

Paula .J. Anderson, David T. Cleland, John C. Zasada; North Central Research Station

1. **Abrams, Marc D. 1984. Uneven-aged jack pine in Michigan. Journal of Forestry. 82:306-307.**

Note: In the sand plains of lower Michigan, regeneration "failure" is common in jack pine stands that are clearcut or burned. Unburned clearcut sites usually become sedge meadows and burned sites are either converted to sedge meadows, or shrubs and early successional hardwoods and grass. But, jack pine can not be expected to quickly regenerate even-aged stands on sand plains, instead, natural seeding will, through time, produce uneven-aged stands as evidenced by tree ring data collected from 20 mature jack pine stands. Study sites were in Roscommon, Crawford, Oscoda and Ogemaw Counties.

Keywords: MI/ vt, pine barrens/ fire, prescribed/ logging, clearcut/ sand plains/ regeneration, seed/ age-class structure/ succession/ pine, jack/ sedge.

2. ---. **1992. Fire and the development of oak forests in eastern North America, oak distribution reflects a variety of ecological paths and disturbance conditions. Bioscience. 42(5):346-353.**

Note: Publications on oak ecology from paleoecology, presettlement and present day vegetation, ecophysiology, and the role of fire on present day expansions are reviewed. The expansion of red oak forests into areas that were previously northern hardwood forests is explained. Highlights include the following: (1) Oak forests dominated the eastern United States by 10,000 B.P. to about 500 B.P., and were associated with fire. Many paleoecological studies show lots of charcoal at times when oak was present. (2) Oak species show many adaptations that allow them to persist in areas with frequent fires. These include thick bark, ability to sprout, resistance to rot, seedbed suitability for seed germination. Drought adaptations include deep roots, xeromorphic leaves, low water potential stomatal closure, and the ability to osmotically regulate. Oaks do not do well in low light. (3) Many past and present vegetation types of eastern North America consist of a dominant or common component of oak where frequent fire occurrence or droughty soil conditions persist, such as in the oak savanna areas throughout the tallgrass prairie region. It is assumed that a fire frequency of 1 to 10 year intervals maintained the tallgrass prairie because precipitation is adequate to maintain a hardwood forest. The northern hardwood forest region has a very long fire interval but, stands of oak savannas within this region were probably supported by Indian-caused fires. Red oak dominates sites that were white pine-red pine, hemlock-birch-maple, maple-birch-pine, etc. after clearcutting and burning. Many oak species persist in the mixed-oak forests of the mid-Atlantic region. It is believed that Indian burning kept fire frequency high enough to maintain these oak forests. After European settlement, oak forests were

maintained and even increased by logging and fire through the 1800's. The evergreen forests of the southeastern coastal plain and Piedmont region include oaks and long leaf pine forests. Burning by Indians, European settlers and lightning maintained these vegetation types. Another forest type in Florida has an overstory of pine and an understory of scrub oak, sand pine scrub and sandhill vegetation. This vegetation type burns infrequently but, when it does burn, the fire is very intense and stand replacing. Longleaf and slash pines, and turkey oak is a common vegetation type that historically had frequent low intensity fires, usually set by Indians. (4) Currently, oak regeneration is very poor in eastern North America. Due to the absence of fire, shade tolerant, long lived species are encroaching upon oak forest types.

Keywords: eastern United States/ FL/ vt, oak forest/ review/ wildfire/ fire, prescribed/ paleoecology/ life history attributes/ fire, Native American use of/ oak, red/ oak, white/ oak, pin/ oak, bur/ oak, black.

3. **Abrams, Marc D., and Dickmann, Donald I. 1982. Early revegetation of clear-cut and burned jack pine sites in northern lower Michigan. Canadian Journal of Botany. 60:946-954.**

Note: Study sites were in Roscommon, Crawford, Oscoda and Ogemaw Counties.

Abstract: Revegetation of clear-cut and (or) burned jack pine (*Pinus banksiana* Lamb.) sites in northern lower Michigan was characterized during the first 5 years following treatment. Burning promoted the establishment of a large variety of species not typical of unburned areas. A total of 89 species was recorded on burned sites, of which 40 were exclusive, compared with 51 species on unburned sites, of which only 2 species were exclusive. Burned sites consistently showed greater species richness compared with unburned sites of the same age. Low species diversity on the older unburned clear-cuts (years 3 to 6) and certain burned sites was directly influenced by the dominance of the sedge *Carex pennsylvanica*. The total domination of *Carex* (up to 86% cover) on many of these sites appears to be unique to northern lower Michigan. It is hypothesized that *Carex*, acting as an opportunistic species, monopolizes the space and soil resources liberated following disturbances and suppresses or excludes other species.

Keywords: MI/ vt, pine barrens/ sand plains/ fire, prescribed/ fire effects/ logging, clearcut/ pine, jack/ sedge/ shrubs/ herbs.

4. **Abrams, Marc D., and Orwig, David A. 1996. A 300-year history of disturbance and canopy recruitment for co-occurring white pine and hemlock on the Allegheny Plateau, USA. Journal of Ecology. 84:353-363.**

Note: The previous stand was destroyed by tornado and/or fire ~1690. Soil charcoal and fire scarred trees indicate last fire occurrence to be before 1900. Windthrow occurred before and after 1900.

Summary

1 Dendroecological techniques were used to examine the patterns of canopy recruitment in relation to disturbance history for two dominant, yet ecologically contrasting, tree species, *Pinus strobus* (white pine; disturbance dependent) and *Tsuga canadensis* (hemlock; late successional), in a 300-year-old primary forest.

2 Most tree recruitment in both species occurred between 1690 and 1810. All of the white pine, which dominated recruitment during the first 40 years due to more rapid height growth, recruited in this period. Low levels of hemlock recruitment continued until 1900. Most of the younger trees comprised several northern hardwood species. No trees were less than 50 years old and the forest was devoid of an understory due to intense deer browsing.

3 Radial growth chronologies were determined for 27 cores across all species and age classes. These exhibited 1-11 major and/or moderate releases (indicative of disturbance) in most decades between 1730 and 1990. Peak releases were recorded in the 1950s when a series of severe windstorms impacted the site. Species recruitment patterns were related to earlier growth releases observed in the oldest cores.

4 White pine exhibited a degree of plasticity in initial radial growth (1-5 mm year⁻¹) depending on the time of establishment, as well as the ability to survive through prolonged periods of depressed growth (<0.5 mm year⁻¹) followed by growth releases. Hemlock was less plastic in its initial growth rates but did have dramatic growth releases (up to 8.8 mm year⁻¹) in several older trees. Thus, both species exhibited some unexpected dendroecological as well as successional attributes.

5 The future of this stand is uncertain due to the impacts of deer and insect outbreaks that plague the region, as well as fortuitous natural disturbances, e.g. wind and fire. Nonetheless, the dendroecological approach elucidated disturbance history, stand development and mechanisms of coexistence of two ecologically contrasting tree species, and should be used to further understanding of the complex ecology of other mixed-species forests and the successional role of various tree species.

Keywords: PA/ eastern North America/ vt, hemlock hardwood forest/ windthrow, occurrence of/ tornado/ fire history/ wildfire/ fire scar/ fire effects/ deer browsing/ insects/ age-class structure/ dendroecology/ disturbance ecology/ succession/ pine, white/ hemlock/ beech.

5. **Abrams, Marc D., Orwig, David A., and DeMeo, T. E. 1995. Dendroecological analysis of successional dynamics for a presettlement-origin white pine-mixed-oak forest in the southern Appalachians, U.S.A. *Journal of Ecology*. 83:123-133.**

Keywords: PA/ eastern United States/ vt, pine-oak forest/ presettlement vegetation/ dendroecology/ succession/ windthrow, effects on vegetation/ fire effects/ pine, white/ hemlock.

6. **Abrams, Marc D., and Scott, M. L. 1989. Disturbance-mediated accelerated succession in two Michigan forest types. *Forest Science*. 35(1):42-49.**

Abstract: In northern lower Michigan, logging accelerated sugar maple (*Acer saccharum*) dominance in a northern white cedar (*Thuja occidentalis*) community, and clear felling and burning quickly converted certain sites dominated by mature jack pine (*Pinus banksiana*) to early successional broadleaves, including *Prunus serotina*, *Populus tremuloides* and *Quercus* spp. In both forest types, the succeeding broadleaves should continue to increase at the expense of the pioneer conifer species. In the cedar community, sugar maple was also increasing in an

undisturbed, old-growth stand, but at a much slower rate than in the logged stand. Traditionally, disturbance was thought to set back succession to some earlier stage. These study sites and at least several other North American forest communities, however, exhibited accelerated succession following a wide range of disturbances, including logging, fire, ice storms, wind throw, disease, insect attack and herbicide spraying.

Keywords: MI/ vt, jack pine forest/ vt, maple forest/ vt, white cedar forest/ vt, oak forest/ disturbance ecology/ succession/ logging, clearcut/ fire, prescribed/ weather, effects on vegetation/ windthrow, effects on vegetation/ disease/ insects/ northern white cedar/ maple, sugar/ pine, jack/ aspen, trembling/ oak/ cherry, black.

7. **Abrams, Marc D., Sprugel, Douglas G., and Dickmann, Donald I. 1985. Multiple successional pathways on recently disturbed jack pine sites in Michigan. *Forest Ecology and Management*. 10:31-48.**

Note: Study sites were in Roscommon, Crawford, Oscoda and Ogemaw Counties. A fire scar study (Simard and Blank, 1982) using red pine in Oscoda county, Michigan, indicates a fire interval of 23 years from 1930 to 1982.

Abstract: Jack pine communities in northern lower Michigan recently disturbed by clearcutting, deliberate burning, or wildfire were studied over three growing seasons, and were compared to undisturbed jack pine stands. Newly disturbed sites generally had more vascular plant species than mature forests. Many of these species did not persist, especially on burned sites, and species richness declined sharply the second year after fire. In several cases annual and biennial species dominated first-year burns but were unimportant thereafter.

Several pathways of early successional development were evident on the disturbed sites, which was facilitated by jack pine regeneration failure on all but one of the disturbed sites. Unburned clearcuts rapidly developed in *Carex* meadows, with few other species of any importance. This pathway was also followed on some deliberately-burned and wildfire sites. Other burned areas developed a stratified canopy of shrubs and early successional hardwoods, and were rich in species and high in cover. Stand replacement by jack pine occurred on one mature jack pine site burned by wildfire. Jack pine regeneration failure has been attributed to numerous factors involving: seed loss due to drought, competition, pathogens, grazing and high surface temperatures.

Index of similarity comparisons showed that different sites of the same post-disturbance age were significantly ($P < 0.01$) less similar in species composition than a single site sampled in 2 or 3 consecutive years. Post-disturbance age was not a particularly strong indicator of species composition on these sites, because each site had a different assemblage of species (30-40% dissimilarity among sites of the same disturbance class and post-disturbance age). Therefore, the individualistic nature of each site, rather than age following disturbance, is the dominant aspect in understanding successional relationships in these communities.

Keywords: MI/ vt, pine barrens/ vt, sedge meadow/ wildfire/ logging, clearcut/

regeneration, seed/ regeneration, vegetative/ fire effects/ fire, prescribed/
succession/ sand plains/ pine, jack/ pine, red/ sedge/ herbs/ shrubs.

8. **Adams, Paul W., and Boyle, James R. 1980. Effects of fire on soil nutrients in clearcut and whole-tree harvest sites in central Michigan. Soil Science Society of America Journal. 44:847-850.**

Note: Study took place in Roscommon County. Fuel combustion in the plots was characterized as light or moderate. Most of the moderate fell in the clearcut site where the windrows were present and fuel load was highest in the windrow.

Abstract: Surface mineral soil samples from adjacent northern red oak (*Quercus rubra* L.)-bigtooth aspen (*Populus grandidentata* Michx.) sites harvested by contrasting methods were evaluated for available Ca, Mg, K, P, and total N before and after a wildfire. Abundant slash from clearcutting contributed to significant and persistent increases in Ca, Mg, K, and N following fire. Sample data grouped by variations in estimated surface burn intensity revealed no significant differences, indicating that slash windrows did not appreciably localize nutrient increases. Minimal residues from whole-tree harvest released smaller quantities of Ca, Mg, and K, and total N exhibited no significant change. Significant increases in soil Ca, Mg, K, and P at both sites occurred within a month after burning. Five months after the fire, soil Ca, Mg, K, and P at both sites generally decreased, in some cases to prefire levels. Cation leaching losses from the surface soils, monitored by porous cup lysimeters at the 1-m depth, increased within 2 months after the fire, but losses appeared to stabilize within 5 months. Leaching losses of Ca were significantly greater in the clear cut site. Although short-term, soil nutrient changes following fire were generally positive, the long-term effects on site quality remain in question due to the probable net loss of organic matter and nutrients through volatilization and accelerated leaching.

Keywords: MI/ sand plains/ vt, oak forest/ wildfire/ fire effects/ logging, clearcut/ soils, nutrient analysis/ aspen, big tooth/ oak, red.

9. **Ahlgren, Clifford E. 1958. The significance of the effect of forest fires on herb and shrub growth in northern Minnesota. Bulletin of the Ecological Society of America. 39:79-80.**

Note: Abstract for a talk given at AES meeting in 1958. Methodology was the only thing discussed. See the following three publications for results.

Keywords: MN/ National Forest, Superior/ vt, jack pine forest/ fire effects/ shrubs/ herbs.

10. ---. 1959. **Vegetational development following burning in the northern coniferous forest of Minnesota. Society of American Foresters meeting, "Forestry and People", San Francisco, CA. Society of American Foresters. p. 21-22.**

Notes: Shrub and herb data collected 5 years after wildfire and prescribed burns in jack pine stands located on the Superior N.F. is summarized. A more detailed description of location and fire effects on trees can be found in Ahlgren (1959).

Results are as follows. Shrub and herb species were classified into the following 3 groups; 1) those only found on unburned (fire 100 yrs ago) areas (4 species), 2) those found only on the burned areas (60 species mostly annuals) and 3) those

present on burned and unburned areas (35 species). *Epilobium angustifolium*, *Geranium bicknellii*, *Corydalis sempervirens*, and *Polygonum cilinode* were in group 2. *Cornus canadensis*, *Maianthemum canadensis*, *Clintonia borealis*, *Aralia nudicaulis*, and *Aster macrophyllus* were included in group 3.

Regeneration of jack pine and black spruce was abundant where the seed source was good, especially in those areas where the organic layer was reduced to 1 to 2 inches. Areas where the organic layer was thicker, seedlings emerged but mortality was high. Five to 7 years after fire, the young jack pine were producing seed that was 80% viable. Paper birch base sprouted and seeded in. Trembling aspen sprouted, and in some areas seeded in.

Keywords: MN/ National Forest, Superior/ vt, jack pine forest/ fire effects/ fire, prescribed/ wildfire/ regeneration, seed/ regeneration, vegetative/ pine, jack/ spruce, black/ aspen, trembling/ birch, paper/ shrubs/ herbs.

11. ---. 1959. **Some effects of fire on forest reproduction in northeastern Minnesota.**

Journal of Forestry. 57:194-200.

Note: The study sites are located near Heart Lake (spring wildfire), Keeley and Polly Lakes (summer wildfires), on Halfway and Isabella districts, and Plum Lake (prescribed burns). Heart Lake Fire was a fast moving crown fire, in jack pine, spruce-fir, aspen, and black spruce timber types, that reduced the organic layer from 2"- 6" to 1" -2". Keeley Creek was a very intense crown fire, through jack pine and black spruce, that removed all surface litter and most duff. Polly Lake fire was a slash fire, in green jack pine, that removed all surface litter and most duff. Halfway District was a spring burn in cut over slash (1 yr old and older) of mature jack pine, aspen, and birch. There, smaller slash and about 1" of surface litter was removed. The prescribed burn on the Isabella District took place in the spring in a cutover jack pine forest that had been logged the summer before. For this burn, smaller windrowed slash and 1 inch litter beneath windrows was removed. The fire burned irregularly between windrows. Plum Lake was similar to Isabella District prescribed burn.

Results pertaining to jack pine: Jack pine regeneration occurred where standing trees (seed trees), or green jack pine slash with seed were present. The older slash did not contribute seed because the dry cones burned up in the fire. Seedling survival averaged 42%. Only on sites where the organic layer was significantly reduced, were seedlings able to germinate and survive. Most of the germination took place in the first 2 years. Because of the high ash content on the soil surface highest seedling mortality occurred after the summer burns. Poor seedling survival was also be associated with some herbs such as *Pteridium aquilinum* (L.) Kuhn, *Calamagrostis canadensis* (Michx.), *Carex adusta* Boott and *Epilobium angustifolium* L.. Shrubs did not seem to contribute to seedling mortality. Seedling growth was very slow the first 3 years but grew rapidly after that. Herbaceous and shrub species, other than the ones listed above, may have provided needed shading for seedlings first few years. Nitrogen content of soil was near optimum for seedling growth.

Results pertaining to black spruce: Black spruce cones are serotinous but, cones

lower in the canopy will be burned up, therefore only cones on the taller trees generally seed in after a fire. The most successful germination occurred in years 2 and 3 on sites where organic material was removed. Seedling survival averaged 54%. Seedlings grew slowly their first few years but grew rapidly in years 4 and 5. Seedling mortality was high where *Polygonum cilinode* Michx. carpeted the ground.

Results pertaining to trembling aspen: Although some seedlings did germinate in low lying areas, all successful reproduction was through sprouting. Sprouting began the season after fire and, by the end of the first growing season, the height of most sprouts exceeded the height of other vegetation. An average of 50% of the sprouts survived. In some instances, growth was slowed by hazel and/or by browsing.

Results pertaining to paper birch: Seed blew in from the surrounding areas years 2 and 3 after the burn. Stump sprouts were the main form of regeneration in areas where mature paper birch was present prior to the fire and, in low lying sites, seeds were the main form of reproduction. Seedling success only occurred on moist seedbeds. On the reproduction plots, seedling survival was 70%. The highest mortality occurred when trees were 1 or 2 years old. Sprout survival ranged from 75 to 100 percent. Seedling height growth was slow the first 3 years but increased on year 4. Where *Calamagrostis canadensis* and *Polygonum cilinode* had high cover, growth did not increase on the 4th year.

Other species: Mountain ash sprouts and seedlings were found on both burned and unburned sites the second and third year. Pin cherry seedling germination was common on the burned sites. Red pine was planted in 4 of the areas after fire and survival was usually 90% or better after 5 years, except when seedlings were planted during a drought year, there survival was 50%.

Soil nutrients were highest immediately following fire and was lower, but not at unburned soil status, by year 5.

Keywords: MN/ National Forest, Superior/ vt, jack pine forest/ vt, spruce-fir forest/ vt, conifer-feathermoss forest/ wildfire/ fire, prescribed/ fire effects/ regeneration, seed/ regeneration, vegetative/ succession/ soils, nutrient analysis/ pine, jack/ pine, red/ spruce, black/ aspen, trembling/ ash, mountain/ cherry, pin/ shrubs/ herbs.

12. ---. 1960. **Some effects of fire on reproduction and growth of vegetation in northeastern Minnesota. Ecology. 41(3):431-445.**

Note: Plant succession, frequency, reproductive methods and distribution, dominance and growth, and responses to differences in soil nutrients were investigated at 5 sites after fire (2 prescribed burns and 3 wildfires) and compared to unburned sites on the Superior N.F.. Fire intensities were classified as light, hard and severe burns. The parameters for each were discussed in the paper. Soil types ranged from sandy loams to sphagnum. Soil profiles were described and soil samples analyzed for pH, available nitrogen, ammonia, calcium, phosphorus,

and potassium. Moisture content and moisture holding capacity were determined. Initially, herbaceous vegetation dominated the more severely burned sites because greater removal of organic material created moister sites. Herbaceous and shrub species were divided into 3 categories, A) those only on unburned sites (4 species), B) those only on burned sites (60+ species), and C) those found on both burned and unburned sites (30+ species). The main mechanism for regeneration of species in class B was by seed, although regeneration also occurred vegetatively on the lightly burned areas. Species listed in class C would normally regenerate vegetatively, although they could also reproduce by seed. Species from class B were dominant on severely burned sites. These sites were usually moist with a deep organic layer which was subsequently burned off in the fire, thereby killing vegetative reproductive plant parts and allowing seeds to germinate and grow without competition. On the less severely burned sites (usually sandy, upland soils), plants that regenerate vegetatively gained dominance quickly. Number of species increased for the first 2 years, and changes in species dominance occurred throughout the first 5 years. Those of vegetative origin continued to increase years 3 through 5. Those that seeded in, peaked after 2 years and frequently began to decline around year 3. Tree cover of paper birch, jack pine, and trembling aspen began to increase after the first 3 years. There was no change in the unburned sites. Soil nutrients were highest after the fires and leached slowly. Higher levels were still detectable after 5 years. Refer to the publication for the full list of species sampled.

Keywords: MN/ National Forest, Superior/ vt, jack pine forest/ vt, spruce-fir forest/ vt, conifer-feathermoss forest/ fire, prescribed/ wildfire/ fire effects/ fire behavior/ soils, nutrient analysis/ regeneration, seed/ regeneration, vegetative/ succession/ birch, paper/ pine, jack/ aspen, trembling/ shrubs/ herbs.

13. ---. 1966. **Small mammals and reforestation following prescribed burning. Journal of Forestry. 64:614-616.**

Note: Study took place on the Superior N.F. in the East Bearskin Lake area and Grass Lake Tract. The treatments were done between 1960 and 1962. Jack pine seedling density is reported for the first 3 years after the burns.

Abstract: Changes in populations of small mammals were investigated on four jack pine tracts in northeastern Minnesota. One tract was left uncut, one was cut with slash evenly distributed, and two were cut and subjected to controlled burning. North American census trapping methods were used in July and October for three consecutive years. Populations of deer mice (*Peromyscus maniculatus*) were significantly higher on burned tracts than on unburned tracts the first and third post-fire years. This increase was related to the supply of seed released by burned jack pine and also other seed exposed in the upper layers of soil, as well as to cover conditions. Since burning created habitat and food conditions favorable to the increase of seed eating mouse species they must be taken into consideration in post-fire reforestation.

Keywords: MN/ National Forest, Superior/ vt, jack pine forest/ fire, prescribed/ fire effects/ mammals/ pine, jack .

14. ---. 1970. **Some effects of prescribed burning on jack pine reproduction in**

northeastern Minnesota. University of Minnesota, Agricultural Experiment Station. Forestry Series 5, Miscellaneous Report 94. 14 pp.

Note: Prescribed fire for seedbed preparation and slash removal from harvested jack pine tracts was compared with unburned tracts for seed tree and clearcuts, with and without seeding, at Bearskin Lake, Grass Lake and Dragon Lake tracts, Superior N.F. The stands, composed mainly of jack pine and aspen, originated after a wildfire 70 years prior to study. Seed traps were used prior to cutting to establish pre-harvest seed rain patterns. Birch, white spruce, balsam fir, jack pine, pin cherry, grass and sedge seeds were abundant in the seed traps. The logging was done in autumn. Bearskin tracts were cut leaving 9 trees per acre. Grass Lake and Dragon Lake tracts were clearcut and burned (Dragon tract was burned 2 years after logging.). Sites were then seeded with 5-6 ounces of jack pine seed per acre. Shrub and herb species composition and frequency were sampled before and after the burns. Soil moisture content, and soil fertility before and after the burns, on the sandy loam soils, were compared. Thermocouples were placed from the ground surface to 40 feet above ground. Burns occurred in early to mid-summer when winds were less than 10 miles per hour. Backfires (against the wind) were normally used for the first 100 feet into the burn. Then, a head fire was ignited to burn up to the blackline created by the backfire. Organic layers were reduced by about 1 inch at each site.

Change in vegetation over 9 years after harvest is as follows. Jack pine became established the first 2 years after the burns. The highest mortality occurred during the first and second growing seasons, especially during the drought year, 1961. By the end of the second year the stocking on all tracts was over 80%. On Bearskin, stocking was adequate 9 years after seeding. Herbaceous plants dominated the ground cover the first 2 growing seasons after which tree seedlings and shrubs became dominant. *Aster* and *Pteridium aquilinum* dominated cover on most tracts. *Cornus* was the third dominant but, on burned sites *Carex* or *Oryzopsis*, as well as, *Geranium bicknellii* Britt., *Epilobium angustifolium* L., and *Polygonum cilinode* Michx. became more common for the first 3-5 years. Shrubs were also affected by the prescribed burn. Hazel was reduced from an average 50% to 6% cover as compared to the unburned tract where cover ranged from 55% to 31%. Recovery of hazel was much slower on the burned sites because fire damaged root collar thereby slowing growth. Aspen sprouting was high in burned sites and sprouts were 4-5 feet by year 5.

Recommended prescription: dry, well distributed slash, dry humus down to within 1" of mineral soil surface, burn in the afternoon when relative humidity is below 40%, winds stable and less than 10 miles per hour.

Keywords: MN/ National Forest, Superior/ vt, jack pine forest/ fire, prescribed/ fire effects/ firing technique/ logging, clearcut/ logging, seed tree/ pine, jack/ aspen, trembling / shrubs/ herbs/ sedge/ hazel.

15. ---. 1974. **Effects of fires on temperate forests: North Central United States.** In, Kozlowski, T. T. and Ahlgren, Clifford E. *Fire and Ecosystems*. New York: Academic Press.

Note: Chapter 1 summarizes past research on the effect of fires in the North Central states on the following subjects: soil temperature extremes and duration, relative humidity; fire adaptation in pines, both to the trees themselves and in seedling production, and postfire survivability; fire adaptation of other conifers, deciduous trees, shrub, herbs, ferns, mosses and lichens; general vegetation interrelationships. There are a lot of good references in this summary.

Keywords: MN/ WI/ MI/ fire effects/ fire, review/ soils.

16. ---. 1976. **Regeneration of red pine and white pine following wildfire and logging in northeastern Minnesota. Journal of Forestry. 74:135-140.**

Note: Study tracts include 2 wildfire sites (Quetico Park, Ontario near McAree Lake, La Croix R.D., Superior N.F., Little Sioux Fire, 2 logging tracts (Basswood Lake, Canada) and 3 undisturbed sites (Basswood Lake, Canada and Minnesota, La Croix R.D.).

Abstract: The exacting silvical requirements for regenerating red pine and white pine in northeastern Minnesota are rarely met by natural disturbance including wildfire. Buildup of aspen to the point of takeover, incidence of white pine blister rust (*Cronartium ribicola*), and lack of abundant seed trees make impossible the re-creation of natural conditions which favored the establishment of these pines in the past. Data from seven areas—two burned, two logged, and three undisturbed—illustrate the point.

Keywords: MN/ National Forest, Superior/ Ontario/ Canada/ Little Sioux fire/ vt, pine forest/ fire effects/ wildfire/ wildfire, historic/ logging, clearcut/ regeneration, seed/ pine, white/ pine, red/ aspen, trembling/ disease/ shrubs/ herbs/ hazel.

17. ---. 1979. **Emergent seedlings on soil from burned and unburned red pine forest. Minnesota Forestry Research Notes 273. 4 pp.**

Abstract: Intact soil blocks from an unburned, old red pine forest and comparable soil burned by wildfire were placed in a greenhouse. Seed was extracted from other soil samples on the same area. The ratio of number of seedlings on the soil blocks to number of seeds extracted from the soil was much higher for the burned area than for the old forest. Factors other than increased light and removal of competition during emergence are responsible for the increased numbers of herbaceous plants which emerge following fire.

Keywords: MN/ National Forest, Superior/ Little Sioux fire/ fire effects/ wildfire, historic/ vt, pine forest/ regeneration, seed/ pine, red/ birch, paper/ shrubs/ herbs.

18. ---. 1979. **Buried seed in prescribed-burned jack pine forest soils, northeastern Minnesota. Minnesota Forestry Research Notes 272. 4 pp.**

Note: Three times as many seed was found on the cut tracts as the uncut-unburned tract. Thus, many of the seed found in the cut tracts were of post-disturbance origin.

Abstract: Seed was extracted from soils beneath cut and burned, cut and unburned, and uncut portions of jack pine forest. Seed quantities varied with disturbance. Seeds of species characteristic of recently burned land were found in all three forest conditions. Species occurrence was similar to that on naturally disturbed areas.

Keywords: MN/ National Forest, Superior/ vt, jack pine forest/ fire, prescribed/ fire effects/ regeneration, seed/ pine, jack/ shrubs/ herbs.

19. ---. 1979. **Buried seed in the forest floor of the Boundary Waters Canoe Area.**

Minnesota Forestry Research Notes 271. 4 pp.

Abstract: Seed was extracted in 11 areas from soils: beneath pine stands last burned from 3 to 200 years ago; beneath a mixed balsam fir stand, and beneath mature aspen stands. In all stands, seeds of species characteristic of recently disturbed land were found. Live plants of many of these species had not been detected on these sites for 6 or more years. Viability of the seed was determined.

Keywords: MN/ BWCAW/ National Forest, Superior/ vt, balsam fir forest/ fire effects/ regeneration, seed/ pine, jack/ pine, red/ pine, white/ balsam fir/ budworm, spruce/ insects/ birch, paper/ spruce, white/ aspen, trembling/ herbs/ shrubs.

20. **Ahlgren, Isabel F. and Ahlgren, Clifford E. 1960. Ecological effects of forest fires. Botanical Review. 26(4):483-533.**

Note: This publication reviews the literature on the effects of fire on soil and living organisms of North America. Many authors are cited.

Keywords: fire effects/ fire, review.

21. ---. 1965. **Effects of prescribed burning on soil microorganisms in a Minnesota jack pine forest. Ecology. 46(3):304-310.**

Note: Study took place on the Superior N.F., probably Bearskin Lake and Grass Lake tracts.

Abstract: Soil dilution plate counts on selective media for bacteria, streptomycetes, and fungi were made at intervals before and after two prescribed burns on 10-acre jack pine tracts. Carbon dioxide determinations were also made. These tracts were compared with similar tracts cut and unburned and uncut and unburned. Three-year results are given. The number and activity of most microorganisms decreased immediately after fire but rose abruptly to a very high level after the first rainfall following burning. This increase is believed caused by the leaching of ash minerals. Depth and extent of the effects were influenced by intensity of fire and moisture conditions. Number and activity of organisms were generally lower in burned soil the second growing season after the fire. Some effects were greatly increased the third growing season. Rainfall also caused a fluctuation of microbial populations on the unburned tracts.

Keywords: MN/ National Forest, Superior/ vt, jack pine forest/ fire, prescribed/ fire effects/ pine, jack/ soils, microorganisms.

22. **Akachuka, A. E. 1993. Recovery and morphology of *Pinus resinosa* trees 50 years after they were displaced by a hurricane. Forest Ecology and Management. 56:113-129.**

Keywords: hurricane/ windthrow, tree damage/ windthrow, effects on vegetation/ pine, red.

23. **Alban, David A. 1976. Influence on soil properties of prescribed burning under**

mature red pine. US Forest Service, Research Paper NC-139. 8 pp.

Note: In 1960 a study was initiated in northern Minnesota, Chippewa N.F., (Cutfoot Experimental Forest) to control beaked hazel growing in the understory of a 90 year old red pine stand. Twenty-eight treatment plots were established. Of the 28, 4 plots were established as controls and the remaining 24 were split between dormant season (spring) burning and growing season (summer) burning. Three different burn intervals were used: annual, biennial, and periodical (6-9 years). Each treatment was replicated 4 times. Fire prescriptions used reduced the forest floor weight by 50% or less, and charring of trees was kept to a minimum. The greatest reduction of hazel stems was achieved in the summer annual and biennial burns. Forest floor nutrients were reduced due to prescribed burning but there were increases within the mineral soil to compensate for the forest floor losses. Thus, up to 50% of forest floor organic matter removal would not affect site productivity.

Keywords: MN/ National Forest, Chippewa/ vt, pine forest/ fire effects/ fire, prescribed/ soils, nutrient analysis/ pine, red/ hazel/ shrubs.

24. **Albert, Dennis A. and Minc, Leah D. 1987. The natural ecology and cultural history of the Colonial Point Red Oak stands. Douglas Lake Biological Station, University of Michigan. General Technical Report 14.**

Note: Overstory species were identified and vegetation communities defined at Colonial Point, Cheboygan county, northern lower Michigan. The six communities are oak dominated forest, white pine stands, northern hardwood forest, hardwood swamp, hemlock dominated seepages and swampy drainages. Age class structure, current regeneration patterns and disturbance history, logging and fire (Native American and European) were described for the communities. Charcoal in the top horizon of the soil was identified to genus to describe prefire stands. Soils were also described. Disturbance history of fire, cultivation and logging rather than soils seems to explain differences in vegetation communities of the upland areas. Windthrow was most common in the lowland, poorly drained sites and does not seem to be a factor in red oak establishment.

Descriptions of 2 forest types currently found on tract

Oak dominated forest: red oak, red maple, sugar maple, white pine, bigtooth aspen, and paper birch. Aspen and paper birch are dying out. Sugar maple and some beech are in the understory. Fire probably destroyed beech seed source. Stands are even-aged and, in the tract, there are stands of 2 different ages. The younger 2 stands, as indicated by fire scars, originated after a wildfire between 1890 and 1900. These may have been logging slash fires or, fires to enhance raspberry production. Also, stump sprouts suggest a fire or clearcut sometime after stand establishment. Sugar maple is the dominant understory tree species. Beech is also present. The older oak forest originated after a catastrophic event between 1830 and 1860. Single stemmed trees indicate no further disturbance. Sugar maple and beech in the understory.

