7 yr after establishment and shortens the life span of this pioneer species. Early establishment of the pathogen in burned sites may control pin cherry development. By 5–6 yr after introducing black knot disease into 1- to 4-yr-old burned or clearcut stands, the disease had spread 10–20 m around the points of inoculation. Best experimental results followed spring inoculations before bud break, and in 1- to 2-yr-old stands where the trees grew rapidly. Due to the resultant reduced height growth and increased mortality of pin cherry, planted conifers and other hardwoods overtopped the pin cherry by yr 6.

328. **Wall, R.E.** 1990. The fungus *Chondrostereum purpureum* as a silvicide to control stump sprouting in hardwoods. Northern Journal of Applied Forestry 7(1):17–19.

Pin cherry growing in 10- to 20-yr-old even-aged stands were treated by *Chondrostereum purpureum*. Stumps with evidence of infection had no stump sprouts by the second yr after treatment.

329. **Wall, R.E.** 1997. Fructification of *Chondrostereum purpureum* on hardwoods inoculated for biological control. Canadian Journal of Plant Pathology 19:181–184.

Basidiocarps of the fungus *Chondrostereum purpureum* were present 2 yr after late spring and summer felling and inoculation of 10- to 20-yr-old pin cherry saplings. By autumn of the fourth growing season, *C. purpureum* was no longer present. Other fungi were frequently observed, and stumps were in the advanced stages of decay. Non-target risks of using this fungus to control stump sprouting are extremely low and do not significantly exceed the risks from naturally occurring sources of inoculums.

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