Northern hardwood forest: Species commonly found in this type are red maple, beech, sugar maple, and red oak. Red oak is found in this forest type as single old

individuals or small stands. The small stands probably originated with fires as there are fire scars on the beech surrounding the small stands.

Current regeneration

Within stand regeneration is poor. Red oak regeneration is only present along roadsides and in an abandoned pasture. Seedlings are also found in areas of windthrow but, seedlings do not grow well.

Recent disturbance history

Land use patterns by humans, rather than soils characteristics, explain red oak distribution on Colonial Point. During the 1800's, slash and burn agriculture (use fields for 10 years then, move on to another forested area) was used by Indians living in the area. European settlers influenced stand composition in the late 1800's to early 1900's by clearcutting of oak stands in the southwestern and northwestern corners of the tract, and intensive selection cutting of sugar maple and red oak in the mid-1940's. The Indian agriculture is evidenced by notes taken by GLO surveyors during 1840 and 1855 surveys, and by higher levels of charcoal in soils beneath red oak stands than in the surrounding northern hardwood forest. European use was documented using aerial photos, aging of stumps, multi-stemmed oaks, and oral history (least dependable).

Keywords: MI/ vt, oak forest/ vt, pine forest/ vt, swamp forest/ vt, hemlock forest/ vt, maple forest/ fire, prescribed/ fire history/ windthrow, occurrence of/ logging, selection/ logging, clearcut/ succession, old field / GLO/ fire, Native American use of / charcoal analysis/ disturbance ecology/ land-use/ maple, sugar/ beech/ oak, red/ hemlock/ maple, red/ aspen, big tooth/ pine, white/ birch, paper.

25. **Alexander, Martin E.; Mason, John A., and Stocks, Brian J. 1979. Two and a half centuries of recorded fire history. Great Lakes Forest Research Centre, Sault Ste. Marie, Ontario. 2 pp.**

Note: The two page pamphlet describes the fire history recorded on one red pine slab collected in 1978 near Pointe aux Pins in Parke Township, Ontario. The tree probably regenerated after a wildfire in 1727 and was subsequently scarred in 1759, 1791, 1805, 1831, and 1877. The average fire interval was 29 years with a range of 14 to 46 years. No known fire had occurred in this area in the last 100 years, although an occurrence was prevented in 1936 by fire suppression. The pamphlet mentions a larger study, but I have not been able to find a more extensive publication.

Keywords: Ontario/ Canada/ vt, pine forest/ vt, boreal forest/ fire scar/ fire interval/ pine, red.

26. **Alexander, Martin E. and Sando, R. W. 1989. Fire behavior and effects in aspen-northern hardwood stands. In, MacIver, D. C. and Auld, H. Whitewood R. Proceedings of the 10th Conference on Fire and Forest Meteorology; Ottawa, Ontario.**

Keywords: MN/ WI/ vt, aspen forest/ vt, northern hardwood forest/ fire, prescribed/ fire behavior/ fire weather/ fuels/ fire effects/ aspen, trembling.

27. **Alway, F. J.; Kittredge, Joseph Jr., and Methley, W. J. 1933. Composition of the forest floor layers under different forest types on the same soil. Soil Science. 36:387-398.**

Note: The chemical composition of forest floor layers (freshly fallen leaves, litter, duff, and leaf mold) of red pine, white pine, jack pine and maple-basswood stands on Star Island are compared. A general description of the fire history is also given. Growth rings on red pine and white pine, ages of jack pine and basswood sprouts and aspen suckers indicate that fires occurred on the island in 1808, 1818, about 1824, 1865, 1871, and 1872. Extent of fires were not given. The fires were not intense enough to alter species composition of the forest. The jack pine forest, located at Cloquet State Forest, originated after a wildfire 60 years prior to the study. Star Island is located on the Chippewa N.F. in the middle of Cass Lake. See Kittredge (1934) for a description of post-fire vegetation dynamics on Star Island.

Keywords: MN/ National Forest, Chippewa/ island/ vt, pine forest/ vt, jack pine forest/ vt, maple forest/ fire interval/ growth ring analysis/ age-class structure/ litter and duff, nutrient analysis/ pine, red/ pine, white/ pine, jack/ maple, sugar/ basswood/ aspen.

28. **Amundson, Donna C. and Wright, H. E., Jr. 1979. Forest changes in Minnesota at the end of the Pleistocene. Ecological Monographs. 49(1):1-16.**

Abstract: The Late-Wisconsin spruce forest that characterized most of Minnesota (and the rest of the Middle West) differed from the modern Boreal Forest of Canada not only in the absence of pine but also in the apparent admixture of black ash, oak, and elm and in the presence of openings in which *Artemisia* was abundant. Close-interval pollen analyses at 3 sites in Minnesota show some of the details in the transformation of this spruce forest to pine or hardwood forests.

At Kirchner Marsh in southeastern Minnesota, the spruce forest was replaced abruptly about 10 000 yr ago by birch, alder, and temperate hardwoods before pine (jack pine) entered the region for a short period. At Wolf Creek in central Minnesota, pine arrived from the east virtually at the moment when spruce declined. At Lake of the Clouds in northeastern Minnesota, spruce forest had succeeded tundra about 10 000 yr ago, but simultaneously pine (jack pine) and the temperate hardwoods (especially elm) appeared in quantity. The spruce and hardwood components then declined about 9300 yr ago as pine (red pine) increased to dominance during the next 400 yr.

Charcoal counts for the 3 sites provide no support for the hypothesis that increased fire incidence explains the forest transformation from spruce to pine. Climatic change must instead be the primary cause. The apparent openness of the spruce forest can be attributed to the continued presence of the wasting ice sheet just to the north, which favored a dry and windy climate, perhaps with relatively mild winters. As the ice sheet withdrew, its influence decreased. Differential rates of tree immigration as well as progressive leaching of upland soils may have been additional factors effecting changes in forest composition.

Keywords: MN/ vt, prairie/ vt, spruce forest/ vt, pine-oak forest/ vt, oak savanna/

vt, jack pine forest/ vt, conifer-feathermoss forest/ paleoecology/ pollen analysis/ charcoal analysis/ climate change/ pine, jack pine, red/ spruce, white/ spruce, black/ elm/ oak/ pine, white/ birch/ aspen/ alder/ shrubs.

29. **Anderson, H. E. 1982. Aids to determining fuel models for estimating fire behavior. US Forest Service, General Technical Report INT-122.**
Keywords: fire modeling/ fire behavior/ fuels.
30. **Anderson, Henry W. 1976. Fire effects on water supply, floods, and sedimentation. In, Tall Timbers Fire Ecology Conference, Oct 16-17, 1974. Tall Timbers Research Station Tallahassee, FL. p. 249-259.**
Note: This paper summarizes fire effects on stream hydrology of selected western watersheds in California, Oregon and Montana.
Keywords: CA/ OR/ MT/ fire effects/ hydrology/ streams .
31. **Anderson, O. 1954. The phytosociology of dry lime prairies of Wisconsin. University of Wisconsin, Madison, Ph.D. dissertation.**
Note: Cited by Curtis (1959) on Indians setting prairie fires.
Keywords: WI/ vt, prairie/ fire, Native American use of.
32. **Anderson, Paula J.; Gilmore, Daniel W.; Yount, Louise S, and Zasada, John C. In press. Effects of blow-down and salvage/fuel reduction activity in forest succession pathways in northern Minnesota. Proceedings of the Society of American Foresters National Convention. Society of American Foresters, Washington, D.C.. pp. 496-500.**
Note:
Keywords: MN/ windthrow, occurrence of/ windthrow, tree damage/ logging, salvage/ fire, prescribed.
33. **Anonymous. 1931. Spring fires on the jack pine plains. US Forest Service, Lake States Forest Experiment Station. Technical Note #44. 1 pp.**
Note: Mortality and damage to trees of an open, uneven-aged jack pine forest (1 to 40 yrs) from a afternoon wildfire that occurred on 4/15/31 are reported. Prevailing weather conditions and the scorch damage to the trees is also given. Mortality of 80% and damage of 90% occurred the stand. Location of fire was not given.
Keywords: MN/ vt, jack pine forest/ wildfire/ fire effects/ fire weather/ pine, jack.
34. **---. 1959. The Badoura Fire, May 1, 1959. Minnesota Department of Conservation, Division of Forestry.**
Keywords: MN/ wildfire/ wildfire, historic.
35. **Apfelbaum, S. I.; Leach, M., and Baller, R. 1989. Report propagation results for *Carex* spp., other wetland species (Wisconsin). Restoration Management Notes. 7(1):38-39.**
Note: Seed production and viability of *Carex stricta*, *C. brevior*, *C. vulpinoidea*,

C. comosa, and *C. lacustris* was greatest after prescribed burning of harvest site. Sedge and herb species seed viability was normally high the first year after harvest. After 2 years in cold storage, successful germination was variable and much lower.

Keywords: WI/ vt, wetland/ fire, prescribed/ fire effects/ restoration ecology/ herbs/ sedge.

36. **Armson, K. A. and Fessenden, R. J. 1973. Forest windthrows and their influence on soil morphology. Soil Science Society of America Proceedings 37:781-783.**
Keywords: windthrow, effects on soil/ soil morphology.

37. **Arnold, R. Keith. 1968. Mass fire-the disaster we face. Michigan Conservation. 37(4):2-6.**
Note: The wildfire potential that was present in Michigan in 1968 was explained and, a description of the fires that occurred in Michigan in 1881 was given.
Keywords: MI/ wildfire.

38. **Attiwill, Peter M. 1994. The disturbance of forest ecosystems: the ecological basis for conservative management. Forest Ecology and Management. 63:247-300.**
Abstract: The extensive literature on natural disturbance in forests is reviewed in terms of the hypotheses: (1) that disturbance is a major force molding the development, structure and function of forests; and (b) that management of forests for all their benefits can be controlled so that the effects can be contained within those which result from natural disturbance. The causal factors of natural disturbance are both endogenous and exogenous; there are major difficulties in the formal characterization of disturbance and of recovery after disturbance. As to the latter, the acceptance of classical generalizations of the nature of succession has led to particular difficulties in the assessment and interpretation of recovery.

Tree fall, which creates gaps, is fundamental to the development of many forests, and has been most intensively studied in the tropical forests of Central America and the Amazon and in temperate forests of North America. Tree fall is part of autogenic change; mechanisms of gap-filling and subsequent growth and species composition vary widely with forest type and geography.

Disturbance by wind is particularly difficult to characterize. Wind varies along a continuum; the blow-down of an individual tree may be mostly due to autogenic processes of ageing and decay, whereas catastrophic hurricanes and cyclones may be defined as wholly exogenous. Nevertheless, the resilience in terms of species diversity of tropical forests following catastrophic disturbance by hurricane is remarkable. A number of studies support the view that the tropical forest in hurricane-prone areas is not a stable steady-state ecosystem but rather that heterogeneity is maintained by catastrophe. The ability to regenerate by suckers and the coincidence of regenerative space and gregarious flowering are important components of the response of rainforest following disturbance.

For much of the world, 'fire is the dominant fact of forest history'. As examples,

fire and its effects are reviewed for the northern boreal forests, oak-pine forests and north-western sub-alpine forests of North America. The effect of fire on species composition varies with intensity and frequency. That, together with the popular view of fires as unnatural and therefore unacceptable, places great demands on management of forests for all of their benefits, including national parks and reserves. These difficulties also affect management of other ecosystems, such as Mediterranean-type shrublands and heathlands where species diversity, productivity and cycles of regeneration and degradation are governed by fire as a natural disturbance.

Shifting agriculture is a traditional form of agriculture used by at least 240 million people in the humid tropics. Shifting agriculture, together with wind, lightning and fire, is an exogenous disturbance which has little effect on soil fertility and on structure and composition of the rainforest which reestablished after abandonment. As the intensity of disturbance of rainforest increases, resilience of the forest decreases and the current problems of extensive clearing for improved pasture and of uncontrolled logging are resulting in degraded ecosystems.

Regeneration follows the often extensive death of trees caused by outbreaks of insects in many coniferous forests of northern America. This disturbance by herbivory halts increasing stagnation (as measured by decreasing rates of ecosystem production and nutrient cycling.) and reinitiates succession. Other disturbances to forests occur through damage from ice-storms, snow avalanches, erosional and earthquake landslides, and volcanic activity; the development of *Nothofagus* forests in Chile and New Zealand is determined by such catastrophic mass movements.

An extensive literature supports the hypothesis that natural disturbance is fundamental to the development of structure and function of forest ecosystems. It follows that our management of natural forest should be based on an ecological understanding of the processes of natural disturbance. Whether or not we want to do this, and the extent to which we want to derive all of the benefits from the forest, including timber, depends on social attitudes. Whereas humanism may treat conservation as the wise husbanding of forests in the interests of social traditions and harmony, animism may give nature unalienable rights. The conclusion from this review is that the ecological framework of natural disturbance and the knowledge of its component processes and effects provides the basis on which we can manage our forests as a renewable resource which can be utilized so that the forests 'retain their diversity and richness for mankind's continuing benefit. Nowhere is this management more desperately needed than for the protection of the world's tropical forests, its peoples and their cultures.
Keywords: review/ disturbance ecology/ fire effects/ canopy gap/ windthrow, effects on vegetation/ insects/ land-use.

39. **Axelrod, A. N. and Irving, Frank D. 1978. Some effects of prescribed fire at Cedar Creek Natural History Area. Journal of the Minnesota Academy of Science. 44:9-11.**

Abstract: On four oak savanna restoration compartments with a total area of 100 acres, annual burns (1965-1972) reduced the percent of milacre plots stocked with hazel to 39 compared with 65 on unburned areas. Four growing seasons after one and three fires the hazel distribution was not significantly different from the control. Annual burns increased the density of hazel stems in clones to 19.5 per .0001 acre compared to 11.0 on controls. Stem density four years after 1 and 3 burns averaged 10.0 and 8.0 per .0001 acre. The o.d. weight of live hazel stems per .0001 on annual burn areas was 16 percent of that on controls. Four years after 1 or 3 fires stem weight was not significantly different from control. Stem height on annual burn areas averaged 17 inches compared with 33 inches on the controls. Maximum stem heights on annual burns averaged 24 inches compared with 42 inches on controls. Four growing seasons after 1 or 3 fires average and maximum stem heights were not significantly different from controls.

Keywords: MN/ Cedar Creek Natural History Area/ vt, oak-savanna/ fire effects/ fire, prescribed/ restoration ecology/ hazel.

40. **Baker, D. G. 1983. Climate of Minnesota: Part XIV. Wind climatology and wind power. University of Minnesota Agricultural Research Station, Technical Bulletin AD-TB1955.**

Keywords: MN/ weather.

41. **Baker, G. T. 1915. A windfall problem. For. Quart. 13:317-324.**

Keywords: windthrow, effects on vegetation.

42. **Baker, William L. 1989. Effect of scale and spatial heterogeneity on fire-interval distributions. Canadian Journal of Forest Research. 19(6):700-706.**

Abstract: Fire-interval distributions for the 187-yr presettlement fire history record in the Boundary Waters Canoe Area, Minnesota, were analyzed using reconstructed 'fire-year' maps. Distributions were determined for sampling units at 5 spatial scales, from about 25 000 to 400 000 ha. Fire-interval distributions varied from positively to negatively skewed, but for most units the Weibull distribution fitted significantly. The distributions varied spatially, and cluster analysis suggested that 3 fire regions, each containing a relatively homogeneous fire regime, could be identified. The sources of this spatial variation are unknown. There was less variation between scales within a fire region than between fire regions. This contrasts with a previous finding, using the same fire-history data, that scale has significant effects on observed landscape age-class distribution. This disparity arises because landscape age-class distributions may fluctuate even if fire-interval distributions do not fluctuate. It is concluded that reconstruction of fire-interval distributions requires historical data; landscape age-class distributions at an instant in time are insufficient.

Keywords: MN/ BWCAW/ National Forest, Superior/ vt, boreal forest/ fire interval/ fire frequency/ age-class structure/ landscape ecology/ fire modeling/ presettlement vegetation.

43. **---. 1989. Landscape ecology and nature reserve design in the Boundary Waters Canoe Area, Minnesota. Ecology. 70(1):23-35.**

Abstract: Fire history data for 1727-1868 are used to reconstruct temporal changes at 5 spatial scales in the patch-mosaic of the 404 000-ha study area. The forests are dominated by pines (*Pinus banksiana*, *P. strobus*, *P. resinosa*), spruces (*Picea mariana*, *P. glauca*), balsam fir (*Abies balsamea*), tamarack (*Larix laricina*), white cedar (*Thuja occidentalis*), quaking aspen (*Populus tremuloides*) and paper birch (*Betula papyrifera*). Before European settlement, fires burned the equivalent of the entire area about every 100 yr. No stability at any scale in the patch-mosaic was observed due to spatial heterogeneity in the fire-regime and/or environment. In the design and management of nature reserves, temporal fluctuations should be seen as part of landscape structure and process, not just as an influence on species.

Keywords: MN/ BWCAW/ National Forest, Superior/ vt, boreal forest/ fire regime/ fire frequency/ landscape ecology/ pine, jack/ pine, red/ pine, white/ spruce, black/ spruce, white/ balsam fir/ tamarack/ northern white cedar/ aspen, trembling/ birch, paper.

44. ---. 1992. **Effects of settlement and fire suppression on landscape structure. Ecology. 73(5):1879-1887.**

Abstract: Natural landscapes subject to disturbances have patchy structure that is important to many species living in these landscapes. This structure may be modified when the disturbance regime is altered by either climatic change or human influences (e.g. fire suppression), yet little is known about how this structure will change.

I used a GIS (geographic information system)-based spatial model and data on historical changes in fire sizes and intervals to simulate the effects of settlement and fire suppression on the structure of the landscape in the Boundary Waters Canoe Area, Minnesota. I used seven measures to assess change in landscape structure.

Settlement and fire suppression altered some but not all components of landscape structure. Settlement produced an immediate significant effect on some measures (age, shape, Shannon diversity, richness, and angular second moment), but no effect on other measures (size, fractal dimension). In contrast, suppression produced an immediate response in fewer measures (shape, Shannon diversity, richness), a delay for several decades in the case of some measures (age, fractal dimension), and a delay for hundreds of years in the case of other measures (size, angular second moment).

Landscapes that have been altered by settlement and fire suppression cannot be restored using traditional methods of prescribed burning, which will simply produce further alteration. Causes of landscape change cannot be separated without control landscapes that lack prescribed burning, fire suppression, or other alterations of the natural fire regime.

Keywords: MN/ BWCA/ National Forest, Superior/ vt, boreal forest/ fire effects/ fire suppression/ fire modeling/ GIS/ landscape ecology/ restoration ecology/ land-use.

45. ---. 1992. **The landscape ecology of large disturbances in the design and management of nature reserves.** *Ecology*. 73:181-194.
Keywords: landscape ecology/ modeling/ disturbance ecology.
46. ---. 1994. **Restoration of landscape structure altered by fire suppression.** *Conservation Biology*. 8(3):763-769.
Abstract: There is increasing interest in applying landscape ecological research to the management of wildlands, particularly regarding the negative effects of fragmentation and the benefits of corridors. Patch-producing large disturbances, such as fires and floods, produce a spatial mosaic structure in landscapes to which many species are sensitive. Management of the spatial structure of the patch mosaic has seldom been an explicit concern, however, in part because of insufficient knowledge about how this spatial structure is affected by alterations in the disturbance regime. Yet the patch mosaic structure of many landscapes has been altered by disturbance control (such as fire suppression), and there is substantial interest in restoring natural disturbance regimes in some wildland landscapes. It has been proposed that, in landscapes subjected to decades of fire suppression, simple reinstatement of the natural fire regime may lead to adverse effects because fuel buildup during fire suppression may result in unusually large fires. It has also been proposed that the use of small prescribed fires may be an effective approach to restoration of landscapes subjected to fire suppression. Here I use a spatial GIS-based simulation model to analyze the effects of reinstating a natural fire regime in the Boundary Waters Canoe Area, Minnesota, after 82 years of fire suppression. The simulation experiment suggests that suppression can be expected to significantly alter landscape structure, but landscape structure can generally be restored within 50-75 years by reinstating the natural fire regime. Unusually large fires would probably hasten the restoration of landscape structure, while small prescribed fires will not restore the landscape but instead will produce further alteration.
Keywords: MN/ BWCAW/ National Forest, Superior/ vt, boreal forest/ fire, prescribed/ fire effects/ GIS/ fire modeling/ fire suppression/ restoration ecology/ landscape ecology.
47. ---. 1995. **Long-term response of disturbance landscapes to human intervention and global change.** *Landscape Ecology*. 10:143-159.
Keywords: disturbance ecology/ landscape ecology/ climate change.
48. Baker, William L.; Egbert, S.L., and Frazier, G. F. 1991. **A spatial model for studying the effects of landscapes subject to large disturbances.** *Ecological Modeling*. 56:109-125.
Abstract: Global warming may have many consequences for natural ecosystems, including a change in disturbance regimes. No current model of landscapes subject to disturbance incorporates the effect of climatic change on disturbances on decade to century time scales, or addresses quantitative changes in landscape structure as disturbances occur. A new computer simulation model, DISPATCH, which makes use of a geographical information system for managing spatial data, has been developed for these purposes. The concept and structure of the

DISPATCH model are described here, and a hypothetical example of its use is illustrated, but the model requires refinement before it can be used to predict the effects of global warming of specific landscapes. The model includes provisions for (1) temporally varying weather conditions and their effect on disturbance sizes, and (2) the effect of spatial variation in vegetation condition and physical setting on the probability of disturbance initiation and spread. The potential use of the model is illustrated with a hypothetical example in which the age structure of disturbance patches is monitored for a 250-year period as weather fluctuates. The model run suggests that landscape structure fluctuates even if a disturbance regime remains constant.

Keywords: landscape ecology/ modeling/ disturbance ecology.

49. **Barnes, Burton V. and Wagner, W. H. 1981. *Michigan Trees*. University of Michigan Press, Ann Arbor.**

Keywords: MI/ fire effects.

50. **Barrett, Linda R. 1995. *A stump prairie landscape in northern Michigan: soils, forest vegetation, logging, and fire*. Michigan State University, East Lansing, Ph.D. dissertation. 206 pp.**

Abstract: Parts of a sandy plain located in northern Michigan today are 'stump prairie.' devoid of trees, although prior to the logging and fires of the late 19th century they supported dense forest. Nearby, otherwise similar sites have regenerated to forest. The aims of this study were to determine how site and human disturbance patterns are related to patterns of long-standing changes in this ecosystem and to examine the possible impact of these forest regeneration patterns on active soil processes. Evidence from the General Land Office survey notes suggests that original forest composition has a strong relationship to forest regeneration patterns, possibly due to the manner in which early logging was accomplished. White pine (*Pinus strobus*) was especially prevalent in the pre-logging forest of current stump prairie areas, but sugar maple (*Acer saccharum*) was nearly lacking there. Land ownership and tax records suggest that stump prairie sites were acquired and logged at least as early as adjacent forested sites. Tree rings and recent stumps provide evidence that in currently forested areas loggers left more trees to provide shade and seed sources for forest recovery. Soil parent material texture is not significantly different between the forest and stump prairie sites. Spodic horizon development, as shown by degree of ortstein cementation and Fe, Al, and organic matter contents, is slightly stronger where forest regeneration has occurred than in areas that have remained stump prairie. Most of the extractable Fe and Al is present in organically-bound forms, but inorganic forms become more important in the lower B horizon. Ortstein content represents the primary difference between the soils in forested and stump prairie areas. In order to study current soil development processes, bags of cation exchange and chelating resins were buried in forested and unforested sites. Although variability within and between pedons was very high, slightly greater amounts of Fe and Al were absorbed in B horizons of soils of forested than of unforested sites, suggesting that podzolization processes are more active in the forest than in the stump prairie. These data highlight the importance of forest

vegetation in maintaining the spodic (Bs) horizon.

Keywords: MI/ vt, stump prairie/ vt, pine forest/ logging/ fire, late 19th century logging/ soils, nutrient analysis/ pine, white.

51. **Barrett, Linda R.; Liebens, Johan Brown; Daniel G.; Schaetzl, Randall J.; Zuwerink, Patricia; Cate, Thomas W., and Nolan, David S. 1995. Relationships between soils and presettlement forests in Baraga County, Michigan. American Midland Naturalist. 134:264-285.**
Abstract: Soils data and data on the presettlement forests of Baraga County, taken from the General Land Office (GLO) Survey, were stored and analyzed in a geographic information system (GIS). The purpose of the research was to determine county-wide witness tree distributions and autecological relationships among 14 major tree species and soil wetness and texture, in this geologically and edaphically diverse region of northern Michigan. In all, 12,760 trees were coded by species, location and diameter from the GLO data, which were recorded between 1846 and 1853. Tree data were overlain on soil mapping units which were coded by natural drainage class and particle-size family. All trees located in mapping unit complexes (two or more soil types) or within 25 m of certain soil boundaries were eliminated from further consideration through a selection/ buffering procedure leaving 6210 trees of 14 species for use in the analysis. Contingency tables were calculated to assess the strength and direction of the relationships between each tree species and soil texture, soil wetness and texture/wetness combinations.

County-wide distributions of species were strongly related to soil patterns, with a prominent forest ecotone occurring near the boundary between distinct till provinces. Most upland forests were dominated by sugar maple and yellow birch; prevalent lowland species included balsam fir, black spruce and white cedar. Hemlock was common only near Lake Superior on sandy tills that lacked a silt cap. Especially notable was the association between a nearly pure stand of jack pine and the dry sandy soils of Baraga (glacial outwash) Plains. Evidence for widespread disturbance by wildfires on the level plains contrasts with the relatively long period of only small gap-scale disturbances that existed on more rolling, mesic and wet sites.

Keywords: MI/ vt, maple forest/ vt, swamp forest/ vt, balsam fir forest/ vt, white cedar forest/ vt, hemlock forest/ vt, pine barrens/ windthrow, occurrence of/ fire history/ wildfire/ GLO/ presettlement vegetation/ sand plains/ soil morphology/ GIS/ pine, jack/ pine, red/ pine, white/ maple, sugar/ balsam fir/ spruce, black/ hemlock/ northern white cedar.

52. **Battles, John J. and Fahey, Timothy J. 1996. Spruce decline as a disturbance event in the subalpine forests of the northeastern United States. Canadian Journal of Forest Research. 26:408-421.**
Abstract: During the last 2 decades red spruce (*Picea rubens* Sarg.) trees have died at high rates in the mountains of New York and New England. Given the importance of disturbance in organizing plant communities, the impact of the decline was evaluated in term of its effect on disturbance processes. The first step

was to describe the current disturbance regime in subalpine forest across the region. Canopy gaps were the predominant mode of disturbance. Estimates of gap-phase disturbance in four old-growth sites ranged from 15% to 42% of the total forested area. Gap abundance varied between 19 and 49 gaps/ha. A constant among the sites was that dead spruce trees accounted for more of the gap area than expected considering their abundance in the canopy. In the spruce-fir forest, most gaps were small (<100 m²). Gaps were not shaped like simple geometric figures but rather like irregular polygons. Forty percent of the canopy gaps were created by the death of a single tree; the rest were multitree gaps. Standing dead trees were the most common damage type. It seems that decline of spruce effected a quantitative but not qualitative shift in the disturbance regime.

Keywords: NY / NH/ ME/ northeastern United States/ canopy gap/ disturbance ecology/ spruce, red.

53. **Battles, John J.; Fahey, Timothy J., and Harney, Ellen M. B. 1995. Spatial patterning in the canopy gap regime of a subalpine *Abies-Picea* forest in the northeastern United States. *Journal of Vegetation Science*. 6:807-814.**
Abstract: Spatial patterning in the disturbance regime of a forest affects the vegetation dynamics. Therefore, the distribution of canopy gaps was examined in detail for a subalpine *Abies-Picea* forest in the northeastern United States. Gaps were not randomly distributed. The fraction of forest area in gaps and the abundance of gaps varied significantly with topographic position, elevation, and slope percent. On average, 15% of the forest was influenced by gaps, but the gap fraction was greater near ridges (23%) and near streams (27%) than on the backslope (13%). Also, gaps were larger and more abundant near streams and ridges. Gap fraction varied with elevation as well: more of the forest was disturbed at lower and higher elevations than at mid-elevations. Significantly more of the forest on steep slopes ($\geq 30\%$) was under gaps. As a result of this patterning, some parts of the *Abies-Picea* forest were predictably more disturbed than others. A remaining question is whether this patterning is sufficient to influence the regeneration environment and thus forest composition.
Keywords: NY/ northeastern United States/ disturbance ecology/ canopy gap/ balsam fir/ birch, yellow/ birch, paper/ spruce, red.
54. **Bayley, S. E.; Schindler, D. W.; Beaty, K. G.; Parker, B. R., and Stainton, M. P. 1992. Effects of multiple fires on nutrient yields from streams draining boreal forest and fen watersheds: nitrogen and phosphorus. *Canadian Journal of Fisheries and Aquatic Sciences*. 49:584-596.**
Keywords: vt, boreal forest/ vt, wetland/ fire effects/ hydrology/ streams/ water chemistry.
55. **Beal, W. J. 1888. Forest fires. *Twenty-seventh Annual Report of the Michigan State Board of Agriculture, Lansing*. p. 72-74.**
Note: The problem of forest fires and forestry in Michigan is presented. Two examples are cited where landowners tried to manage red pine and white pine tracts for future harvest but wildfires, ignited in the stands unintentionally by neighbors, or intentionally by forest laborers, destroyed the stands. Therefore,

landowners must hire guards for these lands during the fire season. Thus, many give up and harvest rather than hold lands for future harvest.

Keywords: MI/ vt, pine forest/ wildfire/ fire suppression/ pine, white/ pine, red.

56. --. 1901. **The succession of forests in Michigan-a brief abstract for the busy man. First annual report of the Michigan Forestry Commission for the year 1900, Lansing. p. 64-65.**

Note: A general description of succession for the dominant forest types of Michigan is given. It was noted that 28 year old maples were not over 1 foot tall and have 3 fire scars each. It was suggested that they may have lived under the shade of pines for 75 years. The stand was located at the Agricultural College in Michigan. The stand, described in Beal (1903), consisted mainly of white, black and red oaks with red maple scattered throughout.

Keywords: MI/ vt, oak forest/ fire history/ fire scar/ succession/ pine, white/ maple, red/ oak, white/ oak, red/ oak, black .

57. ---. 1903. **The future of white pine and Norway pine in Michigan. Michigan Academy of Science. 4:106-107.**

Note: Mature white pine and red pine stands are becoming scarce in Michigan and there is little reproduction where there are stands. Because of fires, areas where conifer stands once grew, only oak, poplar, sumac, pin cherry, red maple, juneberry, sweet fern, roses, dewberries, low willow can now be seen. One location logged unburned stand had very good pine reproduction.

Keywords: MI/ vt, pine forest/ fire/ logging/ land-use/ pine, red/ pine, white/ oak/ aspen/ sumac/ maple, red/ juneberry/ willow/ fern, sweet/ shrubs/ herbs.

58. **Beale, John A. and Dieterich, John H. 1963. Crown fire problems in the Lake States. Wisconsin Conservation Bulletin. 28(1):12-13.**

Note: Crown fires occurring between 1955-1960 in Minnesota, Wisconsin and Michigan are characterized in terms of vegetation (all pine), size, fire weather, and point of ignition. There are suggestions on ways to become more efficient in crown fire suppression. Area maps show present (1961) areas with crown fire potential and additional land that may be available in 20 years. The findings are as follows. From 1955 to 1960 there were 52 crown fires in the Great Lakes region (Minnesota, Wisconsin and Michigan), of these, 24 occurred on days of extreme fire danger, 19 occurred on days of very high fire danger and 9 occurred on days with moderate to high fire danger. Weather conditions conducive to crown fires are 1) a prolonged period of dry weather with low fuel moistures, 2) abnormally low relative humidity, 3) average wind velocities greater than 15-18 miles per hour. Crown fire suppression needs: 1) Adequate planning and quick initial attack. 2) Utilization of natural and artificial fuelbreaks. Vegetation type changes and roads can be used. 3) Development and testing of new equipment.

Keywords: MN/ WI/ MI/ vt, pine forest/ vt, jack pine forest/ vt, pine barrens/ fire suppression/ fire behavior/ pine, red/ pine, white.

59. **Beatty, Susan W. and Stone, Earl L. 1986. The variety of soil microsites created by tree falls. Canadian Journal of Forest Research. 16(3):539-548.**

Abstract: The uprooting of forest trees leads to the formation of microsites on the forest floor, contributing to fine-scale heterogeneity in soil properties. We found the types of microsites formed depended on the way the tree fall occurred. Tree falls were classified as either hinge or rotational types. Hinge tree falls formed when the root mat of a tree and the surrounding soil were uplifted vertically, leaving an adjacent pit in the soil. Hinge tree falls varied as to thickness of the root mat and angle of uplift. Rotational tree falls were usually a result of a ball and socket motion of the root mat and soil, which positioned the tree bole over the newly created pit. The tree falls disrupted and redistributed surface soil organic matter and subsoil. In rotational tree falls, the surface material remained intact, covering some of the pit and the adjacent side of the mound. In hinge tree falls, the surface organic matter was deposited on the throw side of the mound, leaving subsoil on the other side and in the pit. With time, however, hinge-type pits accumulated litter and eventually had more organic matter than mounds. Old mounds from both hinge and rotational tree falls had lower concentrations of calcium and magnesium, lower pH, and less moisture than pits. The tree fall process creates long-term soil patterns and maintains microsite heterogeneity in forest communities.

Keywords: NY/ northeastern United States/ windthrow, tree damage/ windthrow, effects on soil/ soils, nutrient analysis/ microsite.

60. **Beaty, K. G. 1994. Sediment transport in a small stream following two successive forest fires. Canadian Journal of Fisheries and Aquatic Sciences. 51:2723-2733.**

Note: Oldest trees predated fire by 100 to 110 years. Pre-fire vegetation was jack pine and black spruce with patches of quaking aspen, red pine, white pine, and white spruce. Canadian Shield country just north of U.S. border.

Abstract: The transport of streambed load sediment was monitored continuously in a small stream from 1975 to 1982 following forest fires in 1974 and 1980. The stream is located in the east subcatchment (170 ha) of Lake 239 in the Experimental Lakes Area, northwestern Ontario. Precipitation, stream discharge, bedload transport, and concentration of suspended materials were measured quantitatively and organic debris was observed and collected. Bedload transport increased 20-fold following the first fire and threefold after the second. Particle sizes tended to increase during the period of study. Bedload data suggest a recovery period of 5-6 yr following the first fire and a shorter one following the second. A mass budget of material load transported in a single year following recovery indicated a dominance of dissolved load (87%), followed by suspended load (10%), and bedload (3%).

Keywords: Ontario/ Canada/ vt, boreal forest/ fire effects/ streams/ hydrology/ soil drainage.

61. **Beaufait, William R. 1961. Procedures in prescribed burning for jack pine regeneration. Michigan College of Mining and Technology, Forestry Ford Center , L'Anse. 39 pp.**

Note: A handbook explaining established prescribed fire procedures for planning burns. Descriptions of jack pine characteristics, methods of regeneration,

preparations for burning and writing a burn prescription are included. A summary of the report is as follows. (1) The number of seed trees used to restock a stand depends upon the number of cones in the crown. Between 12 and 25 seed trees per acre, with dbh's between 12 to 14" is usually adequate. (2) Prescribed burning should be done as early in the spring as possible. Burning should follow the cutting operation as soon as possible because of the threat of windthrow of seed trees. The burn must be hot enough to expose mineral soil and heat up the crowns of the seed trees. Slash should be well cured usually after 1 month drying time. Burns should precede major flush of vegetation in the spring, or come after killing frosts or drought in the fall. Warm days are better than cool ones. Burns should not be ignited before 1400 hrs. Winds should be less than 6 miles per hour. Fireline width of 6 to 10 feet is usually sufficient. A backfire on the leeward side of the fire to begin with is suggested then, a headfire for the rest. To get adequate cone opening, flame lengths should be between 10 and 20 feet. (3) Seed traps and seedling counts are recommended to determine effectiveness of treatment.
Keywords: vt, jack pine forest/ vt, pine barrens/ fire, prescribed/ fire effects/ management/ silviculture/ firing technique/ pine, jack.

62. ---. 1966. **An integrating device for evaluating prescribed fires. *Forest Science*. 12:27-29.**

Keywords: fire, prescribed/ management.

63. Behre, C. Edward. 1916. **A study of windfall in the Adirondacks. *Journal of Forestry*. :632-637.**

Note: The study began a few weeks after a windstorm in 1916 by the Yale School of Forestry in the Adirondacks. Two areas with different silvicultural treatments were compared in the vicinity of Lake Ne-ha-sa-ne, N.Y.. Both areas had been thinned in 1898 and one had been thinned again in 1915. Damage was slightly higher in the twice thinned stands classified as hardwood and balsam fir swamp. There was no difference in the spruce type. Most of the damage occurred in the taller trees, and uprooting was more common in the conifers, particularly the lowland stand. Snapping was more common in the upland hardwood sites. Because there was no replication, statistical analysis was not done.

Keywords: NY/ northeastern United States/ vt, balsam fir forest/ vt, swamp forest/ vt, spruce forest/ vt, maple forest/ windthrow, tree damage/ silviculture/ spruce, black/ balsam fir/ maple, sugar/ birch, yellow/ beech.

64. Beltrami, J. C. 1962. ***A Pilgrimage in America*. American Classics Quadrangle Books, Inc., Chicago, IL.**

Note: Beltrami describes the wildlands, towns and people he comes across while on his journey up to the Mississippi, Bloody and Ohio rivers headwaters in the early 1800's. Use of fire by native Americans was recorded in 2 locations. First, by Fort St. Peter on the Ohio River, where he describes the annual use of fire by native Americans to reduce shrub cover. The party also boated through a burning forest along the Yahowa (the second by that name) River to l'Embarras River.

Keywords: WI/ fire, Native American use of.

65. **Bergeron, Yves. 1991. The influence of island and mainland lakeshore landscapes on boreal forest fire regimes. Ecology. 72(6):1980-1992.**

Abstract: In order to characterize the fire regime of the southern boreal forest and to understand the way in which landscape and fire regime interact, a detailed study of fire history was undertaken in two adjacent contrasting landscapes in northwestern Quebec. The fire history for the islands of Lake Duparquet was reconstructed and compared to that of the surrounding lakeshore. Fire occurrence was determined by archival search and by collection of information from fire scars. Dendroecological techniques were used to determine years of stand initiation on the lakeshore and for a subsample of the islands. Stand initiation data were used to estimate fire frequency, fire cycle, and fire intensity (lethal and non-lethal fires). Tree composition and surficial deposits were sampled in order to assess the possible effect of topography and forest cover on fire frequency.

Dated fire scars (n=273) revealed 82 fire years, with the earliest dated to 1593. Islands experienced more fire years (56) than the lakeshore (37), and fire years were uncorrelated. Most (72%) of the lakeshore stands were initiated by a few large fires (eight), whereas the fire size on islands was variable, ranging from <10% to 100% of the total surface of the island. Despite these differences in fire regime, fire occurrence and fire frequency decreased concurrently on the islands and the lakeshore starting = 120 yr ago. The lakeshore fire cycle was 63 yr before 1870 and 99 yr since 1870, whereas the fire cycle on the islands was slightly longer (74 yr and 112 yr) during the same intervals. The long-term decrease in fire frequency of both the lakeshore and islands was possibly driven by climatic change.

Fire frequency was generally similar for all surficial deposits and fuel types on the lakeshore, whereas fires were more abundant in pine woodland growing on bedrock on the islands. Lakeshore fires were generally of lethal intensity, whereas both a long cycle of lethal fires and a shorter cycle of non-lethal fires were observed on 50% of the islands. The lightning strikes resulted in a regime characterized by more frequent fires and fires of variable intensity. The specific fire regime observed in the island landscape may be the cause of the abundance of pines, whose presence may contribute, in turn, to the continuation of this regime of less intense and more frequent fires.

We suggest that fire regime in the boreal forest is controlled by long-term climate change at the regional scale, and by a strong interaction with landscape at the local scale, both components having a great impact on the distribution and the dynamics of boreal vegetation.

Keywords: Quebec/ Canada/ vt, boreal forest/ vt, aspen forest/ vt, birch forest/ vt, spruce-fir forest/ vt, conifer-feathermoss forest/ vt, pine forest/ vt, white cedar forest/ vt, swamp forest/ vt, riparian/ island/ fire regime/ fire scar/ fire frequency/ growth ring analysis/ climate change/ spruce, black/ spruce, white/ pine, red/ pine, jack/ aspen, trembling/ birch, paper/ balsam fir/ northern white cedar.

66. ---. 2000. **Species and stand dynamics in the mixed woods of Quebec's southern boreal**

forest. Ecology. 81(6):1500-1515.

Abstract: In order to test whether changes in forest composition observed while sampling portions...

Keywords: Quebec/ Canada/ vt, boreal forest/ vt, aspen-birch forest/ vt, spruce-fir forest/ disturbance ecology/ fire history/ growth ring analysis/ succession/ dendrochronology/ canopy gap/ budworm, spruce/ aspen/ balsam fir/ northern white cedar.

67. **Bergeron, Yves and Archambault, Sylvain. 1993. Decreasing frequency of forest fires in the southern boreal zone of Quebec and its relation to global warming since the end of the 'Little Ice Age'. The Holocene. 3(3):255-259.**

Abstract: Although an increasing frequency of forest fires has been suggested as a consequence of global warming, there are no empirical data that have shown a climatically driven change in fire frequency since the warming that has followed the end of the 'Little Ice Age'. We present here evidence from fire and tree-ring chronologies that the post-'Little Ice Age' climate change has profoundly decreased the frequency of fires in the northwestern Quebec boreal forest. A 300-year fire history (AD 1688-1988) from the Lake Duparquet area (48°28' N, 79°17' W) shows an important decrease, starting 100 years ago, in the number and the extent of fires. This decrease in fire frequency is also associated with a long-term increase in the mean ring width of northern white cedar (*Thuja occidentalis* L.) in the same area. Agreement between the standardized tree-ring chronology and fire years, together with a negative correlation with a drought index reconstructed for the AD 1913-1987 period, shows that the decrease in fire frequency may be related to a reduced frequency of drought periods since the end of the 'Little Ice Age'. The contradictory results between predicted and observed effects of warming on fire frequency call into question our present capability to generalize the effect of increasing CO₂ levels on fire frequency.

Keywords: Quebec/ Canada/ vt, boreal forest/ vt, spruce-fir forest/ climate change/ fire frequency/ dendrochronology/ growth ring analysis/ northern white cedar.

68. **Bergeron, Yves and Brisson, Jacques. 1990. Fire regime in red pine stands at the northern limit of the species range. Ecology. 71(4):1352-1364.**

Abstract: In order to define more precisely the fire regime prevailing in red pine stands, and to evaluate its effect on the maintenance of marginal populations in the boreal forest, we documented the frequency, extent, and intensity of fires that affected red pine populations in northwest Quebec. We focused on two islands in Lake Duparquet, divided the islands into 5 x 5 m plots, and recorded topography, soil moisture, and vegetation for each plot. We mapped stems and noted fire scars, took core samples and stem cross sections to determine the age of trees, and used fire scars, post-fire regeneration, surviving trees, and changes in growth rates as indications of fire passage and intensity. Fire frequency was also estimated using fire history data from 13 other stands.

Before 1906 the fire regime was characterized by: (1) a short but very irregular fire interval averaging ~ 30 yr, (2) a large variation in burned area, including

patches that were generally left unburned, (3) a low fire intensity, although some fires were locally very intense, and (4) the occurrence, roughly every 68 yr, of fires of sufficient intensity to kill most trees on the entire island. Since 1906 the frequency of fire has decreased dramatically.

The fire regime appears to be controlled by abiotic conditions. The high-frequency fires of variable intensity primarily affect the xeric habitats. The less frequent, intense (possibly crown) fires that affect the entire island may depend on stand development from a less susceptible pine and hardwood forest towards a more typical spruce-fir boreal forest in more mesic habitats.

The fire regime described for these insular stands at the limit of the species' range is similar to that described for other parts of the range of red pine. We hypothesize that red pine is restricted to insular habitats at this northern limit of its range because of the particular fire regime that prevails there; the larger and more intense fires of the mainland here led to the elimination of the species.

Keywords: Quebec/ Canada/ island/ vt, boreal forest/ vt, pine forest/ fire scar/ **fire history (omit)**/ fire regime/ fire frequency/ fire effects/ age-class structure/ growth ring analysis/ pine, red/ pine, jack.

69. **Bergeron, Yves and Dansereau, Pierre-Rene. 1993. Predicting the composition of Canadian southern boreal forest in different fire cycles. Journal of Vegetation Science. 4:827-832.**

Abstract: Post-fire succession was reconstructed for a sector located in the southern part of the Quebec boreal forest. Forest composition for different periods since fire was evaluated using a stand initiation map together with ecological maps representing both site conditions and stand types. Nine fires covering at least 100 ha and representing a chronosequence of more than 230 yr were used. Although a relatively clear successional pattern from deciduous to coniferous composition relating to time-since-fire stand composition was observed, *Pinus banksiana* stands showed an erratic distribution not related to succession but possibly to the pre-fire stand composition. A comparison with forest cover maps produced after a recent spruce budworm outbreak, showed that succession toward coniferous dominance appeared to be interrupted by spruce budworm (*Choristoneura fumiferana*) outbreaks which, by killing *Abies balsamea*, lead to a mixed deciduous forest composition. A simple empirical model based on a negative exponential distribution of age classes was developed to evaluate how changes in the fire cycle would affect composition of the forest mosaic. The transition between deciduous dominance and coniferous dominance occurs in a fire cycle > 200 yr. Although pure deciduous stands tend to disappear during long fire cycles, the proportion of mixed stands remains relatively constant. Prediction of the forest composition for longer fire cycles is complicated by the interaction between post-fire composition and stand vulnerability to spruce budworm outbreaks.

Keywords: Quebec/ Canada/ vt, boreal forest/ vt, pine forest/ vt, spruce-fir forest/ vt, aspen forest/ vt, birch forest/ fire history/ fire regime/ succession/ fire modeling/ budworm, spruce/ birch, paper/ aspen, trembling/ spruce, black/ spruce,

white/ northern white cedar/ balsam fir/ pine, jack.

70. **Bergeron, Yves and Dubuc, Michelle. 1989. Succession in the southern part of the Canadian boreal forest. *Vegetatio*. 79:51-63.**

Abstract: Forest succession following fire in a forest mosaic of northwestern Quebec has been studied in order to: (1) describe the successional pathways using communities of different ages and (2) evaluate convergence of successional pathways and possible effect of fire suppression on the establishment of steady-state communities. As a first step, ordination and classification techniques were used in order to remove changes in forest composition which are related to abiotic conditions. Then, ordinations based on tree diameter distributions were used to study shifts in species composition in relation to time since the last fire.

Even under similar abiotic conditions, successional pathways are numerous. However, regardless of forest composition after fire, most stands show convergence toward dominance of *Thuja occidentalis* and *Picea mariana* on xeric sites and dominance of *Abies balsamea* and *Thuja occidentalis* on more mesic sites. Stable communities of > 300 yr occur on xeric sites while on mesic sites directional succession still occurs after 224 yr. Nearly all species involved in succession are present in the first 50 yr following fire. Only *Abies balsamea* and *Thuja occidentalis* increase significantly in frequency during succession. Following initial establishment, successional processes can generally be explained by species longevity and shade tolerance. Early successional species may be abundant in the canopy for more than 200 yr while the rapid decrease of *Picea glauca*, a late successional species could be related to spruce budworm outbreaks. Considering the short fire rotation observed (about 150 yr), a steady-state forest is unlikely to occur under natural conditions, though it may be possible if fire is controlled.

Keywords: Quebec/ Canada/ island/ vt, boreal forest/ vt, white cedar forest/ vt, spruce-fir forest/ vt, pine forest/ fire history/ fire regime/ succession/ classification/ budworm, spruce/ balsam fir/ birch, paper/ spruce, white/ spruce, black/ pine, jack/ pine, red/ pine, white/ aspen, trembling/ northern white cedar.

71. **Bergeron, Yves and Gagnon, Daniel. 1987. Age structure of red pine (*Pinus resinosa*) at its northern limit in Quebec. *Canadian Journal of Forest Research*. 17:129-137.**

Abstract: At the northern limit of red pine (*Pinus resinosa* Ait.) fire may be of critical importance in determining the persistence of red pine and its restriction to islands and shores of lakes. The objectives of the study were to document the distribution pattern of red pine populations of the Lake Duparquet area in northwestern Quebec and to analyze the age structure and fire history of the populations. The combined age structure of 22 red pine populations is balanced and uneven-aged, with two periods of increased recruitment from 1805 to 1864 and from 1926 to 1974. The analysis of individual populations indicates that they can be separated into three groups associated with specific site conditions: (i) uneven-aged populations with constant recruitment occurring on xeric sites, (ii) even-aged populations without regeneration occurring on mesic sites, and (iii)

uneven-aged populations, showing both a constant recruitment and peak periods of regeneration, occurring on sites with xeric and mesic portions. Although all fires registered, lethal and nonlethal, are generally asynchronous between sites, the fires of 1825 and 1944 seem to have affected large areas of the lake. Two mechanisms for maintenance of red pine were detected: self-regeneration of populations resistant to fires on xeric sites, and the transitory colonization of mesic sites by populations susceptible to lethal fires and established by seed from distant seed sources. Red pine may be restricted to lake landscapes because of the abundance of sites protected from lethal fires.

Keywords: Quebec/ Canada/ vt, pine forest/ island/ fire history/ fire regime/ fire scar/ age-class structure/ regeneration, seed/ pine, red.

72. **Bergeron, Yves; Richard, P. J. H.; Carcaillet, C.; Gauthier, Sylvie; Flannigan, M. D., and Prairie, Y. T. 1998. Variability in fire frequency and forest composition in Canada's southeastern boreal forest: a challenge for sustainable forest management. Conservation Ecology. 2(2):6.**

Note: Available online <http://www.consecol.org/vo2/iss2/art6>.

Abstract: Because some consequences of fire resemble the effects of industrial forest harvesting, forest management is often considered as a disturbance having effects similar to those of natural disturbances. Although the analogy between forest management and fire disturbance in boreal ecosystems has some merit, it is important to recognize that it has limitations. First, normal forest rotations truncate the natural forest stand age distribution and eliminate over-mature forests from the landscape. Second, in the boreal mixedwoods, natural forest dynamics following fire may involve a gradual replacement of stands of intolerant broadleaf species by mixedwood and then softwood stands, whereas current silvicultural practices promote successive rotations of similarly composed stands. Third, the large fluctuations observed in fire frequency during the Holocene limit the use of a single fire cycle to characterize natural fire regimes. Short fire cycles generally described for boreal ecosystems do not appear to be universal; rather, shifts between short and long fire cycles have been observed. These shifts imply important changes in forest composition at the landscape and regional levels. All of these factors create a natural variability in forest composition that should be maintained by forest managers concerned with the conservation of biodiversity. One avenue is to develop silvicultural techniques that maintain a spectrum of forest compositions over the landscape.

Keywords: Canada/ Quebec/ vt, boreal forest/ vt, aspen-birch forest/ vt, spruce-fir-cedar forest/ fire regime/ silviculture/ management/ fire, review.

73. **Bergman, H. F. and Stallard, Harvey. 1916. The development of climax formations in northern Minnesota. Minnesota Botanical Studies. 4:333-378.**

Note: Primary and secondary (flood, fire and windthrow) succession, subclimax and climax formations proposed by Clements (1916) are described for Minnesota.

Keywords: MN/ vt, maple forest/ vt, pine forest/ succession/ old-growth/ fire, general reference to stand structure/ flooding/ windthrow, effects on vegetation/ shrubs/ herbs.

74. **Bergstedt, B. and Niemi, Gerald J. 1974. A comparison of two breeding bird censuses following the Little Sioux forest fire. *Loon*. 46:28-33.**
Note: Bird species composition of two sites, aspen and jack pine, that had been surveyed 2 years prior to the Little Sioux Fire of 1971 were resurveyed. The wildfire caused temporary changes in the bird species composition and density but that the values were fairly normal. The stands originated after a fire in 1864.
Keywords: MN/ National Forest, Superior/ Little Sioux fire/ vt, pine forest/ vt, aspen forest/ fire effects/ wildfire, historic/ birds/ pine, jack/ aspen, trembling.
75. **Beyerhelm, C. D. and Sando, R. W. 1982. Regression estimation of litter and one hour time lag fuel loading in aspen-northern hardwood stands. *Forest Science*. 28:177-180.**
Keywords: MN/ vt, aspen forest/ fuels/ aspen, trembling.
76. **Birks, H. J. B. 1976. Late-Wisconsinian vegetational history at Wolf Creek, central Minnesota. *Ecological Monographs*. 46:395-429.**
Note: Climate change from 20,500 to 9150 B.P. is interpreted using pollen, and plant macrofossil records from one of the oldest drumlin fields in central Minnesota. Charcoal was found throughout the cores.
Keywords: MN/ climate change/ paleoecology/ macrofossils/ pollen analysis/ charcoal analysis.
77. **Bloomberg, W. J. 1950. Fire and spruce. *Forestry Chronicle*. 26:157-161.**
Note: Spruce, on the eastern slope of the southern Canadian Rockies in Alberta, may require stand replacing fires to persist. Age-class distribution and stand condition is used in examples to show that spruce regenerates under pine stands that originated after stand replacing fires, rather than older spruce stands.
Keywords: Alberta/ Canada/ vt, spruce forest/ vt, pine forest/ fire effects/ spruce, white/ regeneration, seed/ age-class structure.
78. **Boerner, Ralph E. J. 1982. Fire and nutrient cycling in temperate ecosystems. *Bioscience*. 32:187-192.**
Abstract: Wildfire is an integral component of many temperate ecosystems. The impact of wildfire on the nutrient dynamics of an ecosystem is dependent on the proportion of biomass and nutrients aboveground, which is therefore susceptible to combustion. Mechanisms for postfire nutrient conservation are most strongly developed in nutrient-poor (oligotrophic) ecosystems, in which most of the nutrients are found aboveground, and least well developed in nutrient-rich (eutrophic) ecosystems, whose nutrients are predominantly below ground.
Keywords: fire, review/ fire effects/ carbon and nitrogen cycling.
79. **Bonan, Gordon B. and Shugart, Herman H. 1989. Environmental factors and ecological processes in boreal forests. *Annu. Rev. Ecol. Syst.* 20:1-28.**
Note: Fire regimes and insect outbreaks of boreal forests are summarized. Fire cycle, intensity, severity, and regeneration are detailed in separate sections.
Keywords: vt, boreal forest/ vt, wetland/ vt, conifer-feathermoss forest/ vt, spruce-fir forest/ vt, aspen-birch forest/ vt, pine forest/ fire effects/ fire regime/

fire behavior/ regeneration, seed/ regeneration, vegetative/ insects/ fire, review/ review.

80. **Books, D. J.; Heinselman, Miron L., and Ohman, Lewis F. 1971. Regeneration on the Little Sioux wildfire. *Naturalist*. 22(4):12-21.**
Note: A general description of revegetation after the first growing season of the area burned by the Little Sioux wildfire is given. Many species are listed. Long term studies begun after the fire listed. Lots of pictures of area. A summary is as follows. Two weeks after the fire, which was controlled on May 19, 1971, herbaceous vegetation was emerging. The ground surface was lightly burned. By June, bracken fern, aspen sprouts and jack pine seedlings were beginning to appear. Large-leaf aster, bracken fern, and bunchberry were the most common herbs after mid- September. The most common shrubs were pin cherry, hazel, mountain maple, juneberry, honeysuckle, willow, raspberry, sweet-fern, and blueberry. The pine borer population increased immediately after burn, as did woodpeckers.
Keywords: MN/ Little Sioux fire/ National Forest, Superior/ wildfire/ fire effects/ wildfire, historic/ birds/ insects/ historic wildfires/ willow/ juneberry/ cherry, pin/ blueberry/ fern, sweet/ honeysuckle/ raspberry/ fern, bracken/ aster, large-leaf / shrubs/ herbs.
81. **Borie, Louis. 1981. Tragedy of the Mack Lake Fire. *American Forests*. 87(7):15-54.**
Note: A summary of the events that led up to the Mack Lake Fire. It began as a prescribed burn that was not in prescription.
Keywords: MI/ vt, pine barrens/ fire behavior/ fire weather/ fire, prescribed/ wildfire/ wildfire, historic/ birds.
82. **Bormann, F. Herbert and Likens, Gene E. 1979. Catastrophic disturbance and the steady state in northern hardwood forests. *American Scientist*. 67:660-669.**
Note: The authors contrast the pre-European fire regime of the western Great Lakes region, mostly Minnesota, with that of the White Mountains, PA. All references to wind disturbance are for the eastern United States.
Abstract: Models of ecosystem development usually portray plant succession as an orderly progression of biological changes to an environment that is presumed to be more or less constant (Odum 1969; Woodwell 1974). Yet every terrestrial ecosystem is subject to a range of disturbances varying from those that barely alter the structure, metabolism, or biogeochemistry of the system to those that wholly or dramatically change it. Defining "disturbance" itself is something of a problem, because it is difficult to draw a line between endogenous disturbances, that is, events that come within the scope of normal plant succession (for example, the fall of old trees), and exogenous disturbances, events that might be considered to deflect the autogenic pattern (for example, severe fires or hurricanes).
Keywords: Minnesota/ Wisconsin/ Michigan Pennsylvania/ vt, northern hardwood forest/ vt, pine forest/ modeling/ fire/ windthrow, effects on vegetation/ disturbance ecology.

83. **Bradbury, John P. 1986. Effects of forest fire and other disturbances on wilderness lakes in northeastern Minnesota II, paleolimnology. *Archiv Fur Hydrobiologie*. 106:203-217.**

Note: The study was carried out on Meander and Dogfish Lakes. Charcoal index shown on pollen diagrams show small peaks. Little Sioux fire didn't show up on the Meander profile, even though 1/2 of the watershed was burned. There are many small peaks between 1890 and 1973 that are associated with logging and slash fires that occurred in the area. Dogfish Lake only shows 1 peak sometime prior to 1890. Otherwise, the index is flat.

Abstract: Diatom, pollen, and limited chemical analyses were made on short cores of sediment from two lakes in the Boundary Water Canoe Area—one in a forest area burned in the Little Sioux fire and one outside the limits of the fire. The time scale of sedimentation was determined from the increase in pollen of ragweed, which indicates regional agricultural disturbance about 1890. The diatom stratigraphy of the lake in the fire area indicates that a significant change in trophic status occurred several decades ago, perhaps as a result of nutrient enrichment by dust. The only possible indication of an effect of the fires is a higher percentage of a particular eutrophic species in the water sample than in the core. For the control lake, changes in diatom assemblages coincident with the rise in ragweed pollen as well as later imply perturbations in lake conditions unrelated to fire, which is known not to have occurred in that area within this period of time. Acid precipitation may have been a factor in producing the observed changes.

Keywords: MN/ BWCAW/ National Forest, Superior/ Little Sioux fire / vt, boreal forest/ fire effects/ wildfire, historic/ paleoecology/ pollen analysis/ charcoal analysis/ hydrology/ lake/ aquatics.

84. **Bradbury, John P.; Tarapchak, S. J.; Waddington, Jean C. B., and Wright, Richard F. 1975. The impact of a forest fire on a wilderness lake in northeastern Minnesota. *Verh. Int. Verein. Limnol.* 19:875-883.**

Note: The authors compared the hydrology, chemistry, and phytoplankton biology of 2 oligotrophic lakes, Meander Lake, a burned watershed, and Dogfish Lake, an unburned watershed, after the Little Sioux Fire (May 1971). Comparison indicates a 60% increase in runoff and increases in K and P of 265% and 93%, respectively. No significant changes were found in Ca, Mg, and Na concentrations. The atmosphere is the largest contributor of P, thus in comparison to Dogfish Lake, the loading was only 38% higher than expected and, this increase falls within natural year-to-year variation. The response to phytoplankton to the increase in nutrients was monitored over 2 openwater seasons. Phytoplankton may have increased in 1972 due to an increase in P but, because of year-to-year variation in P and the seasonal changes in phytoplankton, it's not conclusive whether the observed change is fire related.

Keywords: MN/ National Forest, Superior/ Little Sioux fire/ wildfire, historic/ wildfire/ lake/ water chemistry/ hydrology.

85. **Bradbury, John P. and Waddington, Jean C. B. 1973. The impact of European settlement on Shagawa Lake, northwestern Minnesota, U.S.A. *In*, Birks, H. J.**

B. and West, R. G. *Quaternary Plant Ecology*. Blackwell Scientific Publications, Oxford, England. p. 289-307.

Note: The study correlates limnological changes within Shagawa Lake due to pollution caused by European settlement around the lake. Settlement around the lake which began in 1888 when iron mines became established in the area. There were 5 mines by the lake by 1900. Production fluctuated wildly through the early 1900's until 1967, when the last mine closed. Logging began at the same time as the mining and, by 1895, most of timber around Shagawa Lake and Ely was cut. Ely's population increased rapidly in the late 1800s and peaked at 6,000 in 1930. Since that time, the population has been slowly decreasing and becoming increasingly seasonal because of the recreationists visiting the BWCA. Ely has had a municipal sewage system since 1901 and has been periodically updated. Results from the sediment cores are as follows. Iron levels, P, sedimentation, diatom, Cladocera, vegetation and charcoal throughout the cores were analyzed and associated with cultural events. The changes in pine pollen and the results of the charcoal analysis are as follows. A regional reduction in white pine began about 1864, and a compensatory increase in both red pine and jack pine pollen was seen in cores. Pollen from grass, ragweed and other weedy species increased at the time of settlement. A decrease in tamarack pollen indicates the invasion of the larch sawfly. Aspen increases in the late 1800's and early 1900's corresponded with reforestation after extensive logging and severe wildfires of that time period. Charcoal analysis did not correlate the peaks with known local large wildfires, except for the Little Sioux fire. The thickness of the sediment sample may have been too thick to detect local wildfires. Every 2 cm of sediment was analyzed, which corresponds to 6 years.

Keywords: MN/ BWCAW/ Little Sioux fire/ wildfire, historic/ vt, pine forest/ vt, aspen forest/ pollen analysis/ charcoal analysis/ aquatics/ land-use/ insects/ pine, white/ pine, red/ pine, jack/ tamarack/ aspen, trembling.

86. **Brewer, Richard P. and Merrit, P. G. 1978. Windthrow and tree replacement in a climax beech-maple forest. *Oikos*. 30:149-152.**

Keywords: Over a period of 25 seasons, wind throw of trees larger than 25.4 cm dbh at Warren Woods, Michigan, USA, was at the rate of 0.2 trees ha⁻¹yr⁻¹. Beeches (*Fagus grandifolia* Ehrhart) larger than 76 cm dbh were more susceptible than smaller trees. In forests where the subcanopy trees are heavily dominated by sugar maple (*Acer saccharum* Marshall) and beech, wind throw appears not to maintain canopy diversity; nearly all the replacement trees for current gaps are these two species. Maintenance of canopy diversity in such mature forests is probably by more extensive and severe perturbation. Three to five thousand years would be required for the total soil surface to be disturbed by wind throw.

Keywords: MI/ windthrow, tree damage/ windthrow, effects on soil/ maple, sugar/ beech .

87. **Brooks, C. F. 1940. Hurricanes into New England: meteorology of the storm of September 21, 1938. Smithsonian Institute Annual Report 1939. p. 241-251.**

Keywords: weather/ northeastern United States.

88. **Brotak, Edward A. and Reifsnyder, William E. 1977. An investigation of the synoptic situations associated with major wildland fires. *Journal of Applied Meteorology*. 16(9):867-870.**
Abstract: Fifty-two major wildland fires in the eastern half of the United States were analyzed to determine the synoptic situations involved. Three-fourths of the fires were found near surface frontal areas. The vast majority of fires were associated with the eastern portion of small-amplitude but intense short-wave troughs at 500 mb. A lack of moisture advection at 850 mb inhibits precipitation which normally accompanies these systems. This lack of precipitation in association with strong low-level winds found in these regions produces dangerous fire conditions at the surface. Such situations are shown to occur rarely.
Keywords: MN/ OK/ NC/ NJ/ WV/ AS/ MA/ NB/ AL/ KS/ northeastern United States/ eastern United States/ fire weather .
89. **Brown, Elton T. 1894. *A history of the great Minnesota forest fires: Sandstone, Mission Creek, Hinkley, Pokegama, Skunk Lake*. Brown Bros., St. Paul, MN.**
Keywords: MN/ wildfire/ wildfire, historic.
90. **Brown, James K. 1974. Handbook for inventorying downed woody material. US Forest Service, General Technical Report INT-16. 24 pp.**
Note: This publication was added to database because it outlines a good way to measure fuels quickly and efficiently.
Abstract: To facilitate debris management, procedures for inventorying downed woody material are presented. Instructions show how to estimate weights and volumes of downed woody material, fuel depth, and duff depth. Using the planar intersect technique, downed material is inventoried by 0- to 0.25-inch, 0.25- to 1-inch, and 1- to 3-inch diameter classes; and by 1-inch classes for sound and rotten pieces over 3 inches. The method is rapid and easy to use and can be applied to naturally fallen debris and to slash. The method involves counting downed woody pieces that intersect vertical sampling planes and measuring the diameters of pieces larger than 3 inches in diameter. The piece counts and diameters permit calculation of tons per acre.
Keywords: fuels/ fire, prescribed/ methodology.
91. **Brown, Robert Thorson and Curtis, John T. 1952. The upland coniferous hardwood forests of northern Wisconsin. *Ecological Monographs*. 22:217-234.**
Note: Species composition and characteristics, plus soils data were collected from 116 forested stands in northern Wisconsin. This information was rated by combining importance values for the tree species and climax adaptation to create the continuum index. Generally, stands with mostly jack pine and red pine had the lowest continuum index values and sugar maple and hemlock stands had the highest values. In the discussion, fire was mentioned frequently as important to the regeneration and maintenance of current stand vegetative characteristics.
Keywords: WI/ vt, pine forest/ vt, jack pine forest/ vt, hemlock forest/ vt, hemlock-hardwood forest/ vt, maple forest/ vt, oak forest/ fire, general reference to stand structure/ classification/ pine, jack/ pine, red/ pine, white/ oak, red/

maple, red/ maple, sugar/ hemlock/ aspen/ birch.

92. **Brubaker, Linda B. 1975. Postglacial forest patterns associated with till and outwash in northcentral Upper Michigan. Quaternary Research. 5:499-527.**
Note: The jack pine woodlands of the Yellow Dog Plains are an edaphic climax rather than a fire maintained climax. The climax is edaphic because: 1) the consistent pollen levels of jack pine from continuous occupancy since postglacial times and, 2) the lack of serotiny in the cones. Brubaker found that postglacial forest patterns were more closely associated with landforms and soils than disturbance regimes in northcentral Upper Michigan.

Abstract: Pollen analysis of lake sediments reveals that small areas of till and outwash in north central Upper Michigan have influenced plant distributions throughout postglacial time. Each substrate has different textural characteristics. Modern forest communities form a mosaic, with jack pine woodlands occupying the medium sands of the Yellow Dog Plains outwash and white pine-hardwood communities on both till and outwash soils in the Michigamme Highlands to the south.

The analysis of modern pollen samples from 21 lakes within the area indicates that pollen can be used to study the distribution of local vegetation in relation to substrate type. Fossil pollen from three of the lakes documents the character of ancient forest on Yellow Dog outwash, Michigamme outwash, and Michigamme till.

Unique boreal communities occupied each area immediately after deglaciation. Between 8000 to 7000 y.a., white pine and maples migrated into the study area and replaced jack pine in forests on the Highlands, but not on the Plains. Jack pine has continued to occupy the Plains since early postglacial time. White pine reached highest densities on Michigamme outwash, and deciduous trees increased primarily on till during the presumably dry climates which existed 8000-5000 yr BP. As the climate became more mesic, forests on the Highlands changed, so that by 3000 yr BP the communities on Michigamme outwash and till were indistinguishable on the basis of pollen. Present-day forest patterns of the area became established at that time.

Pollen influx rates, measured at each lake, generally support interpretations based on pollen percentages and were similar to values reported elsewhere. Variations in influx values are within the range expected for the method.

Keywords: MI/ vt, pine barrens/ vt, hemlock-hardwood forest/ vt, maple forest/ vt, spruce-fir forest/ vt, pine-hemlock- hardwood forest/ paleoecology/ pollen analysis/ fire, general reference to stand structure/ soil morphology/ pine, jack / pine, red/ pine, white/ maple, sugar/ hemlock/ spruce, white/ balsam fir.

93. **Bruederle, Leo P. and Stearns, Forest W. 1985. Ice storm damage to a southern**

Wisconsin mesic forest. Bulletin of the Torrey Botanical Club. 112(2):167-175.

Note: Canopy species are divided into 3 susceptibility groups with early successional species being most vulnerable to damage and late successional species being the least vulnerable.

Abstract: In 1976, an extensive ice storm struck southern Wisconsin, resulting in substantial damage to the upland forest at the University of Wisconsin-Milwaukee Cedar-Sauk Field Station. Strong northeasterly winds following the storm (80.6 km/hr) exacerbated the damage. A forest fuel sampling technique was modified to measure the volume of macro-litter resulting from the ice storm. The canopy was photographed using both wide-angle and fish-eye lenses to determine the effect upon the overstory. Macro-litter volume was determined to be 19.35 m³/ha, accounting for a loss of approximately 35% of the canopy. Damage was uneven and was influenced by topographic and climatic factors; inclination and aspect of slope, as well as wind were found to be of particular importance. Species susceptibility to glaze varied considerably. Susceptibility was quantified by preparing a ratio of the observed macro-litter volume with the expected volume based upon the relative dominance of each species in the stand. Ratio products ranged from 1.55 for *Ulmus rubra*, the most susceptible species, to 0.17 for *Ostrya virginiana*. Factors responsible for species susceptibility include growth form, mechanical properties of wood, tree age and degree of decay, and position in the canopy.

Keywords: WI/ vt, maple forest/ weather, effects on vegetation/ ice storm/ elm/ ash, white/ ironwood/ cherry, black/ aspen, trembling/ aspen, big tooth/ maple, sugar/ beech/ oak, red/ basswood/ hickory, shagbark/ hickory, yellow-bud.

94. **Bryson, Reid A. 1966. Air masses, streamlines, and the boreal forest. Geographical Bulletin. 8(3):228-269.**

Abstract: The July air mass frequency distribution over Canada is analyzed back to source regions by daily computation of trajectories from grid intersections. A zone of rapid transition from Arctic air dominance to Pacific air dominance is found to lie along the northern border of the boreal forest, suggesting that the summer air mass distribution might be an important causal factor for distribution of forest versus tundra.

An independent analysis of July air mass frequency distribution by resolution of the daily maximum temperature frequency distribution into partial collectives, i.e., component normal distributions, gives results very similar to the trajectory analysis but with more detail. This analysis suggests that air mass dominance might be of importance to other biotic regions as well as the boreal forest and tundra.

A final analysis using monthly resultant wind streamlines near the surface indicates that mean airstreams and confluences between airstreams define climatic regions with a distinctive annual march of airstream and air mass dominance. These regions show a clear congruence with several major biotic regions. These analyses strongly suggest that the boreal forest occupies the region between the

mean or modal southern boundaries of Arctic air in winter and summer.

Keywords: weather / vt, boreal forest/ vt, tundra.

95. **Bryson, Reid A. and Wendland, Wayne M. 1967. Tentative climatic patterns for some late-glacial and post-glacial episodes in central North America. In, Mayer-Oakes, William J.. Life, Land and Water. Proceedings of the 1966 Conference on Environmental Studies of the Glacial Lake Agassiz Region. University of Manitoba Press, Occasional Papers, Department of Anthropology, University of Manitoba, Winnipeg. 1: 271-298.**
Note: This paper is similar to Bryson (1966) but, the analysis and extrapolation of air mass patterns using present day climatic patterns and descriptions of past glacial movements and vegetation composition is in greater detail.
Keywords: vt, boreal forest/ vt, northern hardwood forest/ vt, prairie/ weather.
96. **Bublitz, D. G. 1964. Full Circle. Wisconsin Conservation Bulletin. 29(5):24-25.**
Note: The management plan, utilizing prescribed fire, being used to enhance sharptailed grouse habitat in the Moquah Barrens is described.
Keywords: WI/ National Forest, Chequamegon-Nicolet/ vt, pine barrens/ fire, prescribed/ fire effects/ birds.
97. **Buckman, Robert E. 1962. Two prescribed summer fires reduce abundance and vigor of hazel brush regrowth. US Forest Service, North Central Forest Experiment Station, Technical Note 620. 2 pp.**
Note: Preliminary results of hazel reduction after 2 prescribed fires are reported.
Keywords: MN/ National Forest, Chippewa/ fire effects/ fire, prescribed/ hazel.
98. **---. 1964. Effects of prescribed burning on hazel in Minnesota. Ecology. 45(3):626-629.**
Abstract: Single or repeated spring prescribed fires and single summer fires easily kill aerial stems of hazel (*Corylus* spp.). Although vigorous and abundant resprouting follows spring fires, resprouting is less vigorous after summer fire. Repeated summer fires destroy the ability of hazel to resprout by (1) exposing and destroying underground stem systems and (2) probably exhausting stored food reserves. A single fire may eliminate hazel if humus is sufficiently dry to be completely consumed. This drying may occur in summer or fall, but rarely if ever in the spring.
Keywords: MN/ National Forest, Chippewa/ vt, pine forest/ fire effects/ fire, prescribed/ hazel.
99. **Buckman, Robert E. and Blankenship, Lytle H. 1965. Abundance and vigor of aspen root suckering. Journal of Forestry. 63:23-25.**
Abstract: Two or more prescribed burns in the spring of the year before growth begins reduce the abundance and vigor of suckering by quaking aspen but not that of most shrubs and other hardwoods. This has important practical significance for forest and wildlife management in the Lake States.
Keywords: MN/ fire, prescribed/ fire effects/ aspen, trembling.

100. **Buech, Richard R.; Siderits, Karl; Radtke, Robert E.; Sheldon, Howard L., and Elsing, Donald. 1977. Small mammal populations after a wildfire in northeast Minnesota. US Forest Service, Research Paper NC-151. 8 pp.**
Note: Small mammal populations were estimated after a 1,368 ha wildfire in northern Minnesota. The Roy Lake Fire occurred in the BWCA in late August of 1976.
Keywords: MN/ National Forest, Superior/ BWCAW/ fire effects/ wildfire/ mammals/ aspen/ balsam fir/ spruce, white/ pine, jack/ spruce, black.
101. **Buell, Murray F. 1955. New botanical problems in the New Jersey Pine Barrens. Torreyia. 82(3):237-252.**
Note: The new Pine Region Hydrological Project was presented at the Annual Meeting of the Torrey Botanical Club, January 18, 1955. A number of ecologists, hydrologists and silviculturists set up a long term study comparing the ground and surface runoff of two watersheds, one with repeated prescribed burning and the other without.
Keywords: NJ/ eastern United States/ vt, pine barrens/ fire, prescribed/ fire effects/ hydrology/ soil drainage.
102. **Buell, Murray F and Bormann, F. Herbert. 1955. Deciduous forests of Ponemah Point, Red Lake Indian Reservation, Minnesota. Ecology. 36(4):646-658.**
Note: The old growth maple-basswood and basswood-fir-black ash stands, and associated soils on Ponemah Point are described. In the discussion it was noted that fires were common on the Point but uncommon in the deciduous forests. A shift to a wetter climate caused the shift of vegetation to the deciduous forests.
Keywords: MN/ vt, Big Woods/ vt, maple forest/ vt, basswood-fir-black ash forest/ fire, general reference to stand structure/ climate change/ soil morphology/ maple, sugar/ basswood/ balsam fir/ ash, black/ herbs/ shrubs.
103. **Buell, Murray F. and Buell, Helen F. 1959. Aspen invasion of prairie. Bulletin of the Torrey Botanical Club. 86(4):264-265.**
Note: The aspen invasion of the prairie was examined about 30 miles west of Itasca State Park. Shoots around the thickets were examined and found to extend outward beyond the mother tree about one and a half meters per year. It was concluded that in the past, fire must have kept the aspen from expanding into the prairie. A wildfire occurred at the time of the sampling. All aspen sprouts were killed, supporting the conclusion.
Keywords: MN/ vt, prairie-forest ecotone/ fire effects/ aspen, trembling.
104. **Buell, Murray F.; Buell, Helen F., and Small, J. A. 1954. Fire in the history of Mettler's Woods. Bulletin of the Torrey Botanical Club. 81:253-255.**
Note: Fire scars were counted on a single white oak slab from a tree that originated in 1627. Fire occurred in Mettler's Woods (New Jersey) in 1641, 1652, 1662, 1676, 1701, and 1711 at the very least. Fires were probably set by native Americans regularly in this area.
Keywords: NJ/ eastern United States/ vt, oak forest/ fire, Native American use of/ fire scar/ fire interval/ oak, white.

105. **Buell, Murray F. and Cantlon, John E. 1951. A study of two forest stands in Minnesota with an interpretation of the forest-prairie margin. Ecology. 32(2):294-316.**

Note: The vegetation composition and soils of 2 maple-basswood stands, located in Itasca State Park and 30 miles west of Itasca are compared. The eastern most stand, at the prairie margin, probably invaded the prairie in the early 1800's. The second stand grew up under a pine stand. It is believed that a change in climate just over 100 years ago was a more important reason for the vegetation change than just a change in fire frequency. They acknowledge that it could be both a change in climate and a corresponding change in fire frequency.

Keywords: MN/ Itasca Park/ vt, maple forest/ vt, pine forest/ vt, prairie-forest ecotone/ climate change/ fire, general reference to stand structure/ maple, sugar/ basswood/ succession/ soil morphology/ herbs/ shrubs.

106. **Buell, Murray F. and Facey, Vera. 1960. Forest-prairie transition west of Itasca Park, Minnesota. Bulletin of the Torrey Botanical Club. 87(1):46-58.**

Note: The study was located in southern parts of Mahnomen and Norman Counties, MN.

Abstract: Vegetation and soils were sampled along a 1 mile by 22 mile transect along the prairie-forest border. The natural vegetation was classified into the following 8 categories: 1) maple-basswood forest, 2) oak and oak-aspen groves, 3) aspen stands, 4) shrub communities, 5) marshland, 6) dry prairie, 7) mesic prairie, 8) wet prairie. Many older residents were interviewed to determine turn of the century vegetation and human agricultural or land practices. Many people commented that Native Americans would routinely set fires along the prairie edge. In conclusion, historical burning by native Americans kept aspen from encroaching into the wet prairie. Today, agricultural practices keep aspen from invading the wetter prairie soils.

Keywords: MN/ vt, prairie-forest ecotone/ fire, Native American use of/ soil morphology/ fire history/ fire effects/ aspen, trembling/ oak, bur/ oak, pin/ maple, sugar/ basswood/ herbs/ shrubs.

107. **Buell, Murray F. and Martin, William E. 1961. Competition between maple-basswood and fir-spruce communities in Itasca Park, Minnesota. Ecology. 42(2):428-429.**

Note: This is the conclusion of a study began in 1938.

The vegetation shift that was evident in 1938 in an ecotonal area between maple-basswood and fir-spruce forests from maple-basswood to spruce-fir reversed itself in the 1950's. Many of the white spruce and balsam fir observed within the maple-basswood stands in the 1930's had died and in their place, understory vegetation common to maple-basswood was growing, especially sugar maple and basswood seedlings.

The original study was expanded by surveying vegetation of maple-basswood islands within the spruce-fir forest. These stands were within 200 yards east of

the original study. Three sites were chosen; 1) a low mesic area, 2) a dry slope, and 3) a swamp margin. The maple-basswood seems to be aggressively invading all 3 sites. This invasion occurs after windthrow, as spruce and fir seem to be very susceptible to wind damage and mortality. Black ash was also invading the sites aggressively, although the growth rate of the black ash regeneration was slower than the sugar maple saplings and seedlings. The most vigorous hardwood seedlings were found in the moister sites. The herbaceous stratum found under maple- basswood was also becoming established. These species are listed. It is worth noting that 600 yards east of the original study in a windthrow, spruce and fir seedlings and saplings were well established. A fire somewhere between 1810 and 1815 and heavy deer browse, 1935 to 1945, are other environmental factors affecting the forest but, these factors are not expected to cause significant changes on the vegetation dynamics described. Changes in soil moisture due to a shift from a dry to a wet period is the proposed reason for the vegetation shift.

Keywords: MN/ Itasca Park/ vt, maple forest/ vt, spruce-fir forest/ succession/ windthrow, effects on vegetation/ fire, general reference to stand structure/ deer browsing/ climate change/ maple, sugar/ basswood/ balsam fir/ spruce, white/ ash, black/ shrubs/ herbs.

108. **Buell, Murray F. and Niering, William A. 1957. Fir-spruce-birch forest in northern Minnesota. Ecology. 38(4):602-610.**

Note: All stands grew up under pine stands. The 3 Ely stands were by Moose River, Norway Island, and Wilderness Center.

Abstract: Species composition, and physical characteristics were obtained from five fir-spruce-birch stands. Two were in Itasca Park and 3 were near Ely, MN. The investigators tried to find stands that were self perpetuating but could not find any. Findings from this study include the following observations. All stands showed evidence of growing up under pine stands. In all cases balsam fir was the most abundant tree species, with paper birch, and white or black spruce consistently a common component of the overstory. In all but 1 of the stands, there was evidence of fire, windthrow or logging that released the tree understory. Only 1 stand seemed to have grown up through the pine stand without some disturbance to the overstory. Hazel was the only shrub found at all the sites. *Cornus canadensis*, *Aster macrophyllus*, and *Lycopodium clavatum* had the highest covers of the herb layer. *Calliergonella schreberi* was the most common moss of the well developed moss layer. The fir-spruce-birch gives every indication of perpetuating itself.

Keywords: MN/ Itasca Park/ National Forest, Superior/ vt, spruce-fir forest/ windthrow, effects on vegetation/ logging/ fire effects/ succession/ balsam fir/ spruce, white/ spruce, black/ birch, paper/ pine, jack/ pine, white/ herbs/ shrubs.

109. **Burgess, D. M. and Methven, I. R. 1977. The historical interaction of fire, logging and pine: a case study at Chalk River, Ontario. Canadian Forest Service, Information Report PS-X-66.**

Keywords: Ontario/ Canada/ vt, pine forest/ fire history/ logging/ land-use.

110. **Burley, Marvin W. and Waite, Paul J. 1965. Wisconsin tornadoes. Transactions of the Wisconsin Academy of Sciences, Arts and Letters. 54:1-35.**

Note: Wisconsin tornado occurrence from the early 1800's to 1964 is reviewed. Sources of data include newspapers that would report the more spectacular tornadoes, especially in the 1800s, to the Signal Corps. in the 1870's. An increase in the tornado observation network by the Weather Bureau in 1916. And, in 1953, another increase in effort to report and forecast tornadoes. It can be assumed that from 1870 to 1916 all notable tornadoes were reported and, from 1916 to 1953 most tornados were reported. From 1953 to 1964, nearly all were reported. A summary of the information is as follows.

Ranked 17th, Wisconsin is north of the tornado belt. One hundred and two tornadoes are listed through 1915, and 293 tornadoes from 1916 to 1964. Variables reported are county, town, date and time, direction of advance, length of path, number of persons killed or injured, and estimated crop damage. The following statistics are for data collected from 1916 to 1964. With 135 reports, peak tornado months were May and June. About 95% occurred between April and September. Wisconsin averaged 6 tornadoes per year. Almost 50% came out of the southwest. Length of touch down ranges from a brief touch down to 170 miles. The median was 4 miles long. While tornadoes were up to 1,000 yards wide, the median was 100 yards. Almost every county has had tornadoes. Polk, Clark, Baron, St. Croix, and Dane counties had the most with between 10 and 12 occurrences. West central Wisconsin is considered "tornado alley" because of having the most outstanding tornadoes (greatest loss of life, property damage or path greater than 25 miles long). A U.S. map showing number of tornadoes reported between 1916-61 indicates that southern Minnesota and southern Michigan were similar to Wisconsin. Northern Minnesota, Upper Michigan and northern Lower Michigan were less susceptible.

Keywords: WI/ MN/ MI/ weather.

111. **Canham, Charles D. 1978. Catastrophic windthrow in the hemlock-hardwood forest of Wisconsin. University of Wisconsin, Madison. Masters thesis. 94 pp.**

Note: Return time of 1273 years is for the hemlock-hardwood region.

Considering mostly old growth stands are affected, the reoccurrence rate must be more frequent the 1273 yrs.

Abstract: Both windthrow and fire have been proposed as significant large-scale disturbances in the mesic, hemlock-hardwood forest of Wisconsin. However, there have been no comprehensive studies of the pattern and frequency of either disturbance. A catastrophic wind storm in northern Wisconsin on July 4, 1977 forcibly illustrates the potential for large-scale windthrow in the regional forests. This study was initiated to evaluate the process of complete canopy windthrow as a natural disturbance in the presettlement hemlock-hardwood forest of Wisconsin, and determine the relationship of the 1977 blowdowns to the more general spectrum of wind-caused disturbances in northern Wisconsin.

Records of large-scale patch blowdowns in the original land survey notes and maps (1834-1873) were used to determine the frequency, size distribution and

state-wide pattern of blowdowns in the presettlement forests of Wisconsin. The surveyors recorded 535 blowdowns, totaling 213,084 acres (86,269 ha.), within the state. Patch sizes ranged from 1.6 to 9,352 acres (0.65-3,786.2 ha), with a median size of 80.0 acres (32.4 ha.). The majority of these blowdowns were recorded within the boundaries of the hemlock-hardwood forest. The estimated return time for a patch blowdown at a point within the region of the presettlement hemlock-hardwood forests was 1273 years. Thus, approximately 20% of the regional forest mosaic is expected to have been in various stages of recovery from blowdowns within the 250 years prior to the surveys.

The two principal mechanisms for complete canopy windthrow in northern Wisconsin are tornadoes and thunderstorm "downbursts". Prior to the 1977 Independence Day downbursts, the potential for thunderstorms to produce catastrophic windthrow was not generally acknowledged. However, the range of blowdown patch dimensions observed in the 1977 blowdowns is comparable to the range of patch sizes determined for the presettlement forests. On the basis of contemporary climatological records, tornadoes can account for only a third of the blowdowns recorded by surveyors in northern Wisconsin. Thunderstorm downbursts are considered the principal mechanism for large-scale windthrow in the presettlement forests of northern Wisconsin.

The regional pattern of windthrow is significantly affected by the composition of the regional forest mosaic. The apparent decline in the frequency of blowdowns in northern Wisconsin this century is attributed to both the conversion of forests to non-forested land, and the replacement of the presettlement old-growth forests by second growth forests that are, in many cases, less susceptible to complete windthrow.

Keywords: WI/ vt, hemlock-hardwood forest/ GLO/ presettlement vegetation/ landscape ecology/ windthrow, frequency/ hemlock.

112. **Canham, Charles D. and Loucks, Orie L. 1984. Catastrophic windthrow in presettlement forests of Wisconsin. *Ecology*. 65(3):803-809.**

Abstract: Presettlement survey records for the state of Wisconsin (circa 1834-1873) reveal a widespread pattern of catastrophic windthrow. From these records, we have calculated that there were 51.8 separate patches (>1.0 ha) of complete canopy windthrow covering a total of 4828 ha annually within the region of the presettlement hemlock-northern hardwood forests, in the northeastern part of the state. The estimated return time for catastrophic windthrow at a site in this region is 1210 yr. Catastrophic windthrow was much less common in the forests of southern Wisconsin. Comparisons of the presettlement disturbance regime with contemporary climatological records suggest that catastrophic thunderstorms were the principal mechanism for large-scale windthrow in northern Wisconsin.

Keywords: WI/ vt, hemlock-hardwood forest/ windthrow, frequency/ presettlement vegetation/ GLO/ hemlock/ maple, sugar/ birch, yellow .

113. **Cardille, J. A. and Ventura, S. J. 2001. Occurrence of wildfire in the northern Great Lakes region: effects of land cover and land ownership assessed at multiple**

scales. International Journal of Wildland Fire. 10:145-154.

Abstract: Risk of wildfire has become a major concern for forest managers, particularly where humans live in close proximity to forests. To date, there has been no comprehensive analysis of contemporary wildfire patterns or the influence of landscape-level factors in the northern, largely forested parts of Minnesota, Wisconsin and Michigan, USA. Using electronic archives from the USDA Forest Service and from the Departments of Natural Resources of Minnesota, Wisconsin, and Michigan, we created and analyzed a new, spatially explicit data set: the Lake States Fire Database. Most of the 18 514 fires during 1985-1995 were smaller than 4 ha, although there were 746 fires larger than 41 ha. Most fires were caused by debris burning and incendiary activity. There was considerable interannual variability in fire counts; over 80% of fires occurred in March, April, or May. We analyzed the relationship of land cover and ownership to fires at two different fire size thresholds across four gridded spatial scales. Fires were more likely on non-forest than within forests; this was also true if considering only fires larger than 41 ha. An area of National or State Forest was less likely to have experienced a fire during the study period than was a forest of equal size outside National or State Forest boundaries. Large fires were less likely in State Forests, although they were neither more nor less likely to have occurred on National Forests. Fire frequency also varied significantly by forest type. All results were extremely consistent across analysis resolutions, indicating robust relationships.

Keywords: WI/ MN/ MI/ management/ wildfire statistics.

114. **Carleton, Terence J. 1982. The pattern of invasion and establishment of *Picea mariana* (Mill.)BSP. into the subcanopy layers of *Pinus banksiana* Lamb. dominated stands. Canadian Journal of Forest Research. 12:973-984.**

Note: Stands were located in Ontario, northeast of Lake Superior.

Postfire establishment, especially surface fire, is the most common pattern of black spruce influx found in this study. Jack pine regeneration can be stimulated at the same time depending upon the fire.

Abstract: Stand-structure analysis is used to determine whether establishment of *Picea mariana* (Mill.)BSP. in the subcanopy of *Pinus banksiana* Lamb. dominated stands takes the form of a gradual influx or a sudden event. Twenty-six *P. banksiana* dominated stands were investigated of which 15 contained *P. mariana* trees at moderate to high densities. Postfire ages ranged from 46 years to 132 years for the oldest *P. banksiana* cohort in each stand. The 26 stands were subjectively assigned to one of seven groups on the criterion of age-structure histogram appearance. A multivariate test of the hypothesis that such structure differences could be due to soil differences was not significant. Three patterns of *P. mariana* influx were evaluated. (i) Gradual influx over a long time span in the oldest stands. (ii) Contemporaneous postfire reestablishment of both *P. banksiana* and *P. mariana* on a site. (iii) Invasion of *P. mariana* cohorts following surface fire activity as evidenced by fire scar dates. Results from a *P. Mariana* seedling survival experiment indicated that depth of burn is of critical importance for black spruce seedling establishment in these stands. However, circumstantial evidence suggests that *P. mariana* seed supply may also be limiting to

establishment success. These observations are discussed briefly in relation to models of forest succession.

Keywords: Canada/ Ontario/ vt, boreal forest/ vt, conifer-feathermoss forest/ regeneration, seed/ fire effects/ succession/ age-class structure/ sand plains/ soil morphology/ pine, jack/ spruce, black .

115. **Carleton, Terence J. and MacLellan, Patricia. 1994. Woody vegetation responses to fire versus clear-cutting logging: A comparative survey in the central Canadian boreal forest. *Ecoscience*. 1(2):141-152.**

Note: Strong points to this publication are the large number of data points, one of few publications addressing vegetation change and relative abundance due to differing treatments (fire vs. logging). Weak points include no pretreatment vegetation and fuels data, no measure of treatment.

Abstract: The woody vegetation of 131 clear-cut, postlogged boreal forest stands in central Canada, previously dominated by *Picea mariana* (Mill.)BSP., is compared with 250 natural postfire stands from the same region. Each dataset represents a stand chronosequence on a range of substrate types. Correspondence analysis (CA) based ordination methods is used for structural and compositional comparison in order to address the question of the extent to which woody vegetation recovery and succession are similar between the two disturbance types. In addition, canonical CA is used as a general linear model strategy to examine unique and covariant influences on forest composition. The postlogged stand dataset had a much lower representation of conifer -dominated stands than the postfire dataset and a far greater proportion of stands dominated by poplars. Detrended and canonical CA on all 381 stands indicated a primary influence on stand composition due to site factors, but disturbance type and intensity, *i.e.* wildfire versus horse or mechanical hauling in postlogged stands, showed the strongest correlation of any single variable. Analyses of each dataset, separately, indicated similar predictability of vegetation composition from associated stand environmental and age data but regressions were weak ($R^2 \sim 22\%$). Whereas skidding type and stand age were the most important correlates with the postfire woody vegetation. In addition to *Abies balsamea* (L.) Mill. dominated woodland deriving from postfire succession, such forests also arose on a widespread basis in horse skidded, postlogged stands through the persistence of advanced growth seedlings. Mechanically skidded, postlogged stands show a wholesale conversion and the intensity of boreal forest disturbance lead to different woody vegetation recovery patterns.

Keywords: Ontario/ Canada/ vt, boreal forest/ vt, conifer-feathermoss forest/ wildfire/ logging, clearcut/ logging, skidding/ disturbance ecology/ spruce, black / balsam fir/ aspen, trembling/ birch, paper/ shrubs.

116. **Carlton, G. C. and Bazzaz, Fakhri A. 1998. Regeneration of three sympatric birch species on experimental hurricane blowdown microsities. *Ecological Monographs*. 68(1):99-120.**

Abstract: Tip-up mounds, pits, and other microsities created by hurricanes may promote diversity in many forests by providing opportunities for different species to regenerate. To see if we could detect differences in microsite preference

among closely related species, we studied the regeneration of three sympatric *Betula* species on five types of microsites on experimental mound-pit complexes. Microsites were created by pulling down canopy trees to simulate damage from past hurricanes in southern New England. Seeds were collected in litter traps and experimentally released over mounds and pits to determine effects of microtopography on fine-scale dispersal patterns. The fate of naturally germinating seedlings was monitored on the disturbed site, and seedlings were also transplanted onto microsites to examine growth patterns, causes of mortality, and leaf-level physiology.

Seed rain onto the disturbed site was abundant and spatially heterogeneous because of the scattered residual canopy trees and surviving uprooted trees. Seeds tended to disperse away from vertically oriented surfaces of mounds and to accumulate in pits. Most seedlings germinated on scarified level areas rather than mounds or in pits, but mounds more favorable for germination the second year following disturbance. Two fundamentally different types of mortality were observed in transplanted seedlings. Extrinsic factors such as frost heaving, burial by soil and litter, and browsing were dominant on some microsites. Mortality due to these factors occurred primarily during the winter and was unrelated to seedling size. On other microsites, resource limitation (low light levels and lack of water or nutrients) was the major cause of death. Small seedlings were most susceptible to mortality on these microsites, and most deaths occurred during the growing season.

White birch (*Betula papyrifera* Marsh.) exhibited the fastest growth and most flexible photosynthetic response to changing light levels but suffered greatest mortality on shaded microsites. Black birch (*B. lenta* L.) showed increased leaf area ratio in shaded conditions. Yellow birch (*B. alleghaniensis* Britt.) was least flexible and grew more slowly than the other species but was best able to survive on shaded microsites. All species attained maximum growth on tip-up mounds. After three growing seasons, the tallest seedlings reached nearly 3 m above the forest floor, enabling us to predict which individuals would ultimately reach the canopy to complete the regeneration process.

Keywords: MA/ Harvard Forest/ eastern United States/ windthrow, effects on soil/ windthrow, effects on vegetation/ microsite/ regeneration, seed/ physiology/ birch, paper/ birch, black / birch, yellow.

117. **Carroll, Francis M. 1990. *The fires of autumn: the Cloquet-Moose Lake disaster of 1918*. Minnesota Historical Society Press.**

Keywords: MN/ wildfire/ wildfire, historic.

118. **Cary, Austin. 1936. White pine and fire. *Journal of Forestry*. 34(1):62-65.**

Note: A series of observations on the relationship between white pine and fire are described by the author while working in the woods of Maine, Michigan and Wisconsin. The observations are as follows: Seventy years after a 1825 wildfire in Maine, white pine was part of the young stand. Younger trees seemed to have regenerated 10 years prior to his being there. After doing stem analysis on pines

in Michigan and Wisconsin, many of the stands were found to be even-aged, usually 200-250 years old. There were many signs of fire more recent than the stands ages. The understory was often hemlock and hardwoods. A similar understory was found in a stand of white pine 460 years old. He relates other situations as well. Cary also notes that windfall may be important in white pine regeneration.

Keywords: WI/ MI/ ME/ northeastern United States/ vt, pine-hemlock-hardwood forest/ fire, general reference to stand structure/ windthrow, effects on vegetation/ regeneration, seed/ pine, white/ hemlock.

119. **Castelli, Jeff P.; Casper, Brenda B.; Sullivan, Jon J., and Latham, Roger Earl. 1999. Early understory succession following catastrophic wind damage in a deciduous forest. Canadian Journal of Forest Research. 29:1997-2002.**

Abstract: Early succession was followed in a 2.5-ha gap created by a severe wind storm in a 5.5-ha fragment of eastern North American deciduous forest.

Understory vegetation cover by species, light, soil moisture, and levels of several major nutrients were measured in 1 x 2 m census plots 3 years prior to the disturbance. Coincidentally, the storm felled 50-55% of the trees over a portion of these plots. Vegetation cover by species was again measured in all plots 3 years following the disturbance. Species were grouped by growth form, and group cover values used to examine changes in the composition of the vegetation and to determine whether these changes were correlated with any.

Keywords: eastern United States/ windthrow, effects on vegetation/ succession/ soils, nutrient analysis/ site conditions.

120. **Catlin, George. 1842. *Manners, customs, and conditions of the North American Indians.***

Note: Indians setting prairie fires. Cited by Curtis (1959).

Keywords: vt, prairie/ fire, Native American use of.

121. **Cayford, J. H. 1971. The role of fire in the ecology and silviculture of jack pine. Tall Timbers Fire Ecology Conference, Tallahassee, FL. p. 221-244.**

Note: Ecological research on jack pine emphasizing fire is summarized.

Literature cited extends from work done in Ontario and Manitoba to Minnesota and Wisconsin. Silvical characteristics such as cone production and seed dissemination, seedbed conditions and natural regeneration are listed. Research programs using prescribed fire in jack pine slash and standing trees, operational programs and alternatives to prescribed fire are discussed.

Keywords: MN/ WI/ Ontario/ Manitoba/ Canada/ vt, jack pine forest/ vt, pine barrens/ vt, conifer-feathermoss forest/ fire, prescribed/ fire effects/ regeneration, seed/ fire, review/ silviculture/ pine, jack.

122. **Changery, M. J. 1982. Historical extreme winds for the United States-Great Lakes and adjacent regions. Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington D.C.. NUREG/CR-2890.**

Abstract: Annual extreme wind data were extracted for the complete period of record for 70 locations in the Great Lakes, Ohio, and upper Mississippi valley

regions. Existing models were used to standardize the data to 10 and 30 meters for airport-type exposures and 30 meters for city exposures. Selected probability estimates were developed from application of the Fisher-Tippette Type I extreme value model for all extracted data. Maps present the .99 probability level (100-year return period) for 10 and 30 meters for airport-type exposures, and 30 meters for city exposures.

Keywords: MN/ WI/ MI/ OH/ weather .

123. **Chapman, H. H. 1952. The place of fire in the ecology of pines. *Bartonia*. 26:39-47.**

Abstract: While man has been responsible for a many-fold increase in the occurrence of forest fires, lightning as a natural cause has operated with a frequency that places fire among the determining ecological factors that influenced development, modification, and survival of species, especially pines.

In dry hot climates lightning fires occurred at intervals so short that pines became modified in order to survive as seedlings or saplings. In cooler northern climates fires tended to destroy most of the stand, and adaptations took the form of protecting seed sources.

To successfully reproduce and grow pines we must adapt silvicultural measures to the inherent habits of each species of pine, as determined for it by the environment in which it has developed the adaptations.

This is difficult with some northern species such as white pine (*P.strobus*) and jack pine (*P. divaricata*). The reasons for these difficulties are chiefly the fact that clear cuttings, even with seed sources, do not duplicate natural conditions under which these pines originate, hence special skill and often considerable expense is involved.

With southern pines, the duplication of natural conditions is extremely practical and inexpensive, consisting of the use of prescribed controlled fire at intervals dependent on the species; 3 years for longleaf pine (*P. palustris*), 5-6 years for slash pine (*P. caribea*), and 8-10 years for loblolly pine (*P. taeda*). This practice not only insures abundant reproduction during seed years but fireproofs the forest against almost certain destruction as a result of excluding fire and building up an unnatural fire hazard of brush and dead grass. The extension of the use of prescribed fire to the shortleaf (*P. echinata*) and pitch pine (*P. rigida*) types in New Jersey is an outgrowth of the practices found successful and officially adopted by the Forest Service in the southern pines.

Keywords: vt, pine forest/ fire effects/ fire, review/ pine, white/ pine, jack/ pine, red/ pine, longleaf/ pine, shortleaf/ pine, slash/ pine, pitch/ pine, loblolly.

124. **Clark, James S. 1988. Effect of climate change on fire regimes in northwestern Minnesota. *Nature*. 334:233-235.**

Note: Clark (1990) would be a more reliable source for estimation of fire rotation in red pine/white pine stands.

Abstract: Of all the impacts of projected climate change on forest ecosystems,

perhaps the most difficult to forecast is the potential for altered fire frequency and intensity. Fire regimes in forests are poorly understood for lack of long-term evidence. Petrographic thin sections were used to determine the annual production of charcoal within a lake catchment in northwestern Minnesota over the past 750 years providing the long and high-resolution record required to elucidate fire regimes. Maximum abundance and frequency occurred in the warm, dry fifteenth and sixteenth centuries. Fire importance decreased dramatically with the onset or intensification of the 'little ice age' about AD 1600. Fire cycles with harmonics corresponding to multiples of the 22-year drought cycles of the region and increased fire frequency at times when early successional stands are breaking up, suggest a synergistic influence of climate and fuel accumulation. The anomalously warm, dry twentieth-century climate would have produced substantially different fire regimes from the previous century in the absence of fire suppression.

Keywords: MN/ Itasca Park/ vt, pine forest/ fire interval/ fire regime/ charcoal analysis/ paleoecology/ climate change/ pine, red/ pine, white.

125. ---. 1988. **Forest dynamics, fire, and climate change during the last 2000 yr at Itasca Park, northwestern Minnesota. *Ecological Society Bulletin*. 69(2):100.**
Note: A summary of research done in Itasca State Park on the influence of climate change on fire frequency and species composition. Other publications by Clark are much more detailed on methodology and results of this research.
Keywords: MN/ Itasca Park/ vt, pine forest/ vt, aspen-birch forest/ fire scar/ fire interval/ growth ring analysis/ charcoal analysis / pollen analysis/ paleoecology/ climate change/ summary/ pine, red/ pine, white/ aspen/ birch.
126. ---. 1988. **Stratigraphic charcoal analysis on petrographic thin sections: application to fire history in northwestern Minnesota. *Quaternary Research*. 30:81-91.**
Abstract: Results of stratigraphic charcoal analysis from thin sections of varved lake sediments have been compared with fire scars on red pine trees in northwestern Minnesota to determine if charcoal data accurately reflect fire regimes. Pollen and opaque-spherule analyses were completed from a short core to confirm that laminations were annual over the last 350 yr. A good correspondence was found between fossil-charcoal and fire-scar data. Individual fires could be identified as specific peaks in the charcoal curves, and times of reduced fire frequency were reflected in the charcoal data. Charcoal was absent during the fire-suppression era from 1920 A.D. to the present. Distinct charcoal maxima from 1864 to 1920 occurred at times of fire within the lake catchment. Fire was less frequent during the 19th century, and charcoal was substantially less abundant. Fire was frequent from 1760 to 1815, and charcoal was abundant continuously. Fire scars and fossil charcoal indicate that fires did not occur during 1730-1750 and 1670-1700. Several fires occurred from 1640 to 1670 and 1700 to 1730. Charcoal counted from pollen preparations in the area generally do not show this changing fire regime. Simulated "sampling" of the thin-section data in a fashion comparable to pollen-slide methods suggests that sampling alone is not sufficient to account for differences between the two methods. Integrating annual charcoal values in this fashion still produced much higher resolution than

the pollen-slide method, and the postfire suppression decline of charcoal characteristic of my method (but not of pollen slides) is still evident. Consideration of the differences in size of fragments counted by the two methods is necessary to explain charcoal representation in lake sediments.

Keywords: MN/ Itasca Park/ vt, pine forest/ paleoecology/ charcoal analysis/ pollen analysis/ fire history/ fire scar.

127. ---. 1989. **Ecological disturbance as a renewal process: theory and application to fire history. *Oikos*. 56(1):17-30.**

Abstract: Failure time analysis and renewal theory were used to evaluate two assumptions implicit in most studies involving calculations of disturbance frequency. These calculations assume that the disturbance process is stationary (intervals between disturbances are drawn from the same distribution) and that the probability of disturbance does not change with time since the last disturbance. Quantitative methods are presented and applied to long-term fire occurrence data (fire scars on red pine (*Pinus resinosa*) trees and stratigraphic charcoal data) and climate data from NW Minnesota, USA. Results show that past decade- and century-scale fluctuations in climate correspond to changes in the disturbance regime. Probability of fire occurrence increases with time since the last fire, albeit at different rates during the various climatic conditions that have prevailed over the last 750 yr. These results suggest two reasons to question disturbance regimes calculated from spatial dispersion of events. Firstly, expected fire intervals derived as the inverse of spatial proportion of area disturbed requires a stationary process. The space/time analogy assumed by this method is highly inaccurate when the expected interval between disturbances changes over time. Secondly, because fire hazard is an increasing function of time since the last fire, the number of disturbances predicted to occur over short time intervals will be overestimated by the usual constant hazard assumption. Probability densities of events having age-specific probabilities that increase over time (e.g. fire, windthrow) exhibit modes at time $t > 0$ compared with exponential decrease with time.

Keywords: MN/ Itasca Park/ vt, pine forest/ charcoal analysis/ fire modeling/ fire frequency/ climate change/ pine, red.

128. ---. 1989. **Effects of long-term water balances on fire regime, north-western Minnesota. *Journal of Ecology*. 77:989-1004.**

Keywords: MN/ Itasca Park/ fire regime/ soil moisture.

129. ---. 1989. **The forest is for burning. *Natural History*. 1/89:51-53.**

Note: A general article explaining how climate and the associated fuel moisture conditions, along with fuel load, cause changes in probability of catastrophic wildfire. When fires are more frequent, the intensity of individual fires are lower because of less fuel, and vice versa. A brief explanation of the charcoal accumulation of the past 700 years is given.

Keywords: fire behavior/ fire weather/ fire history/ fuels/ charcoal analysis/ fire, review.

130. ---. 1990. **Fire and climate change during the last 750 yr in northwestern Minnesota.**

Ecological Monographs. 60(2):135-159.

Note: The study was conducted in Itasca State Park, Minnesota. Multiple fire scars seem to be clumped from 10 to 22 yrs and 30-52 yrs and seem to diminish after 80 yrs. I suspect this is a good record of the surface fire intervals with the catastrophic intervals being longer than 80 yrs. For the time interval 1650 to 1920, assuming that the 4 major fire yrs of 1650, 1670, 1690 and 1891 burned over the entire area 2x's and were catastrophic, that would indicate a catastrophic fire rotation of 135 yr. An estimate of the fire rotation for both surface and catastrophic fires would be about 62 yr for mixed red pine/white pine stands. Hardwoods originated in 1880.

Abstract: Charcoal stratigraphic analysis and fire scars on red pine (*Pinus resinosa*) trees were used to determine spatial and temporal occurrence of fire in 1 km² of old-growth mixed conifer/hardwood forests in northwestern Minnesota. Charcoal was analyzed year by year on petrographic thin sections from annually laminated sediments of three small (≤ 5 ha) lakes having adjacent catchments. Dated fire scars ($n=150$) from recent treefalls provided an independent record of the spatial patterns of past burns. Sedimentology of the varved sediments, water-balance models that use 150 yr of instrumental temperature and precipitation data, and published data were used to identify climate changes in separate studies, and they were used in this study to examine the possible connection between changing fire regimes and climate change. Fire-history data were used to show the changing probability of fire with time since the last fire and the effects of spatial variance (slope and aspect) on the distribution of fires through time.

Over the last 750 yr, fire was most frequent (8.6 ± 2.9 -yr intervals) during the warm/dry 15th and 16th centuries. Intervals were longer (13.2 ± 8.0 yr) during cooler/moister times from AD 1240 to 1440 and since 1600 (the Little Ice Age). The fire regime during the Little Ice Age consisted of periods during the mid-18th and mid-19th centuries characterized by longer fire intervals of 24.5 ± 10.4 and 43.6 ± 15.9 yr, respectively, and short-term warm/dry periods from 1770 to 1820 and 1870 to 1920 when intervals were probably in step with fuel accumulation. South- and west-facing slopes burned more frequently than did north and east aspects. Fire suppression began in 1910. During warm periods, probability of fire was sufficiently high that a continuous litter layer was all that was necessary for fire to spread and scar trees. During cool and moist times fire was most likely to occur in years with higher moisture deficits.

The combined methods for fire-history analysis provided a more detailed spatial and temporal documentation of fire regimes than has previously been possible from analysis of fire scars or of charcoal counts derived from fossil pollen preparations. Results support predictions of particle-motion physics that thin sections record a local fire history. Because climate varies continuously, the responsiveness of disturbance regime to short- and long-term climatic change suggests caution in the interpretation of fire frequencies that derive from space/time analogies or extrapolation from short-term data.

Keywords: MN/ Itasca Park/ vt, pine forest/ fire scar/ fire interval/ charcoal

analysis/ paleoecology/ climate change/ pine, red/ pine, white.

131. ---. 1990. **Twentieth-century climate change, fire suppression, and forest production and decomposition in northwestern Minnesota. *Canadian Journal of Forest Research*. 20:219-232.**

Abstract: Long-term fire, climate, and vegetation data were used together with simulation models to estimate the effects of 20th century climate change and fire suppression on fire regime and organic-matter accumulation in mixed-conifer stands of Itasca State Park, northwestern Minnesota. Spatial and temporal patterns of fire occurrence and forest composition over the last 150 years determined by stratigraphic charcoal, fire-scar, tree-ring, and pollen analyses in separate studies provide evidence for vegetation and fire relationships. Water balances constructed from temperature and precipitation data collected since 1840 were used to model fire probability and intensity of burn before fire suppression which began in 1910. Existing patterns of biomass accumulation in forest-floor, herb, shrub, and tree components were compared with fire history and topographic variability to provide a spatial perspective on fire effects. Simulation models used these relationships to estimate (i) how accumulation of organic matter had changed through the past under the different fire regimes that prevailed on different topographic aspects, (ii) the changes brought about by fire suppression in 1910, and (iii) the fire regimes and their effects that would have prevailed since fire suppression with the warm-dry climate of the 20th century. Humus, litter, shrubs, and herb cover were less abundant and more variable spatially and temporally before fire suppression. Spatial variability in forest-floor organic matter, which resulted from different fire frequencies in different vegetation and topographic settings before fire suppression, was largely gone by 1920 as a result of fire suppression. Had fire suppression not been instituted in 1910, fire frequency would have increased by 20-40% in the 20th century because of warmer and drier conditions. Forest-floor organic matter would have been largely depleted by frequent and severe fires exposing mineral soils, particularly during the drought years of the 1930s. Herb biomass would have increased, shrubs would have been more variable, and tree seedling establishment would have been substantially altered. Time required for buildup of fuels limits the extent to which increased moisture deficits increase fire frequency.

Keywords: MN/ Itasca Park/ vt, pine forest/ fire effects/ fire suppression/ climate change/ fire modeling/ pine, white/ pine, red/ shrubs/ herbs .

132. ---. 1991. **Disturbance and population structure on the shifting mosaic landscape. *Ecology*. 72(3):1119-1137.**

Keywords: disturbance ecology/ landscape ecology.

133. ---. 1991. **Disturbance and tree life history on the shifting mosaic landscape. *Ecology*. 72(3):1102-1118.**

Abstract: An analytical model of disturbance and plant population dynamics is developed to explore the optimal life history for a plant within a "shifting mosaic" metapopulation. The population dynamics consist of short-lived recruitment events followed by longer intervals of thinning. Plants balance costs and benefits

of delayed maturation time that result from cohort thinning, a correlation between maturation time and longevity, and the distribution of recruitment events in space and time. Two fundamentally different responses to disturbance are explored: (1) the plant is killed by the disturbance that allows for new recruitment (type A response), and (2) the plant may survive many such disturbances (type B response). Species maximize either the probability of being reproductively mature at the time of the next recruitment opportunity (type A) or the total number of recruitment opportunities to occur during the period of reproductive maturity (type B). Predictions of the theory are compared with the actual life histories of trees that occur in different disturbance regimes.

The costs and benefits associated with delayed maturation from an energy standpoint must be weighed against the probability that a recruitment opportunity (disturbance) will occur at a particular age. Trees subject to low thinning rates should reach reproductive maturity t_1 at $t_1 = 0.4 \times$ (expected disturbance interval in years). At high thinning rates, this optimum is $t_1 = 0.4 /$ (mortality rate per year). Disturbance probabilities that increase with time since the last disturbance select for maturation times that are greater than these values. Species that are not killed by disturbances have optimal maturation times that are independent of disturbance frequency. However, when such species are susceptible as juveniles, optimal maturation time does depend on disturbance frequency. This optimum maturation time is still greater than it is for the case of a mortality response (type A) to disturbance, but less than the case of no susceptibility period (type B). Application of the theory to real-world disturbance regimes results in predictions that closely match the life histories of species that actually occur there. The optimal maturation time for a gap species in temperate North American forests is 30-60 yr, a value that agrees with observed maturation times. A second test involved fire regimes where two species having very different responses to fire and life histories co-occur, *Pinus resinosa* and *P. banksiana*. The maturation times of these species both match the predicted optima for a species that survives fire (*P. resinosa*) vs. one that is killed by fire (*P. banksiana*) subjected to identical fire regimes. Different modes of dispersal are predicted to have important effects of reproductive potential, but little effect on the optimal maturation time. Application of the models to these actual cases is consistent with that prediction. The "intermediate" disturbance frequency is predicted to be that which implies the optimum life history that coincides with the life histories of the greatest number of species.

Keywords: fire effects/ modeling/ life history attributes/ pine, red/ pine, jack.

134. Clark, James S.; Grimm, Eric C.; Donovan, J. J.; Fritz, S. C.; Engstrom, D. R., and Almendinger, J. E. 2002. Drought cycles and landscape responses to past aridity on prairies of the northern Great Plains, USA. *Ecology*. 83(3):595-601.

Abstract: Widespread drought is among the most likely and devastating consequences of future global change. Assessment of drought impacts forecast by atmospheric models requires understanding of natural drought variability, especially under conditions more arid than today.

Keywords: ND/ vt, prairie/ paleoecology/ pollen analysis/ charcoal analysis/

climate change.

135. **Clark, James S.; Grimm, Eric C.; Lynch, Jason, and Mueller, Pietra G. 2001. Effects of Holocene climate change on the C₄ grassland/woodland boundary in the northern plains, U.S.A. *Ecology*. 82(3):620-636.**
Abstract: To determine how grassland, woodland, and bordering forests respond to increased aridity.
Keywords: ND/ MN/ WI/ vt, prairie-forest ecotone/ vt, prairie/ paleoecology/ pollen analysis/ charcoal analysis/ climate change.
136. **Clark, James S. and Royall, D. P. 1996. Local and regional sediment charcoal evidence for fire regimes in presettlement north-eastern North America. *Journal of Ecology*. 84:365-382.**
Keywords: northeastern United States/ fire regime/ presettlement vegetation/ charcoal analysis.
137. **Clark, James S. and Royall, P. D. 1995. Transformation of a northern hardwood forest by aboriginal (Iroquois) fire: charcoal evidence from Crawford Lake, Ontario, Canada. *Holocene*. 5:1-9.**
Keywords: Ontario/ Canada/ vt, northern hardwood forest/ vt, pine forest/ fire, Native American use of/ fire history/ paleoecology/ charcoal analysis/ pollen analysis/ pine, white/ oak.
138. **Clements, F. E. and Chaney, R. W. 1936. Environment and life in the Great Plains. Carnegie Institution of Washington Supplementary Publications, No. 24.**
Note: Yarnell (1964) cites this publication as documenting annual use of fire by the Fox Indians in Wisconsin along the prairie-forest border.
Keywords: WI/ vt, prairie-forest ecotone/ fire, Native American use of/ fire history.
139. **Cogbill, Charles V. 1982. Analysis of vegetation, environment, and dynamics in the boreal forests of the Laurentian Highlands, Quebec. University of Toronto, Toronto. Ph.D. dissertation.**
Keywords: Quebec/ Canada/ vt, boreal forest/ vt, jack pine forest/ vt, aspen forest/ vt, conifer-feathermoss forest/ fire interval/ fire effects/ soil morphology/ pine, jack/ spruce, black/ aspen, trembling/ birch, paper/ feathermoss.
140. **---. 1985. Dynamics of the Boreal Forests of the Laurentian Highlands, Canada. *Canadian Journal of Forest Research*. 15:252-261.**
Abstract: Analyses of species composition and tree increment cores from 145 stands in central Quebec were used to determine the forest history and stand dynamics. Windspread fires, possibly synchronous, burned across central Quebec in at least three periods of record (1661-1663, 1779-1791, 1869-1871). The average fire rotation (time interval between natural fires burning the equivalent of a large area) for spruce-feather moss forests was approximately 130 years, and 70 years in either deciduous or jack pine forests. The traditional succession concept of continual recruitment leading to an all- aged forest was not evident in these

forests. About 70% of the overstory trees were established in the first 30 years after fire disturbance, with little recruitment after this time. These initial trees dominated the canopy for up to 250 years with mortality becoming prominent after 130 years. The short average time between disturbances precludes the probable degeneration into old shrub-filled stands typical of old age.

Keywords: Canada/ Quebec/ vt, boreal forest/ vt, swamp forest/ vt, wetland/ vt, conifer- feathermoss forest/ vt, aspen forest/ vt, birch forest/ vt, balsam fir forest/ vt, fire interval/ fire effects/ growth ring analysis/ age-class structure/ succession/ regeneration, seed/ budworm, spruce/ spruce, black/ spruce, white/ spruce, red/ pine, jack/ balsam fir/ tamarack/ northern white cedar/ aspen, trembling/ birch, paper/ moss.

141. **Cole, Kenneth L.; Klick, Kenneth F., and Pavlovic, Noel B. 1992. Fire temperature monitoring during experimental burns at Indiana Dunes National Lakeshore. *Natural Areas Journal*. 12(4):177-183.**

Abstract: Fire temperature was measured during several prescribed fires in a mosaic of prairies and oak woods within the Indiana Dunes National Lakeshore using temperature sensitive paints on aluminum tags and mica sheets.

Aboveground temperatures were highest in the prairies, often exceeding the melting point of the aluminum tags, and lower in the oak woods. Belowground temperatures, measured by painted mica sheets, were higher in the oak woods than in the prairies. Tree crown mortality was correlated with fire temperature and tree diameter. The results demonstrate high spatial variability in temperature during single burns in this mosaic of plant communities. This variation results from differences in fuel characteristics and the pattern of fire spread. While each community type had its own distinctive temperature profile, temperatures were highly variable among plots within the same community type.

Keywords: IL/ vt, prairie/ vt, oak forest/ vt, fire, prescribed/ fire behavior/ methodology/ oak, black/ oak, white/ maple, red/ cherry, black/ willow/ aspen, trembling/ herbs/ shrubs .

142. **Comer, Patrick J.; Albert, Dennis A.; Wells, H. A.; Hart, B. L.; Raab, J. B.; Price, David Lynn; Kashian, D. M.; Corner, R. A., and Schuen, D. W. 1995. Michigan's native landscape, as interpreted from the General Land Office Surveys 1816-1856. *Michigan Natural Features Inventory, Lansing*. 78 pp. + digital map.**

Note: Cover type boundaries were delineated using surveyors' notes, and topographic maps, then digitized. The landscape was subdivided into ecological subdistricts in order to describe climate, soils, landform, bedrock geology, presettlement vegetation, disturbance regimes, and human land use.

Keywords: MI/ vt, wetland/ vt, swamp forest/ vt, grassland/ vt, oak savanna/ vt, pine barrens/ vt, maple forest/ vt, oak forest/ vt, pine forest/ vt, spruce-fir forest/ vt, hemlock forest/ vt, spruce forest/ GLO/ presettlement vegetation/ GIS/ soil morphology/ fire regime/ geology/ fire, Native American use of/ land-use/ review.

143. **Cook, J. E. 2000. Disturbance history of two natural areas in Wisconsin: implications for management. *Natural Areas Journal*. 20(1):24-35.**

Abstract: Using multiple information sources, disturbance regimes were investigated since the time of overstory establishment in 2 Wisconsin natural areas (New Hope Pines and Haskel-Noyes Memorial Woods), to determine if significant changes had occurred and to assess the relative importance of natural and anthropogenic disturbances. The 2 areas differed in overstory composition, one being white pine (*Pinus strobus*) and oak (*Quercus* spp.) dominated, while the other was largely composed of northern red oak (*Quercus rubra*) and sugar maple (*Acer saccharum*). The current overstories became established over a 60-year period beginning in the mid-1800s, prior to extensive settlement. A series of low- to moderate-intensity disturbances created canopy openings that led to the recruitment of present canopy members. In New Hope Pines, the white pine/oak forest, a combination of logging, low-intensity fire, and natural disturbances resulted in peak establishment between 1891 and 1911, and it is suggested that in the northern red oak/sugar maple forest, all disturbances since 1850 were probably natural but did not include fire. A moderately intense disturbance, possibly wind, initiated the northern red oak cohort that currently dominates the overstory. Accordingly, fire suppression this century had not affected Haskel-Noyes, whereas its exclusion from New Hope Pines reduced pine and oak establishment and allowed red maple (*Acer rubrum*) to increase dramatically. The rate of canopy gap formation accelerated recently, though median gap sizes were relatively small (30 m² at New Hope Pines and 48 m² at Haskel-Noyes). Given the disturbance history of these 2 areas, it is suggested that the current botanical composition and structure will not persist under the current disturbance regimes. It is concluded that white pine and oak dominance at New Hope Pines could be maintained by judicious use of prescribed fire in conjunction with the creation of canopy openings. Size class distributions indicated a strong successional trend toward sugar maple at Haskel-Noyes. It is suggested that a moderately intense disturbance that creates gaps greater than about 0.3 ha would therefore be required to keep northern red oak at its current level of abundance.

Keywords: WI/ vt, pine-oak forest/ vt, maple forest/ fire, prescribed/ windthrow, occurrence of/ logging/ disturbance ecology/ management/ maple, red/ maple, sugar/ oak, red/ pine, white.

144. **Cooper, William S. 1913. The climax forest of Isle Royale, Lake Superior, and its development. Botanical Gazette. 55:1-44, 115-140, 189-235.**

Note: The fir-birch-spruce climax forest and primary succession on Isle Royale, Michigan, is described. In the summary of part I, Cooper states that the forest is a complex of windfall areas of differing ages. In part II, xerarch primary succession (rock and beach) and, in part III, hydrarch succession (bog), is described. Vegetation species are listed. Also, in part II, fire is listed as an important secondary succession. Charcoal was found throughout the Island in the soil layers. Many fires occurred near a mine operated on the Isle years before. Post-fire vegetation dynamics were examined on Smithwick Island where a fire had occurred 15 years prior to the study. A detailed description of post fire succession was given.

Part I.

Bays and Isles provide barriers for wildfire spread, therefore the Island is less influenced by fire than on the mainland. Physiography and climate are described. It is suggested that balsam-birch-spruce is the climax community for the following reasons: "1) extreme mesophytism of the forest; 2) its uniformity of development; 3) all successions lead to it; 4) maintenance of equilibrium.". Smithwick Island is described because the small islands have been least disturbed by fire. But, at least 1 fire occurred on the island as evidenced by charcoal 33 cm below the forest floor. On the island, balsam fir is the most common tree. It is followed by paper birch, white spruce, mountain ash, trembling aspen, black spruce and tamarack. Throughout the quadrats, lots of evidence of windfall was found. Balsam fir seemed to be especially vulnerable to breakage from high winds.

The even-aged structure of the balsam fir forest is attributed to windthrow.

Keywords: MI/ Isle Royale/ island/ vt, spruce-fir forest/ fire barriers/ charcoal/ succession/ windthrow, occurrence of/ weather, effects on vegetation/ old-growth/ balsam fir/ birch, paper/ aspen, trembling/ pine, jack/ spruce, red/ spruce, black/ shrubs/ herbs.

145. **Corson, C. W.; Allison, J. H., and Cheyney, E. G. 1929. Factors controlling forest types on the Cloquet Forest, Minnesota. Ecology. 10(1):112-125.**

Note: Climate, soil characteristics, and disturbance regimes are used to explain presettlement and current vegetation composition of the Cloquet Forest.

Variables include; 1) monthly/annual mean max/min temperature, precipitation, evaporation, and soil moisture data from 1913 to 1915, 2) physical composition of soils down to 24 inches, 3) moisture equivalents by soil class and forest cover type (jack pine, red pine and white pine). A 103 year old red pine, cut in 1922, with fire scars from 1842, 1855, 1864, 1874 and 1894 indicates fires were common in the late 1800's. Logging and associated disturbance reduced red pine and white pine seed trees and seedlings on the forest thereby, causing a change in vegetation cover from predominantly red pine (with scattered jack pine), swamp and white pine to jack pine, swamp, brush, aspen, red pine and remnants of white pine.

Keywords: MN/ vt, pine forest/ vt, swamp forest/ vt, aspen forest/ fire scar/ fire interval/ GLO/ presettlement vegetation/ soil morphology/ site conditions/ aspen, trembling/ pine, red/ pine, jack/ pine, white.

146. **Craig, Alan J. 1972. Pollen influx to laminated sediments: a pollen diagram from northeastern Minnesota. Ecology. 53(1):46-57.**

Note: The author refers to Heinselman (1969) for fire history of the area. There is evidence of fires occurring in 1801, 1827, 1854, 1864, 1875, and 1910, as well as traces of earlier fires. Around the lake, an aspen-birch and a jack pine stand originated after the 1910 wildfire. A second jack pine stand originated after the 1864 fire. White pine is common in stands close to the area that originated prior to the 1864 fire.

Abstract: A pollen diagram is presented from Lake of the Clouds, Lake County, Minnesota, in the Boundary Waters Canoe Area. Of the 5.6 m of sediment

analyzed, almost 5 m are laminated. The 9,349 laminations counted, composed of alternating dark organic and light layers, are annual varves which provide a time scale for study of vegetational history and calculation of pollen influx.

The pollen concentration in each sample was determined by a technique involving the addition of microspheres. The pollen influx was calculated from the pollen concentration and varve count. Pollen concentration was very low in the herb pollen zone of late-glacial time. During postglacial time the pollen influx was generally $2-4 \times 10^4$ grains cm^{-2} year⁻¹.

The pollen diagram has been divided into six zones. Zone 1 records tundra-like vegetation; most of the pollen rain, which was sparse, was probably blown in from a great distance. Zone 2 records spruce forest, with some pine and thermophilous deciduous trees, succeeded in zone 3 and 9,200 years ago by forest dominated by jack or red pine or both. With the start of zone 4, dated about 8,300 years ago, alder migrated into the area, followed about 7,000 years ago by white pine, concurrently with the maximum eastward extension of prairie in the state. In the period represented by zone 5, commencing about 6,500 years ago, white pine was very important, spruce was at a minimum, and climate was probably relatively dry. Environmental changes brought about increases of spruce and cedar and a decline of pine in zone 6, commencing about 3,000 years ago. The diagram is truncated at 200 years or more before the present.

Keywords: MN/ BWCAW/ National Forest, Superior/ vt, pine forest/ vt, aspen-birch forest/ paleoecology/ pollen analysis/ climate change/ birch, paper/ aspen, trembling/ pine, white/ pine, red/ pine, jack/ alder.

147. **Crow, Thomas R. 1988. Reproductive mode and mechanisms for self-replacement of northern red oak (*Quercus rubra*)-A review. *Forest Science*. 34(1):19-40.**

Note: A good review with lots of information about oaks and fire.

Abstract: The requirements for regenerating northern red oak can be hypothesized from an understanding of the species' ecological life-history characteristics along with a knowledge of past and present disturbance patterns. The abundance of oak in the eastern forest is closely related to past land use and extensive disturbances. Frequent fires and heavy cutting favored oak because of its sprouting ability, while fires reduced common competitors. Northern red oak is neither an aggressive colonizer that is characteristic of early successional species nor an enduring, shade tolerant, slow-grower that is typical of late successional species. Its regeneration requires an edge environment; one that is more mesic than exposed, open sites, but less competitive than the deep shade of a forest understory. To regenerate northern red oak, foresters need to create these conditions. Numerous cutting studies, however, have shown that overstory manipulation (partial or complete removal) alone will not regenerate northern red oak. Intense competition can be expected on the mesic sites suitable for northern red oak, and this competition must be controlled when regenerating this species.

Keywords: vt, oak forest/ fire effects/ regeneration, vegetative/ life history attributes/ succession/ review/ oak, red.

148. **Curtis, J. D. 1943. Some observations of wind damage. *Journal of Forestry*. 41:877-882.**
Keywords: windthrow, tree damage.
149. **Curtis, John T. 1959. *The vegetation of Wisconsin*. The University of Wisconsin Press, Madison. 657 pp.**
Note: *The Vegetation of Wisconsin* is the best source of information on Wisconsin plant ecology. The author references fire effects on plant communities many times throughout the book. He gives very little specific information on fire regime, fire frequency, and fire intensity. One reference not found in other publications is of fire effects on Powell Marsh, north of the Lac Du Flambeau Indian Reservation, where fire has maintained the sedge bog where woody vegetation is constantly encroaching. Charcoal fragments are found throughout the organic layer of this bog indicating fires have occurred frequently throughout post-glacial times. The author also cites many publications by European explorers and settlers that witnessed annual fire use by Native Americans in the prairie region. He discusses the prescribed burns that occurred in Crex Meadows (See Vogl).
Keywords: WI/ vt, prairie/ vt, sedge meadow/ vt, swamp forest/ vt, wetland/ vt, pine forest/ vt, maple forest/ vt, balsam fir forest/ vt, spruce-fir forest/ vt, hemlock- hardwood forest/ vt, hemlock forest/ fire history/ charcoal/ soils/ fire, Native American use of/ review/ plant ecology/ pine, red/ pine, white/ pine, jack/ maple, sugar/ hemlock/ shrubs/ herbs.
150. **Cwynar, Les C. 1977. The recent fire history of Barron Township, Algonquin Park. *Canadian Journal of Botany*. 55:1524-1538.**
Note: Presettlement vegetation, similar to current vegetation composition, consisted of mostly white pine, big tooth aspen, trembling aspen, and scattered red pine. There were a few stands of jack pine, and hardwoods, composed of red oak, sugar maple, aspen, yellow and white birch, beech and red maple. Major fires occurred after prolonged summer drought, as opposed to prolonged 2 or 3 year drought.
Abstract: The recent fire history of Barron Township (18 600 ha) in Algonquin Park was studied by examining historical records and dating past forest fires using dendrochronological techniques. Lightning is still a major source. Over the 36-year period of 1939-1974, lightning accounted for 48.5% of all fires at a rate of 0.19 fires per year per 10 000 ha. Dendrochronological data show that 16 fires burned during the 225-year presuppression interval from 1696 to 1920 for a mean frequency of 14.1 years. Five major fires (1875, 1864, 1854, 1780, and 1763) each burned at least half of the township with a mean frequency of 45 years. Meteorological data show that drought prevailed across southern Ontario during 1875, when major fires burned in Barron Township and northern Minnesota, supporting the suggestion that severe fire years correspond with periods of subcontinental drought. Similarly, 1864 appears to have been a major fire year in Barron as it certainly was in Minnesota. The recent fire rotation, i.e., the average time required to burn an areas equivalent to the size of the study area, is about 70 years. Field evidence and increment borings suggest that the present vegetation

mostly originated as a consequence of the fire of 1875.

Keywords: Canada/ Ontario/ vt, aspen forest/ vt, pine forest/ vt, maple forest/ vt, oak forest/ vt, conifer-feathermoss forest/ vt, pine barrens/ fire scar/ fire interval/ fire frequency/ fire weather/ pine, red/ pine, white/ maple, sugar/ maple, red/ birch, paper/ birch, yellow/ oak, red/ aspen, big tooth/ aspen, trembling.

151. ---. 1978. **Recent history of fire and vegetation from laminated sediment of Greenleaf Lake, Algonquin Park, Ontario. Canadian Journal of Botany. 56:10-21.**

Note: White pine dominates watershed in both pure and mixed stands. Red pine is common throughout. Other species growing on specific landforms include big tooth and trembling aspen, red oak, sugar maple and yellow birch, white birch and red maple. The estimated 80 yr fire frequency from 770-1270 A.D. derived from charcoal analysis contrasts with the 45 yr fire frequency estimated by dendrochronological methods described in Cwynar (1977). While 80 yr is conservative, it matches with the estimate derived by Swain (1973) in BWCA. Cwynar concludes that the fire frequency over the past 300 years was probably higher than between 770 and 1270 A.D., but the change was not enough to affect vegetation structure.

Abstract: Laminated sediment (presumed varved) from Greenleaf Lake was examined for evidence of forest fires. A 500-year section dating approximately 770-1270 A.D. was analyzed for influx of pollen, charcoal, aluminum, and vanadium using decadal samples. Intervals showing concurrent peaks in charcoal, aluminum, and vanadium influx, varve thickness, and charcoal:pollen ratio were interpreted as representing major fires within the drainage basin of Greenleaf Lake. By these criteria, six fires occurred within 500 years, or one fire approximately every 80 years. The pollen diagram indicates a stable forest composition for the past 1200 years. This, coupled with natural phenomenon affecting the landscape during this period. There is a significant positive correspondence between peak charcoal influxes and peak influxes of aluminum and vanadium, indicating that increased soil erosion is responsible for their deposition.

Keywords: Canada/ Ontario/ vt, pine forest/ fire interval/ paleoecology/ pollen analysis/ charcoal analysis/ pine, white/ pine, red .

152. **Dansereau, Pierre-Rene and Bergeron, Yves. 1993. Fire history in the southern boreal forest of northwestern Quebec. Canadian Journal of Forest Research. 23:25-32.**

Abstract: Age determination of post-fire forests and the analysis of fire scars on surviving trees have allowed for the historical reconstruction and mapping of fires in a forest area of 11 715 ha in northwestern Quebec, south of Lake Abitibi. Most of the study area was burnt by two large fires (>1000 ha) in 1760 and 1923. All the other fires recorded (1797, 1823, 1870, 1907, 1919) were smaller in extent and occurred in a restricted part (1984 ha) of the study area, characterized by the fragmentation of the forest landscape by water bodies. The compilation of data concerning area burnt per type of surficial material confirms that the physical environment exerts a stronger control on the delimitation of these smaller fires.

The data do not allow for the estimation of the fire cycle owing to the small size of the study area and possible temporal changes during the observation period. However, methodological observations are formulated for future studies covering a larger area in the bioclimatic region.

Keywords: Canada/ Quebec/ vt, boreal forest/ vt, spruce-fir forest/ vt, pine forest/ vt, aspen forest/ fire scar/ fire interval/ fire barriers/ balsam fir/ spruce, black/ spruce, white/ birch, paper/ pine, jack/ aspen, trembling.

153. **Darlington, Henry Townsend. 1930. Vegetation of the Porcupine Mountains, northern Michigan. Michigan Academy of Science, Papers. 13:9-66.**
Note: The vegetation, succession, soils, climate, and geology of the Porcupine Mountains of Upper Michigan is described. While there is mention of recent wildfires, such as the one that occurred in 1919, and evidence of fire and windthrow in vegetation quadrats, there is no estimation of fire or windthrow frequency.
Keywords: MI/ Porcupine Mountains/ vt, hemlock-hardwood forest/ fire history/ windthrow, occurrence of/ soil morphology/ hemlock/ maple, sugar.
154. **Daubenmire, Rexford F. 1936. The "Big Woods" of Minnesota: its structure, and relation to climate, fire, and soils. Ecological Monographs. 6:233-268.**
Note: The influence of climate, fire and soils on the vegetation composition of the Big Woods is described. While the Big Woods is on the edge of the prairie, abundant streams and lakes in the area have provided barriers against the frequent prairie fires. Prairie soils were found in the area indicating that the sugar maple, basswood, elm communities recently invaded the prairie.
Keywords: MN/ vt, prairie-forest ecotone/ vt, Big Woods/ fire barriers/ climate change/ soil morphology/ maple, sugar/ basswood/ elm.
155. **Davis, Anthony M. 1977. The prairie-deciduous forest ecotone in the upper middle west. Anals of the Association of American Geographers. 67(2):204-213.**
Note: A synthesis of existing reports, publications, etc.
Abstract: The prairie-deciduous forest ecotone changes from a distinct boundary in northern Minnesota to a fragmented mosaic type in Wisconsin, Iowa, and Illinois. The differences largely can be attributed to topography and fire, but edaphic factors, the survival of disjunct relicts, and the differential migration rates of some taxa are contributory. Fossil pollen spectra from the Driftless Area attest to the persistence of the mosaic character throughout the Holocene. Modern surface spectra illustrate the difficulties of recognizing vegetation changes along and across the ecotone.
Keywords: MN/ WI/ IA/ IL/ vt, prairie-forest ecotone/ pollen analysis/ paleoecology/ fire barriers/ landform/ weather, effects on vegetation/ fire, review/ review.
156. **Davis, Charles M. 1935. The high plains of Michigan. Michigan Academy of Science, Arts and Letters, Papers. 21:303-341.**
Note: The presettlement vegetation, current vegetation, soils, geology, roads, towns, etc. of northern Michigan is described. The prelogging vegetation map

was adapted from J.O. Veatch. The fires mentioned occurred after logging operations began.

Keywords: MI/ vt, pine forest/ vt, maple forest/ vt, hemlock forest/ vt, hemlock-hardwood forest/ fire, late 19th century logging/ logging/ soil morphology/ GLO/ presettlement vegetation/ land-use/ geology/ review/ pine, jack/ pine, red/ pine, white/ maple, sugar/ hemlock/ birch, yellow/ beech.

157. **Davis, M. A.; Duke, A.; Ibsen, T.; Tran, Hai, and Rhodes, R. 1997. Spatial distribution of *Penstemon grandiflorus* (Nutt.) and *Geomys bursarius* in a fragmented oak woodland in Minnesota, USA. *Natural Areas Journal*. 17(2):136-143.**

Abstract: A method was tested for evaluating the vulnerability of a species to the fragmentation of open area that occurs in oak (*Quercus* spp.) savannas and woodlands in the absence of fire. The method, which is based on detailed analyses of the current spatial distribution of the species, was used to describe and analyze the spatial distribution of an herbaceous perennial, *Penstemon grandiflorus*, and pocket gophers, *Geomys bursarius*, in an oak savanna and woodland in east-central Minnesota (USA) that had not been burned for more than 30 years. In the absence of fire, woody canopy encroached into the open area of the savanna at an average rate of 7 cm/year. This increase in woody canopy resulted in a 50% reduction of open area and transformed the savanna landscape into a woodland containing 62 openings of different sizes. Analysis of the current spatial distributions of *P. grandiflorus* and *G. bursarius* showed that both species were primarily restricted to open areas and that the abundance of both declined rapidly in the woody edges surrounding openings. Occupancy rates for both species were significantly lower in small openings than in large openings. Both species were absent from most openings <100 m², while *G. bursarius* always occupied openings >328 m² and *P. grandiflorus* always occupied openings >670 m². The percent area that was occupied in openings was also positively correlated with opening size for both species. In the case of *G. bursarius*, a decline in opening size of an order of magnitude was associated with a 50% decline in the relative area occupied in openings. In the case of *P. grandiflorus*, an order of magnitude decline in opening size was associated with a decline of relative area occupied of nearly 60%. These results indicate that both species are likely to be vulnerable to further decline and fragmentation of open area in the study site.

Keywords: MN/ vt, oak savanna/ fire suppression/ succession/ mammals/ herbs/ Large beard-tongue.

158. **Davis, Margaret B.; Sugita, Shinya; Calcote, Randolph R., and Frelich, Lee E. 1992. Effects of invasion by *Tsuga canadensis* on a North American forest ecosystem. In, Teller, A.; Mathy, P., and Jeffers, J. N. R. *Responses of forest ecosystems to environmental changes*. Elsevier Applied Science, London and New York. p. 34-44.**

Summary: Temperate forest ecosystems have gained and lost tree species throughout the last 10,000 years as tree species ranges expanded and contracted in response to changing climate. The ecosystem-level effects of these events are illustrated by the invasion of forested landscape in northern Michigan, USA 3000

yr B.P. by hemlock (*Tsuga canadensis*). Fossil pollen from small forest hollows, recording trees within 50 m, provides histories for individual hemlock-dominated, hardwood-dominated and mixed stands which now form a mosaic over the landscape.

At the time of hemlock entry the regional climate was gradually becoming more moist. Climatic changes were apparently amplified by the effect of hemlock on microclimate and fuel type, reducing the frequency of fire. Fire-sensitive species increased throughout the forest, changing the species composition of hardwood stands as well as hemlock stands. At present sugar maple (*Acer saccharum*) stands are not easily invaded by hemlock, but tend to persist for thousands of years, with minor shifts in the positions of the boundaries.

Hemlock invasion slowed rates of nutrient cycling, changed microclimate, and affected deer habitat, as well as reducing fire frequency. Hemlock invasion increased diversity by producing the landscape mosaic of hemlock- and hardwood-dominated forests.

Keywords: MI/ Sylvania Recreation Area/ vt, hemlock-hardwood forest/ vt, maple forest/ fire regime/ fire history/ climate change/ species migration/ paleoecology/ pollen analysis/ charcoal analysis/ hemlock/ maple, sugar .

159. ---. 1994. **Historical development of alternate communities in a hemlock-hardwood forest in northern Michigan, USA.** In, Edwards, P. J.; May, R. M., and Webb, N. R. *Large-Scale Ecology and Conservation Biology*. Blackwell Scientific Publications, Oxford, England. p.19-39.

Note: The authors investigate invasion and establishment differences between hemlock and sugar maple forest types from about 3200 BP to present through pollen data in Sylvania Recreation Area. Both types have a positive feedback mechanism that perpetuates their existence. Hemlock established on disturbed sites which then, under went a long disturbance free period, aided by hemlock characteristics. Sugar maple, on the other hand, invaded areas that had not been recently disturbed and had inherently long disturbance free periods associated with it. Remnant species within pollen record and soils are evidence of the mechanisms.

Summary: Hemlock-hardwood forests of Sylvania, Michigan, USA, are composed of 1-20 ha patches dominated by either hemlock (*Tsuga canadensis*) or by sugar maple and basswood (*Acer saccharum* and *Tilia americana*). The mosaic pattern began about 3200 years ago when hemlock extended its geographical range into the region. Local stand histories reconstructed from fossil pollen preserved in small hollows 5-25 m in diameter show that hemlock invasion preceding white pine-red maple-oak (*Pinus strobus*-*Acer rubrum*-*Quercus rubra*) forest was patchy. Where hemlock invaded, hemlock-dominated stands were established which persisted ever since. In the intervening patches sugar maple and basswood became dominant. The two stand types have both differentiated from a very different kind of forest- a forest type that no longer exists at Sylvania.

Hemlock patches and hardwood patches each have distinctive soil humus, nutrient

availability, microclimate and ground flora. Local dominance by either hemlock or sugar maple creates a local environment in which recruitment by competing species is reduced, a positive feedback encourages the persistence of patches. We do not observe invasion of the alternate stand type today, although hemlock invasion of the pine-oak-red maple forest apparently occurred rapidly 3200 years ago as climate and fire regime changed to favor the invading species and to increase the competitive advantage of resident sugar maple, basswood and yellow birch relative to pine, oak and red maple. Thus the mosaic is quite different from forest mosaics described in the literature that depend upon patchy disturbances or patchy distributions of physical features of the environment.

The mosaic is seen only in remnants of the original old-growth forest, because logging has converted both stand types to hardwoods. Restoration of the mosaic pattern could prove difficult, because the climatic and biotic environments that permitted hemlock stands to become established are no longer present.

Keywords: MI/ Sylvania Recreation Area/ vt, hemlock forest/ vt, maple forest/ fire interval/ climate change/ disturbance ecology/ species migration/ paleoecology/ charcoal analysis/ pollen analysis/ hemlock/ pine, white/ maple, red/ maple, sugar/ oak, red/ basswood/ birch, yellow.

160. **Day, Gordon M. 1953. The Indian as an ecological factor in the northeastern forest. Ecology. 34:329-346.**

Note: Observations by early explorers and historians of utilization of the forest by Indians in New England, New York and New Jersey are summarized. Influences on the forest include village clearing, fuelwood cutting, agricultural clearing, using fire, hunting controls (i.e. lower deer populations), favoring foods and medicinal plants. Summarized by Stewart (1951), fire was used for driving game, improving visibility, making travel easier, driving away reptiles and insects, increasing the supply of grass seeds and berries, and for offense and defense in war. This is a frequently cited publication.

Keywords: NY/ NJ/ MA/ VT/ eastern United States/ fire, Native American use of/ review.

161. **Day, R. J. and Carter, J. V. 1990. Stand structure and successional development of the white and red pine communities in the Temagami Forest. The Ontario Ministry of Natural Resources, Northeastern Region, Sudbury.**

Abstract: The objectives of the research conducted at Temagami in 1989 were to: 1) define the principal forest communities at Temagami by making an aerial survey of a typical 9-township study area; this was completed by photo-interpreting the species composition and stand structure of approximately 330 5-hectare plots (2% sample), 2) evaluate the fire and logging history of the Temagami forest to determine the effect of these ecological 'pressures' on the forest, 3) randomly select ten 5-hectare Case History Areas for study and measure 30 1/5 ha field plots in the White (*Pinus strobus* L.) and Red Pine (*P. resinosa* Ait.) Communities and to describe their stand structure and successional status, and 4) propose ecologically sound, economically feasible and practical silvicultural methods for the reproduction and development of white and red pine

forest at Temagami. Owing to financial and time constraints, it was only possible to complete objectives 1 and 3.

The results of the aerial survey showed that the Temagami forest is composed of six communities, as follows: 1] Black Spruce (*Picea mariana* (Mill.) B.S.P.), 23.2%; 2] White Birch (*Betula papyrifera* Marsh) 22.5%; 3] Jack Pine (*Pinus banksiana* Lamb.), 14.0%; 4] Poplar (*Populus tremuloides* L. and *Populus grandidentata* Michx.), 11.1%; 5] White Pine, 4.8%; and 6] Red Pine, 4.8%.

This paper presents the results of the research completed under objective 3 in 1989. In the 9-township study area, eleven of the 330 5-hectare photo-interpretive survey plots were randomly selected for field sampling on the ground in the White and Red Pine Communities. Each of the eleven 5-hectare photo-interpretive survey plots were then designated as 'Case History' areas for ground sampling. In most case history studies, 3 1/5 hectare sample plots were randomly located within the boundaries of the eleven 5-hectare photo-interpretive survey plots so that the DBH-height- and age-class structure of each Case History area could be assessed in detail. In addition, the authors were given special permission to cut a total of 20 sample white and red pine trees in all the Case History areas for growth layer analysis. Where feasible, from 2 to 3 dominant or emergent pines were selected and their Mean Annual Sheath Volume Increment in dm² and Specific Volume Increment in cm was calculated.

The results of the eleven Case History studies showed that the White and Red Pine Communities at Temagami were mainly composed of natural stands with even-aged or broadly even-aged overstories composed of a minimum number of aging white and red pine emergents, dominants and intermediates (average 175/ha) that overtopped broadly even-aged to uneven-aged understories that were mainly composed of more than 100 times the number of red maple and tolerant hardwoods and balsam fir (average 20200/ha).

A careful study of the emergent and dominant white and red pine trees in these stands showed that there were from 8 to 18 white pine and from 2 to 17 red pine emergents/ha. In addition there were from 12 to 42 white pine and from 13 to 116 red pine dominants/ha. Thus the stands that now compose the White and Red pine Communities at Temagami are very poorly stocked to pine and are in the process of being replaced by recruitment of tolerant species, particularly red maple and tolerant hardwoods and balsam fir, which form thick understories and reach up into the suppressed and intermediate layers beneath the aging pine overstory. In addition, careful study of the Current Annual Stemwood Increment and particularly Specific Volume Increment of the emergent and dominant trees selected for growth layer analysis showed that many of the emergent and dominant pines had annual growth rings that were declining towards thicknesses of only 0.1 to 0.05 mm. As a consequence of inability to form an adequate annual ring, many of the large emergent and dominant trees were found to be suffering from bark necrosis and bark beetle attack in spite of maintaining or even

increasing Current Annual Stemwood Increment.

There was strong evidence in all eleven case histories that the aging pine in the even-aged and broadly even-aged overstories of the various stands studied had reproduced after one or several of 10 wildfires that occurred in the Temagami forest between 1729 and 1864/65. These fires appear to have scorched and opened the overstory, burned out the balsam fir, red maple and tolerant hardwood understory and prepared seedbeds for both white and red pine. The lack of hot wildfires in the White and Red Pine Communities since 1912 is probably related to the introduction of very effective fire suppression and protection programs. Fire suppression and protection since 1912 has extended the fire rotation for white and red pine from 125 years to over 1200 years and 13500 years respectively and has begun to eliminate both species from the Temagami forest.

There is now an urgent need to practice silviculture in the White and Red Pine Communities at Temagami that is in harmony with the ecology of the pines. The Shelterwood and Clearcutting Systems are recommended for white pine and the Clearcutting System and the Shelterwood Systems for red pine. Prescribed burning is advocated where it is feasible. The Single Tree and Group Selection Systems are not considered ecologically acceptable for the reproduction of either white or red pine in the Temagami forest.

Keywords: Canada/ Ontario/ vt, pine forest/ vt, birch forest/ vt, conifer-feathermoss forest/ vt, aspen forest/ fire interval/ fire suppression/ logging, clearcut/ logging, shelterwood/ logging, selection/ insects/ disease/ pine, white/ pine, red/ pine, jack/ spruce, black/ balsam fir/ birch, paper/ aspen, trembling/ aspen, big tooth.

162. **Day, W. R. 1950. The soil conditions which determine windthrow in forests. Forestry. 23:90-95.**
Keywords: windthrow, effects on soil/ soil morphology.
163. **De Grandpre, L. Bergeron Yves. 1997. Diversity and understory community stability following disturbance in the southern boreal forest. Journal of Ecology. 23:777-784 .**
Keywords: Canada/ Quebec/ fire effects/ succession/ herbs/ shrubs.
164. **Debano, L. F. and Krammes, J. S. 1966. Water repellent soils and their relation to wildfire temperatures. Bull. Int. Assoc. Sci. Hydrol. 11:14-19.**
Keywords: soils, hydrophobic/ wildfire/ fire effects.
165. **Denevan, William M. 1992. The pristine myth: the landscape of the Americas in 1492. Annals of the Association of American Geographers. 82(3):369-385.**
Note: The author references many of the latest findings and opinions of experts of the subjects of Native American influence. Very good first reference on the state of the Americas from 1492 on.
Abstract: The myth persists that in 1492 the Americas were a sparsely populated wilderness, "a world of barely perceptible human disturbance." There is

substantial evidence, however, that the Native American landscape of the early sixteenth century was a humanized landscape almost everywhere. Populations were large. Forest composition had been modified, grasslands had been created, wildlife disrupted, and erosion was severe in places. Earthworks, roads, fields, and settlements were ubiquitous. With Indian depopulation in the wake of Old World disease, the environment recovered in many areas. A good argument can be made that the human presence was less visible in 1750 than it was in 1492.
Keywords: fire, Native American use of/ review.

166. **Dey, D. C. and Guyette, R. P. 2000. Anthropogenic fire history and red oak forests in south-central Ontario. *Forestry Chronicles*. 76:339-347.**
Keywords: Ontario/ Canada/ vt, oak forest/ fire, prescribed/ fire interval/ oak, red/ maple, sugar/ pine, red/ pine, white.
167. **Dieterich, John H. 1963. Fire and sand. *Wisconsin Conservation Bulletin*. 28(4):18-19.**
Note: A publication informing the public of the conditions required for a forest fire to start and the influence of soils on those conditions. A county map of Wisconsin is included showing sandy soils and where the most fires occur.
Keywords: WI/ fire and soils/ soil morphology/ fire, review.
168. **Dieterich, John H. and Brown, James K. 1964. Comparing severity of fire seasons. *US Forest Service, Research Note LS-47*. 4 pp.**
Note: Buildup indices from Cass Lake, Little Fork, Waskish, Ely, Baudette, and Cut-Foot Sioux Ranger Station weather stations in northern Minnesota are compared for 1936 and 1961. It was found that the fire weather of 1961 was more severe than 1936. Precipitation and temperature are used to develop index.
Keywords: MN/ fire weather.
169. **Dix, R. L. and Swan, J. M. 1971. The roles of disturbance and succession in upland forest at Candle Lake, Saskatchewan. *Canadian Journal of Botany*. 49:657-676.**
Abstract: Eighty-nine upland forest stands were selected to cover the ranges of tree species composition, stand ages, understory composition, and site in the areas. The role of each tree species as a pioneer, transient, or self-maintaining component of the forest was determined from the number of stems, their vigor, and distribution in tree, sapling, and seedling strata among all stands and from growth increment cores of trees and saplings in 39 stands. Conclusions are drawn regarding the species likely to dominate different sites following severe fire and the kinds of vegetational change likely to occur on them between disturbances. Changing patterns in the non-arboreal vascular flora, moss, and lichen cover were related to changes in tree species composition with site and time. The forest and its environment are linked in an irregular "pulse" strategy of alternating disturbance and regrowth that repeatedly rejuvenates the growing stock.
Keywords: Canada/ Saskatchewan/ vt, boreal forest/ fire effects/ succession/ age-class structure/ soil morphology.

170. **Dorney, Cheryl H. and Dorney, John R. 1989. An unusual oak savanna in northeastern Wisconsin: the effect of Indian-caused fire. American Midland Naturalist. 122(1):103-113.**
Note: Shawano and Brown Counties.
Abstract: Evaluation of the impact of native Americans on vegetation has largely relied on historical accounts of fire use. Remnant vegetation communities may also provide evidence. A large (49 km²), disjunct oak savanna in northeastern Wisconsin was recorded by the original public land survey in 1834. Surrounding vegetation was mixed conifer-hardwood forest typical of northern Wisconsin. The oak savanna was not associated with unusual soil, topographic or climatic conditions of the area but instead was associated with Potawatomi and Winnebago Indian agricultural villages. A remnant woodlot (89 ha) is still dominated by *Quercus alba* but the canopy has closed and the stand has apparently been invaded by *Carya ovata*. This pre-European settlement oak savanna is strong evidence that native Americans influenced vegetation through fire in this region.
Keywords: WI/ vt, oak savanna/ fire, Native American use of/ GLO/ presettlement vegetation/ oak, white.
171. **Dorney, John R. 1981. The impact of Native Americans on presettlement vegetation in southeastern Wisconsin. Wisconsin Academy of Sciences, Arts and Letters. 69:26-36.**
Abstract: Indians occupied southeastern Wisconsin long before European settlement, utilizing and influencing native vegetation. The magnitude of this influence was studied using the General Land Office surveyor's notes and historical, ecological and archaeological literature. About 15,000 Potawatomi and Winnebago Indians lived in SE Wisconsin immediately before European settlement. Their summer villages and associated winter camps occupied about 1500 acres of cleared land (0.06% of region). There is little evidence in the surveyor's notes of direct impact on vegetation but other references note Indian fires and dispersal of favored plant species. Other evidence indicates that lightning fires occurred in the region. Apparently, native Americans in presettlement southeastern Wisconsin had little direct impact on the landscape but their indirect influence through fire was probably appreciable.
Keywords: WI/ vt, oak savanna/ fire, Native American use of/ GLO/ presettlement vegetation.
172. **Dunn, Christopher P.; Guntenspergen, Glenn R., and Dorney, John R. 1983. Catastrophic wind disturbance in and old-growth hemlock-hardwood forest, Wisconsin. Canadian Journal of Botany. 61:211-217.**
Abstract: On 4 July 1977, the Flambeau River Hemlock-hardwood Scientific Area (Sawyer County, WI) was leveled by a downburst of hurricane-force winds. This paper documents preblowdown and postblowdown composition in a 61-ha portion of a state Scientific Area. Total stand basal area after the blowdown was reduced to 6% of prestorm levels. Total seedling density increased greatly following the blowdown, especially that of *Betula alleghaniensis* Britt. *Acer saccharum* Marsh. continued to dominate the relatively unaffected sapling layer.

A dense shrub layer of *Sambucus pogens* Michx. developed. Such massive blowdowns do not appear uncommon in northern Wisconsin. Implications for forest regeneration and structure are discussed.

Keywords: WI/ vt, hemlock-hardwood forest/ windthrow, effects on vegetation/ downburst/ birch, yellow/ maple, sugar/ shrubs.

173. **Dyer, James M. and Baird, Philip R. 1997. Wind disturbance in remnant forest stands along the prairie-forest ecotone, Minnesota, USA. Plant Ecology. 129(2):121-134.**

Abstract: Strong winds are an important disturbance agent in northern Minnesota forests. On June 19, 1994, strong winds ($>160 \text{ km h}^{-1}$) associated with a tornado damaged forested areas within the Rydell National Wildlife Refuge, situated in Polk County Minnesota along the prairie-forest boundary. Field sampling was conducted immediately following the storm to quantify the type and extent of damage in four different community types, and to project future composition based on the nature of the storm damage and current understory characteristics, including the impact of overbrowsing by deer. Basal area in six sampled remnant forest stands was reduced by 33.5%, although the damage was heterogeneous; basal area in one stand was reduced by 68.1%. The overall effect of the storm was the removal of early-successional species (primarily *Populus tremuloides*) in larger size classes. Trees situated at stand edges were not more susceptible to snapping or uprooting than interior trees. Projections of future stand composition indicate that wind disturbance, unlike other agents of disturbance such as fire, may accelerate succession on the Refuge, such that early-successional stands will assume a later-successional character, while *Acer-Tilia* stands should maintain their late-successional character. Overbrowsing and preferential foraging by deer may significantly alter stand recovery patterns.

Keywords: MN/ vt, prairie-forest ecotone/ windthrow, effects on vegetation/ windthrow, tree damage/ tornado/ deer browsing/ canopy gap/ aspen, trembling/ basswood/ maple, sugar/ hop hornbeam/ elm/ oak, red/ boxelder/ aspen, big tooth/ balsam poplar/ ash, green/ cherry, choke/ oak, bur.

174. **Dyrness, C. T. and Norum, Rodney A. 1983. The effects of experimental fires on black spruce forest floors in interior Alaska. Canadian Journal of Forest Research. 13:879-893.**

Abstract: Seven units (about 2 ha each) of black spruce-feather moss forest were experimentally burned over a range of fuel moisture conditions during the summer of 1978. Surface woody fuels were sparse and the principal carrier fuel was the forest floor (largely mosses and their decomposition products). Forest floors after burning comprised a small-scale mosaic of unburned, scorched, lightly burned, and heavily burned (organic materials entirely consumed) conditions. Percentage of the unit area in the moderately and heavily burned condition ranged from 11.2 to 77.2% and percent decrease in forest-floor thickness varied from 27.4 to 63.1% in the seven units. Forest-floor consumption was most closely correlated with the moisture content of lower moss (01 horizon) and lower duff layers (022 horizon) at the time of burning. For the first 3 years after fire, burned sites were completely dominated by the invading species *Epilobium angustifolium*

L., *Ceratodon purpureus* (Hedw.) Brid., and *Marchantia polymorpha* L., whereas lightly burned plots were occupied by sprouting species such as *Calamagrostis canadensis* (Michx.) Beauv., *Vaccinium uliginosum* L., and *Ledum groenlandicum* Oeder. Soil pH and amounts of total P and available P in the forest floor increased significantly as a result of burning; and in all cases, increases reached a maximum in moderately and heavily burned areas. Total N and total P showed smaller increases in the surface mineral soil as a result of burning. Supplies of available P in the mineral soil increased almost 4-fold in moderately burned and over 16-fold in heavily burned areas.

Keywords: AK/ vt, conifer-feathermoss forest/ fire, prescribed/ fire effects/ litter and duff, nutrient analysis/ spruce, black/ bilberry, bog/ moss/ fireweed/ liverwort/ shrubs/ herbs.

175. **Eggler, Willis A. 1938. The maple-basswood forest type in Washburn County, Wisconsin. Ecology. 19(2):243-263.**

Note: This study of 3 sites in Washburn County was initiated to add to the descriptions of the maple-basswood forest type of the Great Lakes region. Species composition and soils were compared with that of the "Big Woods" of Minnesota. The 3 dominant overstory trees are sugar maple, basswood and red oak. Species composition of the first stand are as follows: Sugar maple has the most stems in the less than 1" size class and red oak has the highest density in the 10+" size class. Age class distribution indicates a few old sugar maple that were part of the previous (prefire probably) stand that were seedlings in the early to mid-1700s. There were a large number of red oak and basswood, and a few white pine, that grew into the stand beginning in the early 1800's and continued to sprout and seed into the stand until the late 1800's. Sugar maple was becoming increasingly important again. In the second stand, sugar maple density is consistent through the stand with the greatest number of trees less than 1" in dbh. Both basswood and red oak were lower densities, but still very common. They don't seem to be in danger of dying out of the stand. In the third stand, sugar maple is the dominant species but with very little reproduction in the smaller size classes. Basswood and American hop hornbeam are second and third in density. There was no evidence of past disturbance in either of the last 2 stands. Shrubs and herbaceous vegetation were also listed.

Keywords: WI/ vt, maple forest/ fire, general reference to stand structure/ soil morphology/ maple, sugar/ basswood/ oak, red/ hop hornbeam/ shrubs/ herbs.

176. **Eichenlaub, V. L. 1979. Weather and climate of the Great Lakes region. Notre Dame University Press, Notre Dame.**

Keywords: MN/ WI/ MI/ weather.

177. **Engelmark, O.; Bradshaw, R., and Bergeron, Yves. 1993. Disturbance dynamics in boreal forest. Opulus Press, Uppsala, Sweden.**

Keywords: vt, boreal forest/ disturbance ecology.

178. **Ennos, A. R. 1997. Wind as an ecological factor. Tree. 12(3):108-111.**

Abstract: Wind has long been regarded as an important ecological factor in

forests owing to the dramatic damage hurricanes can wreak. However, the long-term wind regime of a site also exerts a strong influence on the growth of trees. A relatively large amount is known about the acclimation of trees to wind but less about intra- or interspecific adaptation to high winds. In fact, changes resulting from the effect of wind may have a greater effect on the ecology of forests than the more acute effects of destructive storms. Improved understanding of the mechanical effects of wind is helping foresters manage their plantations and may help us to account better for local and geographical variations in forest ecology.
Keywords: plant ecology/ windthrow, effects on vegetation/ windthrow, review.

179. **Everham III, Edwin M. and Brokaw, Nicholas V. L. 1996. Forest damage and recovery from catastrophic wind. *The Botanical Review*. 62(2):113-185.**

Note: A good review of the literature.

Abstract: The literature on the effects of catastrophic wind disturbance (windstorms, gales, cyclones, hurricanes, tornadoes) on forest vegetation is reviewed to examine factors controlling the severity of damage and the dynamics of recovery.

Wind damage has been quantified in a variety of ways that lead to differing conclusions regarding severity of disturbance. Measuring damage as structural loss (percent stems damaged) and as compositional loss (percent stems dead) is suggested as a standard for quantifying severity. Catastrophic wind produces a range of gaps from the size caused by individual treefalls to much larger areas. The spatial pattern of damage is influenced by both biotic and abiotic factors. Biotic factors that influence severity of damage include stem size, species, stand conditions (canopy structure, density), and the presence of pathogens. Abiotic factors that influence severity of damage include the intensity of the wind, previous disturbance, topography, and soil characteristics.

Recovery from catastrophic wind disturbance follows one of four paths: regrowth, recruitment, release, or repression. The path of recovery for a given site is controlled both by the severity of disturbance and by environmental gradients of resources. Recovery is influenced also by frequency of wind disturbance, which varies across geographical regions.

To develop robust theories regarding catastrophic wind disturbance, the relative roles of different abiotic factors in controlling the patterns of severity and environmental gradients must then be considered relative to the long-term dynamics of recovery.

Keywords: WI/ MN/ MI/ other countries/ windthrow, tree damage/ windthrow, effects on vegetation/ windthrow, review.

180. **Ewing, J. 1924. Plant successions of the brush prairie in northwestern Minnesota. *Journal of Ecology*. 12:238-266.**

Note: Plant associations, and the associated soils and watertable characteristics, from prairie to deciduous forest on the White Earth Indian Reservation of Minnesota are described. A reference to fire and how it affects the vegetation is

made in almost every plant association description. While fire frequency is not specifically stated, ages of plants since last fire and char observations are made for each of the quadrats sampled. By using this data, one gets a general idea of fire frequency for each plant association.

Keywords: MN/ vt, prairie/ vt, prairie-oak scrub/ fire frequency/ aspen, trembling/ oak.

181. **Faber-Langendoen, Don and Tester, John R. 1993. Oak mortality in sand savannas following drought in east-central Minnesota. Bulletin of the Torrey Botanical Club. 120(3):248-256.**

Abstract: Savanna plots that were established and sampled in 1984 at Cedar Creek Natural History Area in east-central Minnesota were resampled in 1989, towards the end of a major drought period. Tree diameter was measured and mortality was assessed for all stems ≥ 10 cm dbh in eleven 50 x 75 m plots. *Quercus ellipsoidalis* E.J. Hill (northern pin oak) and *Q. macrocarpa* Michx. (bur oak) dominate the savannas, accounting for $> 95\%$ of all stems ≥ 10 cm dbh. In 1984, diameter distributions and species composition were significantly different on different soil types. Zimmerman soils had a larger proportion of stems in the 10-25 cm dbh size classes (62%) than did Sartell soils (36-60%), and a significantly larger proportion overall of *Q. ellipsoidalis* stems (93%) than did Sartells (51-84%). Plots burned during the previous 20 years had fewer stems in the 10-25 cm dbh size class (45%) compared to unburned plots (58%). These differences were not changed by mortality over the 1984-1989 period, nor did diameter distributions within a plot change significantly over this period. Average five-year mortality rates per plot from 1984-1989 for *Q. ellipsoidalis* (21.4%, range 0.0-60.0%) were significantly higher than *Q. macrocarpa* (6.1%, range 0.0-33.3%). Five-year mortality rates of *Q. ellipsoidalis* declined from 60% to 15% with higher total stem basal area and density. Drought or large moisture changes may have been primary factors responsible for oak mortality. Other factors, such as percent organic matter, depth to water table, and fire frequency were not correlated with mortality rates. The inverse relation between mortality and stand density suggests that the possible effects of drought varied with stand structure. Closed savannas or woodlands had lower mortality rates than open savannas. These findings emphasize the role of climate in maintaining sand savannas in the prairie-forest border region.

Keywords: MN/ Cedar Creek Natural History Area/ vt, oak savanna/ oak, bur/ oak, pin/ weather, effects on vegetation/ soil morphology.

182. **Fassett, Norman C. 1944. Vegetation of the Brule Basin, past and present. Brule River Survey: Paper No. 4. Wisconsin Academy of Sciences, Arts and Letters. 36:33-56.**

Note: The presettlement vegetation and current vegetation of the Brule watershed is mapped, and general differences in relation to soils and topography, and fire regime are described. Although the fire regime is not quantified, comments are made on differences in fire regimes noted by the surveyors. For instance, fire was noted in the wet bog area of the upper Brule and in the jack pine barrens, recently burned over and blowdown areas. It was noted that the sandy rolling hills provide

very few natural barriers to fire spread. Shrubby oaks and a few red pine were also noted in this area. In the valley of Nebagamon, tree species observed were oak, sugar maple, hazel and aspen indicating a very different fire regime. The mix of low and high disturbance species is possible because this loamy area is dissected with many bogs and lakes. Lastly, clay soils of the lower Brule basin were heavily wooded with white pine, balsam fir and aspen. These species indicate a lower fire frequency because of the higher water holding capacity of the clay soils compared to the sand or loam soils.

Keywords: WI/ vt, wetland/ vt, pine barrens/ vt, pine forest/ vt, maple forest/ vt, balsam fir forest/ vt, oak savanna/ fire and soils/ soil morphology/ landform/ GLO/ presettlement vegetation/ pine, jack/ pine, red/ pine, white/ aspen/ balsam fir/ maple, sugar.

183. **Ferris, James E. 1980. The fire and logging history of Voyageurs National Park: an ecological study. Michigan Technical University, Houghton. Masters thesis.**
Abstract: To document original vegetation, historic fire patterns, modern fire patterns, logging activities, their impact on the vegetation and successional patterns developing in Voyageur's National Park, a two-year study was conducted (1978-1980). Present vegetation, fire evidence, logging evidence, and relevant historic records were investigated during the course of this study. A type map of the original vegetation was prepared from the original survey notes taken in 1881-1894. Comparison of this map with the current type map shows significant type shifts from predominantly pine and spruce-fir forests to predominantly aspen forests today. The presettlement fire regime was the primary factor maintaining the pine types while logging has been the primary factor effecting the establishment of the aspen types.

Five general site types were identified using Bray-Curtis ordination and synecological coordinates. These site types ranged from dry jack pine sites to wet swamp conifer sites. These different types have had differing fire and logging histories and the successional dynamics reflect these differences. In the absence of fire or other major disturbances most stands will climax in spruce-fir types.

Keywords: MN/ Voyageur's National Park/ vt, pine barrens/ vt, swamp forest/ vt, spruce-fir forest/ fire history/ logging/ disturbance ecology/ GLO/ presettlement vegetation/ pine, jack/ aspen/ balsam fir/ spruce.

184. **Finney, Mark A. 1994. Modeling the spread and behavior of prescribed natural fires. In, Proceedings of 12th Conference of Fire and Forest Meteorology, Jekyll Island, GA. Society of American Foresters. p. 138-143.**

Keywords: fire modeling/ **wildfire**.

185. **--. 1998. FARSITE: Fire area simulator - model development and evaluation. US Forest Service Research Paper, RM-4. 47 pp.**

Abstract: The structure of a fire growth simulation model, FARSITE, and its performance under simplified test conditions are reported. FARSITE incorporates existing models of surface fire, crown fire, point-source fire acceleration, spotting, and fuel moisture. It is suggested that this documentation of how the simulation

was constructed, and how the individual fire behavior models perform, will be useful to researchers and managers who use FARSITE or are interested in fire growth simulation. The models were integrated using a vector propagation technique for fire perimeter expansion that controls for both space and time resolution of fire growth over the landscape. The model produces vector fire perimeters (polygons) at specified time intervals. The vertices of these polygons contain information on the fire's spread rate and intensity, which are interpolated to produce raster maps of fire behavior. Because fire behavior at each vertex is assumed independent of the others, the simulation outputs illustrate the strict spatial consequences to fire behavior of incorporating the models into a two-dimensional simulation. Simplified test conditions show that surface fire growth and intensity conform to idealized patterns. Similarities also exist between simulated crown fires and observed patterns of extreme wind-driven fires. Complex patterns of fire growth and behavior result from the spatial and temporal dependencies in the model. The limitations and assumptions of this approach are discussed.

Keywords: wildfire/ fire modeling.

186. ---. 1999. **Mechanistic modeling of landscape fire patterns.** *In: Mladenoff, David J. and Baker, William L. *Spatial modeling of forest landscape change: approaches and applications.* Cambridge University Press, Cambridge, UK.
Keywords: fire modeling/ wildfire/ landscape ecology.*
187. **Fire and Aviation Staff. 1996. Land Management Considerations in Fire-Adapted Ecosystems: Conceptual Guidelines.** US Forest Service, Washington, D.C., FS-590.
Note: This publication is to be used as a guide for managers to integrate fire management considerations into the assessment phase of the land management planning cycle. The guide discusses the shift in fire regime from the 1800s to current times.
Keywords: fire behavior/ fire effects/ management.
188. **Fire and Aviation Staff. 1997. Integration of Wildland Fire Management into Land Management Planning: A desk guide.** US Forest Service, Washington, D.C.
Note: A guide to be used for integrating fire management considerations into forest plans. Chapters include: land management planning process, plan-to-project analysis and fire management plan.
Keywords: management/ fire, prescribed.
189. **Flannigan, M. D.; Bergeron, Yves; Engelmark, O., and Wotton, M. 1998. Future wildfire in circumboreal forests in relation to global warming.** *Journal of Vegetation Science.* 9:469-476.
Keywords: vt, boreal forest/ climate change/ wildfire/ fire modeling.
190. **Flannigan, M. D. and Harrington, J. B. 1988. A study of the relation of meteorology variables to monthly provincial area burned by wildfire in Canada.** *Journal of Applied Meteorology.* 27:441-452.

Keywords: Canada/ wildfire/ fire weather.

191. **Flannigan, M. D. and Van Wagner, C. E. 1991. Climate change and wildfire in Canada. Canadian Journal of Forest Research. 21:66-72.**

Keywords: Canada/ wildfire/ climate change.

192. **Foot, Lyman. 1836. Remarks on Indian Summers. Amer. Jour. Sci. Arts. 30:8-13.**

Note: Cited by Curtis (1959), Indian set prairie fires.

Keywords: vt prairie/ fire, Native American use of.

193. **Foster, David C. 1976. Lower LaSalle Lake, Minnesota: sedimentation and recent fire and vegetation history. University of Minnesota, St. Paul. Masters thesis. 103 pp.**

Note: Important finding: short interval sampling (2 yr interval) is necessary to record a meaningful fire history.

Abstract: Lower LaSalle Lake is a deep (65 m) lake in northwestern Minnesota containing laminated calcareous sediments in the profundal region. During spring and summer, only the epilimnion is super-saturated with respect to calcium carbonate; at all other times the entire water column is under-saturated. The data suggest that calcium carbonate is biogenically precipitated in the epilimnion and then partially redissolved in the hypolimnion.

No chemocline was found; however, since lack of oxygenation to the bottom during overturn has been observed, the lake is predisposed towards meromixis. The morphometry of the lake basin and the surroundings (steep narrow basin, steep hills all around) tends to protect the depths from turbulence and thus oxygenation, and it may be responsible for the preservation of the laminae. The sediments consist of light layers rich in calcium carbonate alternating with dark layers.

The recent (past one-hundred years) sediments were analyzed for charcoal influx and pollen percentages, and it was found that close-interval sampling (two years) is necessary to attain a meaningful record of fire history. The extensive 1864 fires are represented on the 1973 core by peaks in the charcoal curve, as are other important fires, such as those in 1910 and 1918. Charcoal influx was highest about 1896-1898, when logging began in the area and fires were numerous. The correlation between the charcoal peaks and known fire dates is based on the assumption that the laminae are annual.

Pollen was analyzed in order to identify when the percentage of Ambrosia pollen increased and that of Pinus decreased following settlement and extensive logging. Ambrosia increased during the late 1880's, reflecting agricultural land clearance in counties to the west, and Pinus began to decrease about 1895 in response to regional logging.

Keywords: MN/ Itasca Park/ fire history/ pollen analysis/ charcoal analysis.

194. **Foster, David R. 1983. The history and pattern of fire in the boreal forest of**

southeastern Labrador. *Canadian Journal of Botany*. 61:2459-2471.

Keywords: Labrador/ Canada/ vt, boreal forest/ wildfire/ fire history.

195. ---. 1988. **Disturbance history, community organization and vegetation dynamics of the old-growth Pisgah forest, south-western New Hampshire, U.S.A.** *Journal of Ecology*. 76(1):105-134.

Abstract: Long-term data (1905-85), age-structure analysis, tree-ring chronologies, stand ordination and fire-scar data suggest that natural disturbances are characterized by frequent local events (windstorms, lightning, pathogens and fire) and occasional broad-scale damage (e.g. hurricanes). Landscape pattern, stand damage and vegetation development are discussed in more detail in relation to the 1938 hurricane. The post-hurricane landscape was a mosaic of differentially damaged stands related to physiography, wind direction and pre-hurricane vegetation. Succession followed the pattern of even-aged stand development with all trees established within 25 yr of disturbance.

Keywords: NH/ eastern United States/ succession/ windthrow, effects on vegetation/ fire history/ fire scar/ hurricane/ dendrochronology/ age-class structure/ disturbance ecology/ old-growth.

196. ---. 1988. **Species and stand response to catastrophic wind in central New England, U.S.A.** *Journal of Ecology*. 76:135-151.

Summary: (1) The effect of catastrophic hurricane wind on forest vegetation in central New England was examined at the species and stand level.

(2) Species susceptibility to wind is largely explained by canopy position: fast-growing pioneer species that form overstory dominants (*Pinus strobus*, *P. resinosa*, *Populus* spp. and *Betula papyrifera*) suffered much greater damage than slower growing, or tolerant species occurring primarily in codominant, intermediate and suppressed canopy positions (*Carya* spp., *Acer rubrum*, *Quercus alba*, *Q. velutina* and *Tsuga canadensis*). Uprooting was much more important than breakage as the primary form of damage. This result, which contrasts with the findings of most studies of wind damage, may perhaps be explained by the very high levels of precipitation that accompanied the storm, saturating the soils and loosening the roots.

(3) Damage to forest stands exhibits a positive, linear relationship with stand age and height and negative relationship with density. Conifer forests are significantly more susceptible than hardwood forests. *Pinus strobus* and *P. resinosa* stands are susceptible to wind at 15 years of age and are completely destroyed at 30 years: hardwood stands exhibit increasing damage from age 20 years, but are not completely blown down until age 80-100 years.

(4) Within stands, damage shifts progressively from the dominant trees in young stands to include trees in codominant, intermediate and suppressed layers in older forests. Parallel changes with age in the type of damage include a decline in the number of leaning trees and increase in uprooting.

(5) Damage to species and stands from a catastrophic windstorm occurs quite predictably and specifically within the forests studied. This discriminating impact of wind has profound consequences on the vegetation at a range of spatial scales and is largely mediated by historical factors and structural and compositional

aspects of the vegetation mosaic.

Keywords: MA/ eastern United States/ hurricane/ windthrow, effects on vegetation/ windthrow, tree damage/ birch, paper/ birch, yellow/ hickory/ pine, white/ pine, red/ aspen/ maple, red/ oak, white/ oak, black/ hemlock/ ash, white.

197. **Foster, David R.; Aaber, John D.; Melillo, Jerry M.; Bowden, Richard D., and Bazzaz, Fakhri A. 1997. Forest responses to disturbance and anthropogenic stress. *BioScience*. 47(7):437-445.**

Abstract: The publication compares 3 simulated events, hurricane, chronic nitrogen and soil warming, that were created on the Harvard Forest for the Harvard Forest Long Term Ecological Research program. The simulated hurricane compared structurally to the 1938 hurricane. Results indicate less change occurs from a hurricane than previously published literature on the 1938 hurricane would suggest. Little change was seen in net flux of carbon dioxide, water, and vegetation composition. The area, though it looked bad, recovered quickly through increased growth of surviving vegetation. The reinterpretation of data from the 1938 hurricane indicates that the salvage logging caused a lot of the change in the system.

Keywords: MA/ eastern United States/ Harvard Forest/ windthrow, effects on vegetation/ hurricane/ disturbance ecology/ logging, salvage/ carbon and nitrogen cycling.

198. **Foster, David R. and Boose, Emery R. 1992. Patterns of forest damage resulting from catastrophic wind in central New England, USA. *Journal of Ecology*. 80:79-98.**

Summary: 1. The effect of catastrophic winds on a forested landscape in central Massachusetts was examined to investigate the factors controlling the geographic pattern of damage. The study area, Tom Swamp Tract, Harvard Forest, comprises a valley and adjoining hillslopes supporting second-growth hardwood and conifer stands. Much of the study used records and maps that were analyzed cartographically with a geographic information system (GIS).

2. Areally, forest damage was distributed fairly evenly among different damage classes ranging from no damage to more than 75% of stems broken or uprooted. However, there was a negative exponential size distribution of contiguous areas of the same damage intensity, with a preponderance less than 2 ha; These areas ranged from less than 0.04 ha to more than 35 ha; hurricane damage exhibited a continuum ranging from minor damage of individual trees to extensive blow-down of broad areas of forest.

3. The spatial pattern of wind damage was controlled by vegetation height and composition and by site exposure, which is predominantly determined by slope orientation and angle. Approximately 3% of the stands in the study site occupied protected sites, 31% intermediate sites, and 66% exposed sites.

4. Forest type susceptibility followed the ranking: *Pinus strobus*>conifer plantations>*Pinus strobus*-hardwood=*Tsuga canadensis*-hardwood-*Pinus strobus*>hardwood-*Pinus strobus*>hardwood. Damage increased with increasing site exposure to wind and increased approximately linearly with stand height.

5. An empirical GIS model of landscape-level response to wind was constructed

based on other stands in the same township (not including Tome Swamp Tract). Hurricane damage in these stands was analyzed as a function of site factors (exposure) and vegetational factors (height and composition). Model predictions for the study area agreed well with observed effects, suggesting that a relatively small number of variables can be used to explain the damage in this topographically simple area. Significant variation in the predicted damage under different vegetational scenarios suggests that the landscape-level response to catastrophic wind may be highly sensitive to historical changes in vegetation.

Keywords: MA / Harvard Forest/ eastern United States/ vt, pine forest/ vt, maple forest/ vt, pine- hemlock-hardwood forest/ hurricane/ windthrow, tree damage/ landscape ecology/ GIS/ pine, white / hemlock.

199. **Frasier, A. I. 1962. The roots and soils as factors in tree stability. *Forestry*. 35:117-127.**
Keywords: windthrow, tree damage/ soil morphology.
200. **Frelich, Lee E. 1986. Natural disturbance frequencies in the hemlock-hardwood forests of the upper Great Lakes region. University of Wisconsin, Madison. Ph.D. dissertation.**
Keywords: MN/ WI/ MI/ vt, hemlock-hardwood forest/ disturbance ecology/ windthrow, frequency/ dendrochronology/ age-class structure/ hemlock/ maple, sugar.
201. ---. 1992. **The relationship of natural disturbances to white pine stand development. In, Stine, Robert A. and Baughman, Melvin J. The White Pine Symposium: History, Ecology, Policy and Management, Sep 16-18, 1992, Duluth, MN. Minnesota Extension Service, University of Minnesota, St. Paul. p. 27-37.**
Note: This paper summarizes past research on white pine stand dynamics. Relevant publications on white pine and selected forest species within the range of white pine are listed and explained in terms of establishment and recruitment rotation ages and the relationship between fire regime and windthrow.
Abstract: Under natural conditions white pine is most abundant in forests with a rotation period of 150 to 300 years between catastrophic fires. After a fire, white pine seedling establishment occurs slowly, over a period of 20 to 40 years. Seed sources are permanent populations of pine near lakeshores or swamps, on rock outcrops, and individual trees or nearby stands that survive disturbance by chance. Establishment usually occurs under a canopy of faster-growing or sooner-established species such as aspen, birch, red maple, or oak. On relatively dry sites, surface fires every 20 to 40 years gradually eliminate hardwoods and create multi-aged pine forests that may persist for centuries. On relatively moist sites, succession to shade-tolerant hardwoods may occur. Severe windstorms that occur several times each century gradually reduce the pine component and advance succession towards hardwoods. White pine persists indefinitely at a low level in hardwood forests by the mechanism of gap phase dynamics. Succession from shade-tolerant hardwoods back to white pine may occur when intense fires get started in slash from catastrophic blowdowns.
Keywords: vt, pine forest/ regeneration, seed/ canopy gap/ disturbance ecology/

fire interval/ fire regime/ windthrow, effects on vegetation/ fire, review/ review/
pine, white.

202. ---. 1995. **Old forest in the Lake States today and before European settlement.**

Natural Areas Journal. 15:157-167.

Abstract: This paper provides estimates of the area occupied by old forests today, compares these statistics with estimated forest areas prior to European settlement of Minnesota, Wisconsin, and Michigan, and describes case studies that highlight the differences between modern commercial forests and presettlement forests. Forest Inventory and Analysis (FIA) data from the U.S. Forest Service's North Central Forest Experiment Station, natural heritage program databases, and scientific literature were used as sources for current forests. Data on presettlement forest were obtained from analyses of maps based on nineteenth-century land surveys (Wisconsin and Minnesota) and an early twentieth-century soil/forest cover survey of Michigan. The Lake States currently have 19.8 million ha of forest, compared with approximately 32.7 million ha in presettlement times. About 5.2-8.3% of Lake States forest is old-growth or old-seral forest today, compared with an estimated 68% prior to settlement. Approximately 369,000 ha of unlogged, or primary, forest remain (1.1% as much as in presettlement times), 40% of which is in the Boundary Waters Canoe Area Wilderness (BWCAW) and 50% in swamp conifer forests. The areas of unlogged red-white pine, riverbottom, northern hardwood, and oak-hickory forests remaining are extremely small-ranging from 0.02% to 0.6% of that in presettlement times. The largest area of secondary old growth is in oak-hickory and northern hardwood forest types, but this is highly fragmented. Michigan's Porcupine Mountains Wilderness State Park and Sylvania wilderness Area are the only presettlement-like upland forest landscapes in the Lake States. The largest single block of unlogged forest in the Lake States is Minnesota's BWCAW. However, the BWCAW's spatial pattern, age structure, and species composition have been significantly altered from presettlement conditions because of lower fire frequency since 1910.

Keywords: MN/ WI/ MI/ BWCAW/ National Forest, Superior/ National Forest, Ottawa/ Sylvania Recreation Area/ Porcupine Mountains/ vt, swamp forest/ vt, pine forest/ vt, hemlock forest/ vt, hemlock-hardwood forest/ vt, maple forest/ vt, oak forest/ GLO/ presettlement vegetation/ FIA/ logging/ landscape ecology/ fire regime/ old-growth/ pine, jack/ pine, red/ pine, white/ spruce, white/ balsam fir/ aspen, trembling/ birch, paper/ hemlock/ maple, sugar.

203. **Frelich, Lee E.; Faber-Langendoen, Don; Tester, John R., and Tilman, David. 1992. Changes in age structure of oak woodlands along a topographic and disturbance gradient. 77th Annual Ecological Society Meeting. 180.**

Note: The complete article is below.

We examined interactions between species composition and disturbance along a topographic gradient on a sand plain at Cedar Creek, MN. A tally of trees and 18 cores were obtained from 12 plots (.375 ha) distributed across the gradient. A dramatic shift in composition occurs, from very-dry bur oak savannas, to dry pole-sized pin oak woodlands, to dry-mesic pin- and white-oak woodlands. A parallel shift in age structure also occurs. Bur oak savannas experience frequent

droughts and fires, and are all-aged, with cohorts from 20 to 240 yr. More mesic pin oak woodlands have less frequent but more intense fires, resulting in even-aged stands (mean 54-64 yr), with 3/4 of tree recruited within 25 yr. The observed differences in disturbances in disturbance regimes are expected given the species' life-history characteristics. Bur oak has thick fire resistant bark. Pin oak is fire sensitive, but is capable of prolific stump sprouting after a major disturbance. The topographic gradient mediates disturbance frequency, which mediates composition and structure.

Keywords: MN/ Cedar Creek Natural History Area/ vt, oak savanna/ vt, oak forest/ sand plains/ fire history/ fire regime/ growth ring analysis/ landform/ oak, bur/ oak, pin/ oak, white.

204. **Frelich, Lee E. and Lorimer, Craig G. 1991. Natural disturbance regimes in hemlock-hardwood forests of Upper Great Lakes region. Ecological Monographs. 61:145-164.**

Note: The study took place in the Porcupine Mountains, Sylvania Tract, and the Huron Mountains. The average presettlement surface and crown fire rotation rates for the study area were estimated to be 566 and 2797 yrs, respectively.

Abstract: The frequency of natural disturbances and their influence on the forest landscape mosaic were investigated on three large tracts of primary forest in Upper Michigan. Seventy 0.5-ha plots were randomly distributed in a total forest area of 23 000 ha dominated by sugar maple (*Acer saccharum*) and eastern hemlock (*Tsuga canadensis*). Radial increment patterns were used to estimate canopy accession dates for each of a number of randomly selected overstory trees on each plot. From these data a disturbance chronology, representing the percentage of stand area occupied by cohorts originating during each decade over the last 130 yr, was compiled for each plot.

Average rates of disturbance or canopy mortality are estimated at 5.7 to 6.9% per decade. The corresponding average canopy residence time of a tree is 145-175 yr. No significant differences were detected in average disturbance rates among the three study areas, between plots near the coast of Lake Superior and inland plots, among several different aspects, and among several different slope positions.

Natural rotation periods increase exponentially with increasing disturbance intensity, which is defined as the approximate percentage of the plot area converted to gaps during a disturbance episode. Estimates of rotation periods range from 69 yr for $\geq 10\%$ canopy removal to 1920 yr for $\geq 60\%$ canopy removal. Spatial autocorrelation analysis indicated that plots with light and medium disturbances ($< 40\%$) are randomly distributed over the landscape. Plots with heavy disturbances ($\geq 40\%$) are clustered with a patch radius of = (approx.) 2 km, consistent with the sizes of thunderstorm downbursts.

The data indicate that light and medium disturbances dominate the disturbance regime. The majority of stands on the landscape are composed of several major and many minor age classes. Even-aged stands with on predominant age class are uncommon. The age distribution of individual patches or cohorts in the two

larger study areas (14 500 and 6073 ha) follows a nearly uniform distribution. None of the three study areas had more than 15% of the forest area converted to gaps in a single decade. The two larger areas meet most of the criteria that have been proposed for equilibrium landscapes.

Keywords: MI/ Porcupine Mountains/ Huron Mountains/ Sylvania Recreation Area/ vt, hemlock-hardwood forest/ fire history/ fire regime/ fire scar/ windthrow, frequency/ disturbance ecology/ age-class structure/ maple, sugar/ hemlock/ birch, yellow.

205. ---. 1991. **A simulation of landscape-level stand dynamics in the northern hardwood region. *Journal of Ecology*. 79:223-233.**

Summary

(1) The STORM simulation was developed to predict the response of regional stand age structure to a given disturbance regime. The outcome of STORM depends upon rotation periods of canopy disturbance, diameter growth rates of trees, and the relative susceptibility of pole, mature and large trees to windthrow.

(2) The simulation was run using data on disturbance frequencies from remnants of primary forest in western Upper Michigan. Rotation periods ranged from 69 years for > 10% canopy removal to 3734 years for > 70% canopy removal. Stands were classified into eight structural types, ranging from even-aged sapling stands to steady-state stands, which reflect the state of recovery from recent disturbances.

(3) The model suggests that most (87.4%) stands in the primeval hardwood forest were multi-aged, with several major and many minor age classes. Quasi-even-aged stands resulting from catastrophic disturbance occupied 9.2% of the landscape, and steady-state stands about 3.6%. The low frequency of steady-state stands on the landscape appears to be determined primarily by the high frequency of disturbances removing part of the canopy, rather than the interval between catastrophes.

(4) Sensitivity analyses indicate that changes in disturbance rates result in disproportionately large changes in the proportion of even-aged stands on the landscape, while mean canopy residence time for trees shows a damped effect.

Keywords: MI/ Porcupine Mountains/ vt, northern hardwood forest/ vt, hemlock forest/ vt, hemlock-hardwood forest/ modeling/ windthrow, effects on vegetation/ hemlock/ maple, sugar.

206. **Frelich, Lee E. and Martin, G. L. 1988. Effects of crown expansion into gaps on evaluation of disturbance intensity in northern hardwood forests. *Forest Science*. 34:530-536.**

Keywords: vt, northern hardwood forest/ canopy gap/ disturbance ecology.

207. **Frelich, Lee E. and Reich, Peter B. 1995. Neighborhood effects, disturbance, and succession in forests of the western Great Lakes Region. *Ecoscience*. 2(2):148-158.**

Note: In the conclusions, 2 other pubs. are cited as making reference to punctuated stability. They are Heinselman (1970), and Wilson and Agnew (1992).

Abstract: Neighborhood effects that enhance conspecific replacement at the time of canopy-tree death were examined in 3 cold-temperate forest types, using spatial analyses and historical reconstruction on mapped plots. Important neighborhood effects in these forest include overstory-understory effects whereby a species enhances likelihood of self replacement by influencing the local understory, and disturbance-activated affects that switch on after stand-killing disturbance. Neighborhood analyses (radius 9 m) show that understory composition is significantly related ($p < 0.001$) to overstory composition in a hardwood-hemlock forest, but not in white pine or near-boreal jack pine forests. Jack pine has strong disturbance activated effects in the form of abundant serotinous seedfall after fire. White pine apparently has no significant neighborhood effects of either type. Other species are likely to replace white pine in treefall gaps, and after fire it must reinvade a given neighborhood by means of outside seed sources. In the forest types with strong neighborhood effects a change in the usual disturbance regime may occur that overwhelms the self-replacement mechanisms. Such events would include lack of fire in near-boreal jack pine forest, which causes succession to a spruce-fir-birch- cedar mixture, and intense fire after heavy windfall in hardwood-hemlock forest, which can convert the forest to paper birch and aspen. From the point of view of species compositional stability, these changes in disturbance regime are true catastrophes, unlike stand-killing fires in jack pine or complete canopy windthrow in hardwood-hemlock. These compositional catastrophes operate in a punctuated- stability context, and initiate episodes of succession, which are relatively short periods of rapid change in species composition. We put forth the neighborhood- effect hypothesis of forest dynamics. This hypothesis predicts that forest types with weak neighborhood effects have great temporal instability of composition, with recovery from disturbance and related successional sequences nearly always in progress, whereas species composition may be generally stable with sudden alternation between different states in forests with strong neighborhood effects.

Keywords: MN/ MI/ WI/ vt, hemlock-hardwood forest/ vt, pine forest/ vt, jack pine forest/ succession/ fire, general reference to stand structure/ neighborhood effects/ disturbance ecology/ hemlock/ pine, jack/ pine, white.

208. ---. 1995. **Spatial patterns and succession in a Minnesota southern-boreal forest. Ecological Monographs. 65(3):325-346.**

Abstract: Succession was studied in a cold-temperate forest in the Boundary Waters Canoe Area Wilderness (BWCAW) of northeastern Minnesota. The 13 x 18 km study area comprises a complex forest mixture of jack pine (*Pinus banksiana*) and other pines, quaking aspen (*Populus tremuloides*), paper birch (*Betula papyrifera*), black spruce (*Picea mariana*), balsam fir (*Abies balsamea*), and white cedar (*Thuja occidentalis*) on thin soils over the Canadian Shield bedrock. The main objectives of this study were to examine the relationships between spatial patchiness, spatial scale, and canopy succession in the southern-boreal forest of the BWCAW, and to evaluate under what conditions successional

direction may remain stable, converge, or diverge. Knowledge of the successional direction of old forests in the BWCAW that are undergoing demographic transition from even-aged to uneven-aged is important because the landscape now has many old stands as a result of reduced fire frequency. Rotation periods for fires have changed from ~50-100 yr in presettlement times to >1000 yr since 1910.

Analyses were conducted at spatial scales ranging from individual tree (0.01 ha) to the large stand (16 ha). Two permanent mapped plots (of area 0.53 and 0.56 ha) were established in stands of different age. Fine-scale age structure, successional change, transition from one species to another, and development of small patches (of area <0.25 ha) were studied by means of stand history reconstruction with increment cores, spatial autocorrelation, and analysis of replacement trees in canopy openings. Spatial processes at nested scales of 1, 4, and 16 ha were examined on 15 square 16-ha tracts of upland forest, which are distributed among forests ranging from 15 to 190 yr old. Canopy species composition and patch development over time on these 15 tracts were interpreted on air photos taken in 1934, 1961, and 1991. Thus, the study includes a chronosequence approach, with verification of chronosequence validity by checking patch development processes at more than one time point. This checking was done at small spatial scales with sequential air photos of the same locations spanning a 57-year period.

Results show that the reduced fire frequency in recent years has changed the dominant successional pathways. When fire frequency was high, jack pine or aspen stands usually burned while still in the even-aged stage of development, and the new trees after the burn were the same species as before. Currently, many stands are undergoing demographic transition from even-aged stands of catastrophic fire origin to uneven-aged stands. This transition parallels a change in canopy composition from jack pine (occasionally red pine (*Pinus resinosa*); or aspen to an old-growth multi-aged mixture of black spruce, balsam fir, paper birch, and white cedar. The mechanism that moves this successional path forward is canopy openings, 10-30 m across on average, caused by wind, insect, and disease, that gradually chip away at the relatively uniform canopy of pines and aspen. Successional direction is individualistic in the sense that time and rate of transition from pine/aspen to other species depends on the action of heavy windstorms, insect infestation, and senescence of old pines that create canopy opening. Canopy openings are often filled with one of several species, but if more than one species invades an opening, monodominant patches of each species generally result. Understory-overstory interactions are very weak; the dominant species within each patch is apparently independent of the overstory species that died when the opening was created or the species dominating surrounding patches. During succession, the spatial structure of the stands at the 1-16 ha scales generally changes from a matrix heavily dominated by pine or aspen to a mosaic with relatively large mono-dominant patches that may be remnants of the extensive original matrix, and finally to a mixture with small patches (mean area

35 m², maximum ~ 0.1 ha) of black spruce, balsam fir, white cedar, and paper birch. Thus, at 1-16 ha spatial scales, succession leads to convergence on a mixture of species. At smaller spatial scales (e.g., 0.01-0.1 ha) successional pathways appear to diverge into four community types. The same successional pathways can be reconstructed from historical analysis of individual stands as from a chronosequence of stands; therefore, chronosequences in this area have been stable at least during the lifetime of the current generation of trees.

Keywords: MN/ BWCAW/ National Forest, Superior/ vt, boreal forest/ vt, pine forest/ vt, jack pine forest/ vt, aspen-birch forest/ vt, conifer feathermoss forest/ vt, balsam fir forest/ vt, white cedar forest/ fire regime/ succession/ birch, paper/ aspen, trembling/ balsam fir/ pine, jack/ pine, red/ northern white cedar.

209. ---. 1998. **Disturbance severity and threshold responses in the boreal forest.** *Conservation Ecology*. 2(2):7.
Note: Found online at: <http://www.consecol.org/vo2/iss2/art7>.
Keywords: disturbance ecology/ vt, boreal forest.
210. ---. 1999. **Neighborhood effects, disturbance severity, and community stability in forests.** *Ecosystems*. 2:151-166.
Keywords: MN/ MI/ WI/ disturbance ecology/ vt, hemlock-hardwood forest/ vt, pine forest/ succession/ pine, jack/ pine, white/ hemlock.
211. **Friedman, S. K.; Reich, Peter B., and Frelich, Lee E. 2001. Multiple scale composition and spatial distribution patterns of the north-eastern Minnesota presettlement forest.** *Journal of Ecology*. 89:538-554.
Keywords: MN/ presettlement vegetation/ GLO/ vt, boreal forest/ vt, pine forest/ vt, conifer-feathermoss forest/ vt, spruce forest/ landscape ecology/ disturbance ecology/ fire, general reference to stand structure/ pine, white/ pine, red/ pine, jack/ spruce, black/ tamarack.
212. **Frissell, Sidney S., Jr. 1968. A fire chronology for Itasca State Park, Minnesota.** *Minnesota Forestry Research Notes* 196. 2 pp.
Note: Fire scar data, collected from mostly red pine, indicate the occurrence of 32 fires in the park between 1650 and 1922. The data are probably not complete prior to 1700 because few trees were greater than 250 years old. The logging fire intervals were greater than 10 years prior to 1850 and ~ 4 years between 1850 and 1922, after logging began. Refer to Frissell (1971 and 1973) for an in depth analysis of the fire history of Itasca State Park.
Keywords: MN/ Itasca Park/ vt, pine forest/ fire history/ fire scar/ pine, red/ pine, white.
213. **Frissell, Sidney S., Jr. 1971. An analysis of the maintenance of presettlement biotic communities as an objective of management of Itasca State Park, Minnesota.** *University of Minnesota, St. Paul. Ph.D. dissertation.*
Note: Chapter 7 describes vegetation of the Itasca State Park area in 1891. Notes of explorers and GLO surveyors are used to develop maps of pre-European settlement vegetation composition. In chapter 8, the fire history, developed from

fire scar data from 1650 to 1922, and its influence on vegetation composition is described. Also, see Frissell (1973).

Keywords: MN/ Itasca Park/ vt, pine forest/ fire interval/ fire scar/ GLO/ presettlement vegetation/ management/ pine, red/ pine, white/ pine, jack/ birch, paper/ aspen, trembling.

214. ---. 1973. **The importance of fire as a natural ecological factor in Itasca State Park, Minnesota. *Quaternary Research*. 3:397-407.**

Note: A study of the fire history of Itasca State Park from 1650 to 1922 indicates a fire interval of 22 years for the park. During the sampled period, at least 32 fires occurred, of which 21 were very large. Burn sizes ranged from 580 acres to approximately 31,960 acres. Most of the area is considered part of the red pine and white pine type, although considerable acreage was also in hardwood type (aspen, paper birch, etc.). Fire frequency was established using dendrochronological techniques. Frelich (1992) references this publication as having a catastrophic fire rotation of 150 years.

Keywords: MN/ Itasca Park/ vt, pine forest/ vt, aspen-birch forest/ fire scar/ fire interval/ pine, red/ pine, white/ pine, jack/ aspen/ birch, paper.

215. **Futyma, Richard P. 1987. Fossil pollen stratigraphy of 12-Mile Bog, Pictured Rocks National Lakeshore, Michigan. 7 pp.+ tables and appendices.**

Note: 4000 to 5000 years of vegetation change and charcoal presence was described for the 12-Mile Bog area. Typical of dry sites in Michigan, pine and birch dominated the stratigraphy with few definite trends. Charcoal abundance was inconclusive, although fairly consistent throughout time period.

Keywords: MI/ vt, pine forest/ paleoecology/ pollen analysis/ charcoal analysis/ fire history/ pine, red/ pine, jack/ birch/ hemlock/ oak/ maple, sugar/ birch, paper.

216. **Gajewski, K.; Winkler, Margorie G., and Swain, Albert Marvin. 1985. Vegetation and fire history from three lakes with varved sediments in northwestern Wisconsin (U.S.A.). *Review of Palaeobotany and Palynology*. 44:277-292.**

Note: The author did not try to estimate fire frequency using charcoal peaks. It may have been possible for the past 200 yrs.

Abstract: The vegetation and fire history for the past 900 yrs. in northwestern Wisconsin is interpreted from pollen and charcoal analysis of cores from three lakes in Chippewa County, Wisconsin. The sediments are annually laminated and provide accurate time control. The cores from the three lakes contain similar pollen sequences which have been divided into three pollen assemblage zones. Pollen Zone 1 records a period (A.D. 1050-A.D. 1700) of *Pinus* and *Quercus* forests during which mesic hardwoods increased in abundance. From A.D. 1700 to A.D. 1830 (Pollen Zone 2), mesic hardwoods and *Betula* trees remained abundant, while *P. Strobilus* decreased. In the past 130 yrs. (Pollen Zone 3), European settlement has significantly altered the vegetation and fire regime of the landscape. The time series for pollen deposition rates and charcoal/pollen ratios are similar in the three lakes, although single charcoal peaks are not always seen in all three lakes.

Keywords: WI/ vt, pine forest/ vt, oak forest/ vt, maple forest/ fire history/

paleoecology/ pollen analysis/ charcoal analysis/ pine, white/ birch, paper/ oak/ shrubs.

217. **Galipeau, C.; Kneeshaw, D. D., and Bergeron, Yves. 1997. White spruce and balsam fir colonization of a site in the southeastern boreal forest as observed 68 years after fire. Canadian Journal of Forest Research. 27:139-147.**
Keywords: Canada/ vt, boreal forest/ vt, spruce-fir forest/ wildfire/ fire effects/ succession/ spruce, white/ balsam fir.
218. **Gallimore, R. G. and Lettau, H. H. 1970. Topographic influence on tornado tracks and frequencies in Wisconsin and Arkansas. Transactions of the Wisconsin Academy of Sciences, Arts and Letters. 58:101-127.**
Keywords: WI/ weather.
219. **Gardner, Robert H.; Romme, W. J., and Turner, Monica G. 1999. Scale-dependent processes on predicting patterns of forest fires. In, *Spatial modeling of forest landscape change: approaches and applications*. Cambridge University Press, Cambridge, UK.**
Keywords: wildfire/ fire modeling/ landscape ecology.
220. **Garrison, O. E. 1881. The upper Mississippi region. Minnesota Geological and Natural History Survey, 9th Annual Report.**
Note: The vegetation and soils along the Mississippi River from Verndale, Wadena County to Aitken Station by the Mud River are described. Large burned areas, probably ignited by local Indians to improve deer habitat are noted on many occasions.
Keywords: MN/ vt, riparian/ vt, pine forest/ fire, Native American use of/ pine, red/ pine, white.
221. **Gates, Frank C. 1930. Aspen association in northern lower Michigan. Botanical Gazette. 90:233-259.**
Note: The succession of aspen associations growing on three soil types, sandy upland, sandy lowland and clayey upland, in Emmet and Cheboygan counties, is described. The influence of varying fire regimes on vegetation dynamics is also described.
Keywords: MI/ vt, aspen forest/ fire effects/ succession/ soil morphology/ aspen, big tooth/ aspen, trembling/ birch, paper.
222. **Gauthier, Sylvie; Gagnon, Julie, and Bergeron, Yves. 1993. Population age structure of *Pinus banksiana* at the southern edge of the Canadian boreal forest. Journal of Vegetation Science. 4:783-790.**
Abstract: To assess the effects of site type, forest initiation periods and fire regimes on the dynamics of *Pinus banksiana* (Jack pine), the age structure of 69 populations of the species was analyzed. Two landscapes with different fire regimes were selected in the southern part of the Canadian boreal forest in Quebec: the 'mainland landscape' is characterized by a fire regime of large lethal fires, the 'island landscape' is affected by a complex fire regime including lethal

and non-lethal fires. Age structure was compared between forest initiation periods and site types (mesic mainland, xeric mainland and xeric island) using the Shannon regularity index. An even-aged population structure was found within the first 100 yr following a lethal fire, while after that period the population structure becomes more uneven-aged. Under mesic conditions, populations tend to have an even-aged structure, under xeric conditions an uneven-aged structure. Natural openings present in xeric sites allow for recruitment in the absence of fire. This permits the self-maintenance of *Pinus banksiana*. Xeric island populations show more uneven-aged structures. Further, the results suggest that the selection pressure of the island fire regime, favoring non-serotinous and mixed *P. banksiana* individuals, is one of the factors responsible for a higher recruitment in the absence of fire on islands than on the mainland.

Keywords: Quebec/ Canada/ island/ vt, boreal forest/ vt, jack pine forest/ vt, conifer-feathermoss forest/ fire regime/ age-class structure/ pine, jack.

223. Gerlach, John P.; Gilmore, Daniel; Puettman, Klaus J.; Zasada, John C. 2002. **Mixed-species forest ecosystems in the Great Lakes region: A bibliography.** University of Minnesota, St. Paul. Department of Forest Resources, Staff Paper Series 155. 279 pp.
Note: This bibliography contains over 700 abstracts from relatively recent publications concerning wildland vegetation and natural resource management. A good source for silviculture and forestry related publications.
Keywords: MN/ MI/ WI/ Ontario/ Canada/ bibliography.
224. Gilmore, Daniel W.; Anderson, Paula J.; Kastendick, Douglas; Yount, Louise S., and Zasada, John C. 2001. Pre- and post-blow down stand structure of two cover types in northern Minnesota. *In*, Yount, Louise S. ed. Third North American Forest Ecology Workshop Program, Issues of Scale from Theory to Practice, Jun 24-27, 2001, Duluth, MN. p. 116.
225. Gilmore, Daniel W.; Seybold, S. J.; Zasada, John C.; Anderson, Paula J.; Kastendick, Douglas; Gandhi, Kamal J. T., and Johnson, Hugh P. 2002. Cumulative effects of a severe windstorm and subsequent silvicultural treatments on plant and arthropod diversity in northern Minnesota: project design. *In*. Proceedings of the 2001 SAF National Convention; Denver, CO.
226. Gleason, Henry Allan. 1913. The relation of forest distribution and prairie fires in the middle west. *Torreyia*. 13:173-181.
Keywords: vt, prairie/ fire frequency/ wildfire.
227. Goder, H. A. 1961. Hemlock reproduction and survival on its border in Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters*. 50:175-182.
Keywords: WI/ windthrow, effects on vegetation/ hemlock.
228. Goodess, C. M. 1987. Precipitation fluctuations over Northern Hemisphere land areas since the mid-19th century. *Science*. 237:171-175.

Keywords: weather.

229. **Graff, Paul W. 1936. Invasion of *Marchantia polymorpha* following wildfires. *Bulletin of the Torrey Botanical Club*. 63:67-74.**
Note: This publication lists specific locations where the liverwort *Marchantia polymorpha* has been found invading post-wildfire sites in Montana.
Keywords: MT/ fire effects/ liverwort.
230. **Grafstrom, M. D. and Hansen, Henry L. 1962. Post-fire regeneration study of the 1959 Badoura and 1960 Bemidji fires. University of Minnesota Forestry Notes 116. 2 pp.**
Note: Post-fire jack pine regeneration was quantified by pre- and post-fire vegetation condition classes. Characteristics measured include stand composition, crown size, cone abundance, tree size, and burn intensity. Cone crop and post-fire precipitation had the greatest influence on regeneration success. Pre- and post-burn changes stem number for *Corylus Americana*, *Salix humilis*, and *Rosa acicularis* were also estimated.
Keywords: MN/ vt, jack pine forest/ fire behavior/ wildfire, historic / regeneration, seed/ pine, jack/ shrubs.
231. **Graham, Samuel A. 1941. Climax forests of the Upper Peninsula of Michigan. *Ecology*. 22(4):355-362.**
Note: Fifty years (1890 to 1940) of vegetation change on 5 selectively logged sites, on clay and sandy clay soils, located on the west side of the UP, is described. The stands originated after a severe wildfire between 1400 and 1600 but, there is no other indication of fire after that. The prelogging stands were composed of scattered white pine in the overstory, sugar maple and yellow birch in the middle layers, and hemlock in the understory. Fifty years after logging of the white pine, middle and understory tree species dominate the stand, and balsam fir is in the understory. It is probable that an aspen stand preceded the white pine stand.
Keywords: Michigan/ National Forest, Ottawa/ vt, maple forest/ vt, pine forest/ vt, hemlock-hardwood forest/ fire, general reference to stand structure/ logging/ soil morphology/ succession/ pine, white/ hemlock/ maple, sugar/ birch, yellow/ aspen/ balsam fir.
232. **Grange, Wallace. 1965. Fire and tree growth relationships to snowshoe rabbits. In, *Proceedings of the Annual Tall Timbers Fire Ecology Conference, Mar 18-19, 1965, Tallahassee, FL*. p. 110-125.**
Note: The relationship of the fluctuating hare population and vegetation condition is described by examples in the Wisconsin and Minnesota where jack pine stands were burned in large fires in the 1920's and the regeneration of jack pine seedlings were heavily browsed for a few years by the increasing hare population. Also, the author lists "fire years" for Minnesota, Wisconsin and Michigan by summarizing work of Mitchell.
Keywords: WI/ MN/ vt, jack pine forest/ fire effects/ fire history/ regeneration, seed/ mammals/ pine, jack.

233. **Grant, Martin L. 1929. The burn succession in Itasca County, Minnesota. University of Minnesota, St. Paul. Masters thesis.**
Note: Succession sequences occurring on mineral and wetland soils of Itasca County are developed. Herbaceous, shrub and trees species found are listed.
Keywords: MN/ vt, spruce-fir forest/ vt, balsam fir forest/ vt, jack pine forest/ vt, pine forest/ fire, general reference to stand structure/ succession/ aspen, trembling/ pine, jack/ pine, red/ pine, white/ birch, paper/ spruce, white/ balsam fir/ basswood/ cherry, pin/ balsam poplar/ herbs/ shrubs.
234. **Gray, J. R. A. and Edington, J. M. 1969. Effect of woodland clearance on stream temperature. Journal of the Fisheries Research Board of Canada. 26:399-403.**
Keywords: Canada/ vt, boreal forest/ fire effects/ streams/ hydrology.
235. **Green, David G. 1981. Time series and postglacial forest ecology. Quaternary Research. 15:265-277.**
Abstract: Forest ecology suffers from a lack of long-term community records. Preserved pollen data are richer in such information than is generally realized. By applying suitable statistical techniques to pollen records, one can learn much about competition, succession, and population dynamics in past tree communities. In this study, preserved pollen records from Lake Everitt, Nova Scotia, are analyzed as time series. Time domain studies reveal the post-fire responses of individual tree taxa. Correlograms yield models of past forest succession patterns. The models explain some effects of changing fire frequency, thus suggesting mechanisms by which fire, competition, and climate combine to produce long-term forest composition changes. Frequency domain studies suggest relationships between disturbance cycles, stand composition, and forest mosaics. Fire frequencies are seen to be highest where fire-dependent species abound and most regular where tree stands have uniform, not mixed, composition.
Keywords: Nova Scotia/ Canada/ fire frequency/ paleoecology/ pollen analysis/ charcoal analysis/ climate change/ fire modeling/ maple, sugar/ hemlock/ pine, red/ pine, white/ birch, paper/ northern white cedar/ balsam fir/ spruce, white/ elm.
236. ---. 1989. **Simulated effects of fire, dispersal and spatial pattern on competition within forest mosaics. Vegetatio. 82:139-153.**
Keywords: fire modeling.
237. **Greenberg, Cathryn H. and McNab, W. Henry. 1998. Forest disturbance in hurricane-related downbursts in the Appalachian mountains of North Carolina. Forest Ecology and Management. 104:179-191.**
Abstract: We characterized five 0.2-1.1 ha gaps created by downbursts during hurricane Opal in xeric oak forests at the Bent Creek Experimental Forest, Asheville, NC. Direction of windthrow was nonrandom in four of the five gaps, but differed among gaps suggesting that each was caused by an independent downburst. Windthrows reduced tree density by 19-39% and basal area (BA) by 30-53% within gaps. Most windthrows were uprooted (17-38% of all trees)

versus broken below 1.8 m height (0-3%). Most species were uprooted in proportion to their abundance regardless of canopy position. Red oaks (*Quercus coccinea*, *Quercus rubra* and *Quercus velutina*) were disproportionately uprooted, while *Nyssa sylvatica* and *Acer rubrum* were resistant to uprooting. As a group, *Quercus* lost 27-47% of individuals and 41-50% of BA. *Q. coccinea* lost $\geq 44\%$ of trees and $>55\%$ of BA in sites where it occurred. Only minor shifts in canopy species dominance were evident. For several species, significantly more large-diameter individuals uprooted than their smaller counterparts. No relationship between dbh and number uprooted was detected for the red oaks, however. Canopy position appeared to have little bearing on this relationship. Uprooting disturbed 1.6-4.3% of the ground area and displaced 130-587 m³ of root-soil-rock masses (rootmasses) per gap. We suggest that episodic, high-intensity wind is not uncommon, and has a substantial influence on forest structure, species composition, regeneration and microtopography of the southern Appalachian mountains at variable scales.

Keywords: NC/ canopy gap/ hurricane/ windthrow, tree damage/ oak, red / oak, scarlet/ oak, black/ tupelo, black/ maple, red.

238. **Greene, D. F.; Zasada, J. C.; Sirois, L.; Kneeshaw, D. D.; Morin, H.; Charron, I., and Simard, M. J. 1999. A review of the regeneration dynamics of North American boreal forest tree species. Canadian Journal of Forest Research. 29(6):824-839.**

Abstract: In this review, we focus on the biotic parameters that are crucial to an understanding of the recruitment dynamics of North American boreal tree species following natural (fire, budworm infestation, windthrow) or human induced (clearcut, partial cut) disturbances. The parameters we emphasize are (i) the production of seeds and asexual stems (both of which, we argue, are a function of basal area density), (ii) the dispersal of seeds by wind (or the dispersion of asexual stems) as a function of distance from source, (iii) dormant seed bank capacity, (iv) organic layer depth as a determinant of germinant mortality and asexual bud response, and (v) shade tolerance as a partial arbiter of the density of advanced regeneration. Having identified the gaps in our knowledge, we conclude by suggesting a short-term research agenda whose completion of which would lead to the parameterized functions that would constitute the recruitment subroutine in a landscape-scale forest dynamics simulator.

Keywords: MN/ MI/ North America/ Canada/ vt, boreal forest/ regeneration, seed/ regeneration, vegetative/ review/ wildfire/ logging, clearcut/ logging, partial cut/ windthrow, effects on vegetation/ modeling/ budworm, spruce/ litter and duff/ life history attributes/ aspen, trembling/ birch, paper/ spruce, black/ pine, jack/ spruce, white/ balsam fir/ balsam poplar/ tamarack.

239. **Gresswell, Robert E. 1999. Fire and aquatic ecosystems in forested biomes of North America. Transactions of the American Fisheries Society. 128(2):193-221.**

Abstract: Synthesis of the literature suggests that physical, chemical, and biological elements of a watershed interact with long-term climate to influence fire regime, and that these factors, in concordance with the postfire vegetation mosaic, combine with local-scale weather to govern the trajectory and magnitude

of change following a fire event. Perturbation associated with hydrological processes is probably the primary factor influencing postfire persistence of fishes, benthic macroinvertebrates, and diatoms in fluvial systems. It is apparent that salmonids have evolved strategies to survive perturbations occurring at the frequency of wildland fires (10^0 - 10^2 years), but local populations of a species may be more ephemeral. Habitat alteration probably has the greatest impact on individual organisms and local populations that are the least mobile, and reinvasion will be most rapid by aquatic organisms with high mobility. It is becoming increasingly apparent that during the past century fire suppression has altered fire regimes in some vegetation types, and consequently, the probability of large stand-replacing fires has increased in those areas. Current evidence suggests, however, that even in the case of extensive high-severity fires, local extirpation of fishes is patchy, and recolonization is rapid. Lasting detrimental effects on fish populations have been limited to areas where native populations have declined and become increasingly isolated because of anthropogenic activities. A strategy of protecting robust aquatic communities and restoring aquatic habitat structure and life history complexity in degraded areas may be the most effective means for insuring the persistence of native biota where the probability of large-scale fires has increased.

Keywords: North America/ fire effects/ aquatics/ fire, review.

240. **Grier, C. C. 1975. Wildfire effects on nutrient distribution and leaching in a coniferous ecosystem. Canadian Journal of Forest Research. 5:599-607.**

Keywords: fire effects/ soils, nutrient analysis.

241. **Grigal, David F. and McColl, John G. 1975. Litter fall after wildfire in virgin forests of northeastern Minnesota. Canadian Journal of Forest Research. 5:655-661.**

Abstract: The Little Sioux Fire burned virgin forests in northeastern Minnesota on 14-17 May 1971. We monitored litter fall for 3 years after the fire in mixed conifer-deciduous forests both within and outside the fire boundaries. We separated four categories of litter: conifer needles, deciduous leaves, woody material, and miscellaneous material. Significantly more litter fell in the burned area during the 3 years (575 g/m^2) than in the unburned areas (340 g/m^2). Major differences were related to an increased fall of needles from conifers that had been killed by the fire and an increased fall of woody material from dead trees on the burn. Needles falling from these dead trees had significantly higher concentrations of N, P, and K and lower concentrations of Ca than did needles falling in the unburned areas. No other litter components showed significant differences in concentrations of N, P, K, Ca, and Mg between the burned and unburned areas for the unburned area, and the proportion of litter in all components except needles was similar in both areas.

Keywords: MN/ Little Sioux Fire/ National Forest, Superior/ vt, mixed conifer deciduous/ litter and duff, nutrient analysis/ fire effects/ wildfire, historic.

242. **Grimm, Eric C. 1981. An ecological and paleoecological study of the vegetation in the Big Woods region of Minnesota. University of Minnesota, St. Paul. Ph.D. dissertation.**

Keywords: MN/ vt, Big Woods/ vt, prairie-forest ecotone/ paleoecology/ pollen analysis/ fire history.

243. ---. 1983. **Chronology and dynamics of vegetation change in the prairie-woodland region of southern Minnesota, U.S.A.** *New Phytologist*. 93:311-350.
Summary: The pollen and sediment stratigraphy of Wolsfeld Lake and French Lake in the Big Woods of southern Minnesota was investigated. Wolsfeld Lake is in the northeastern Big Woods, and French Lake is in the western Big Woods about 1.5 km from the prairie-woodland border. During the mid-postglacial, most of the present Big Woods was prairie. Oak woodland began invading prairie about 5000 years ago in the eastern Big Woods, then expanded westward, becoming established near French Lake 2400 years ago. Topography and water bodies, which control fire frequency, strongly influenced where and when woodland invaded prairie. Oak woodland persisted until 300 years ago, when *Ulmus*, *Ostrya virginiana*, *Tilia americana* and *Acer saccharum* rapidly expanded and became dominant. The changes from prairie to oak woodland and from oak woodland to 'bigwoods' must have required reductions in fire frequency, which were probably caused by increased precipitation and possibly decreased temperatures. About 100 years before the expansion of bigwoods, sediment influx increased at the coring site in Wolsfeld Lake, probably because of an increase in runoff and, therefore, precipitation. A conceptual model is presented in which climatic changes trigger vegetation changes, but interactions among the existing vegetational pattern, fire, and topography cause climatic thresholds for vegetation change to vary in space and time.
Keywords: MN/ vt, Big Woods/ vt, prairie-forest ecotone/ vt, oak forest/ pollen analysis/ paleoecology/ climate change/ fire barriers/ maple, sugar/ basswood/ elm/ ironwood/ ash/ hickory, bitternut/ butternut.

244. ---. 1984. **Fire and other factors controlling the Big Woods vegetation of Minnesota in the mid-nineteenth century.** *Ecological Monographs*. 54(3):291-311.
Abstract: Bearing-tree data from the original land-survey records of 1847-1850 were used to reconstruct the vegetation of the Big Woods and adjacent areas along the prairie-woodland border in south-central Minnesota. The characteristic tree taxa of the Big Woods were elm (*Ulmus*), basswood (*Tilia americana*), sugar maple (*Acer saccharum*), ironwood (*Ostrya virginiana*), bitternut hickory (*Carya cordiformis*), butternut (*Juglans cinerea*), and ash (*Fraxinus*). The most common tree was elm, which comprised 27% of the bearing trees. A buffer zone of fire-tolerant oaks and aspen generally lay between the Big Woods and prairie. The width of this zone depended on topography and on the presence of additional firebreaks, which in places formed sharp boundaries between the Big Woods and oak-aspen. The prairie-woodland border was characteristically a sharp boundary along firebreaks (water bodies and physiographic breaks). In some places very effective firebreaks formed sharp boundaries between prairie and the Big Woods, with no intervening oak-aspen zone.

The vegetation was most strongly correlated with the fire-probability pattern, which was a function of both abiotic and biotic factors. Soils influenced the

probability of fire, but they also were the major factor controlling the vegetation within areas of similar fire probability. Soil drainage was the most important factor controlling vegetation within the units of the overall pattern.

Because the locations of firebreaks and the existing pattern of vegetation controlled the fire probability pattern, sites with virtually identical physical characteristics supported qualitatively different types of persistent or stable vegetation.

Keywords: MN/ vt, Big Woods/ vt, prairie-forest ecotone/ vt, oak forest/ fire barriers/ GLO/ presettlement vegetation/ soil morphology/ soil drainage/ elm/ basswood/ maple, sugar/ ironwood/ hickory, bitternut/ butternut/ ash/ oak/ aspen.

245. ---. 1985. **Vegetation history along the prairie-forest border in Minnesota.** *In*, Spector, J. and Johnson, E. eds. *Archaeology, ecology, and ethnohistory of the prairie-forest border zone of Minnesota and Manitoba.* J&L Reprint Co., Lincoln, NE. p. 9-29.

Keywords: MN/ Canada/ Manitoba/ vt, prairie-forest ecotone/ fire, Native American use of/ fire history/ archaeology.

246. Habecker, M. A.; McSweeney, K., and Meyers, N. L. 1990. **Variability of a Fragiocrept with windthrow microtopography in north central Wisconsin.** *Soil Science Society of America Journal.* 54:483-488.

Keywords: WI/ soil morphology/ microsite/ windthrow, effects on soil.

247. Haines, Donald A.; Johnson, Von J., and Main, William A. 1975. **Wildfire atlas of the northeastern and north central states.** US Forest Service, General Technical Report NC-16. 25 pp.

Note: National Forest data from 1960 to 1969, was used to characterize wildfire patterns in the northeastern and north central United States. The national forests are: Allegheny, Chequamegon-Nicolet, Chippewa, Clark, Green Mountain, Hiawatha, Huron-Manistee, Mark Twain, Monongahela, Ottawa, Shawnee, Superior, Wayne-Hoosier, and White Mountain National Forests. Data was analyzed by vegetation cover, number of fires, acreage burned, man-hours-to-control, day-of-week, fire cause and peak activity seasons.

Keywords: MN/ WI/ MI/ northeastern United States/ eastern United States/ National Forest, Allegheny/ National Forest, Chequamegon-Nicolet/ National Forest, Chippewa/ National Forest, Clark/ National Forest, Green Mountain / National Forest, Hiawatha/ National Forest, Huron-Manistee/ National Forest, Mark Twain/ National Forest, Monongahela/ National Forest, Ottawa/ National Forest, Shawnee/ National Forest, Superior/ National Forest, Wayne-Hoosier/ National Forest, White Mountain/ fire weather/ wildfire statistics.

248. Haines, Donald A. and Kuehnast, Earl L. 1970. **When the midwest burned.** *Weatherwise.* 23(3):112-119.

Note: Publication explains climatic departures and synoptic weather conditions prior to and during the wildfires that occurred in the midwest early October, 1871. The midwest was experiencing a drought during summer of 1871. Sturgeon Bay,

Wisconsin, normally receives 12" of rain from June to September, only received 4.75" during that time period. Lansing, Michigan was 70% of normal and Thunder Bay was 64% of normal. Logging activity in Michigan, Minnesota and Wisconsin was very high at that time and about 1/4 of the tree was left as slash. On October 5 and 6 and low-moisture, high pressure system moved through the midwest and, a frontal system was over the upper midwest on October 8. The surface winds were fairly light. Some explanation is given as to why the major conflagrations happened with very little wind.

Keywords: Canada/ WI/ MI/ MN/ fire weather/ fire, review.

249. **Haines, Donald A. and Sando, Rodney W. 1969. Climatic conditions preceding historically great fires in the north central region. US Forest Service, Research Paper NC-34.**

Note: Prefire weather conditions of 7 large fall wildfires from Illinois, Michigan, Minnesota, and Wisconsin, that occurred between 1870 and 1920, are explained. Decreased precipitation over a 3 to 8 month period, vegetation in the wilt stage for 1 1/3 to 1 1/2 months, long-term below-normal humidity and above-average solar radiation were found to be important variables in explaining these mass fires. Other occurrences at the time such as multiple ignitions and a large build up of slash were also important in the fire behavior and extent of fire.

Keywords: MN/ MI/ WI/ IL/ fire weather .

250. **Hansen, Henry L.; Krefting, Laurits W., and Kurmis, Vilis. 1973. The forest of Isle Royale in relation to fire history and wildlife. University of Minnesota, Agricultural Experiment Station, Forestry Series 13, Technical Bulletin 294.**

Note: The changes in moose population after a large wildfire in 1936 (26,000 acres-19% of island area) changed the vegetation composition is explained. Also, a brief fire history from 1940-1965, summarized from Park records is given. There were a total of 48 wildfires on the island between 1940 and 1965 and of these, 26 were of lightning origin and 22 were human ignitions. The total area burned was 1,477.24 acres.

Keywords: MI/ Isle Royale/ vt, spruce-fir forest/ fire effects/ fire history/ fire weather/ mammals.

251. **Hansen, Henry L.; Kurmis, Vilis, and Ness, Darwin Delbert. 1974. The ecology of upland forest communities and implications for management in Itasca Park, Minnesota. University of Minnesota Agricultural Experiment Station, Forestry Series 16, Technical Bulletin 298. 43 pp.**

Note: Research done at Itasca State Park is summarized to answer management questions related to the possible re-creation of prelogging vegetation patterns. New information is presented on windthrow damage and experimental prescribed burns.

Itasca Park is in a transition zone between prairie, boreal forest and temperate hardwood forest. Past land-use includes logging on the private lands within the park boundaries between 1903 and 1919.

A 15 acre opening was created by a severe wind in 1953. Permanent plots were placed in damaged area and the damage to the trees was recorded. All damaged marketable red pines were salvaged. Data indicates balsam fir is the most susceptible to wind damage, and oaks and maples are the least. For red pine 12" dbh or greater, the annual wind induced mortality rate was 1.9%. Table in publication indicates more trees were broken than uprooted. Percent of stand damaged was as follows: balsam fir (22%), aspen (16%), red pine (14%), paper birch (14%), white pine (13%), and spruce (9%). There was no damage to oaks and maples.

Cover types and ecological units are discussed. Thirty-three communities were distinguished, and 5 ecological vegetation types that correspond to different soil/moisture conditions. They are: 1) moist, loam and silt loam soils, nutrient rich supporting northern hardwood stands. Sugar maple, basswood and ironwood are characteristic species. 2) Dry to moist, sandy loam to loam, intermediate nutrient to nutrient-rich supports mainly aspens and paper birch of post-disturbance origin. 3) Moist, loamy sand to coarse sand, intermediate nutrients supports the pine-fir association. Balsam fir is the most common regeneration species. 4) Dry to moist, loamy coarse sand to gravelly sandy loam soils, nutrient-poor to intermediate supports jack and red pines. 5) dry, medium to coarse sand to loamy sand soils, nutrient poor, supports jack pine. Red pine may dominate in the future.

Because pine does not seem to be regenerating itself in the park, a few sites were designated for prescribed burning and others for harvest and plant to maintain the pine component in the park. These areas were sampled before and after treatment and will be monitored in the future. The sites and the treatments were discussed

Keywords: MN/ Itasca Park/ vt, maple forest/ vt, aspen-birch forest/ vt, pine forest/ windthrow, tree damage/ fire, prescribed/ fire effects/ management/ classification/ soil morphology/ maple, sugar/ basswood/ ironwood/ aspen, trembling/ birch, paper/ balsam fir/ pine, jack/ pine, red/ pine, white/ spruce/ oak.

252. **Harvey, LeRoy H. 1922. Yellow-white pine formation at Little Manistee, Michigan. Botanical Gazette. 73:26-46.**

Note: Soils and vegetation of 2 remnant unlogged stands of the "Big Pines" formation were sampled in Lake county, Michigan. Data analysis indicates slight differences in vegetation composition due to differences in soil characteristics between the 2 sites. The age-class structure of the stands indicates that the stands originated after a catastrophic fire 400 to 450 years ago. Another catastrophic fire may have occurred 200 years ago. Since that time, the stands have not been affected by stand replacing fire.

Keywords: MI/ vt, pine forest/ fire history/ succession/ age-class structure/ soil morphology/ pine, white/ pine, red/ oak, red/ oak, white/ maple, red.

253. **He, Hong S. and Mladenoff, David J. 1999. Spatially explicit and stochastic simulation of forest-landscape fire disturbance and succession. Ecology.**

80(1):81-99.

Abstract: Understanding disturbance and recovery of forest landscapes is a challenge because of complex interactions over a range of temporal and spatial scales. Landscape simulation models offer an approach to studying such systems at broad scales. Fire can be simulated spatially using mechanistic or stochastic approaches. A fire module in a spatially explicit, stochastic model of forest landscape dynamics (LANDIS) that incorporates fire, windthrow, and harvest disturbance with species-level succession is described. A stochastic approach is suited to forest landscape models that are designed to simulate patterns over large spatial and time domains and are not used deterministically to predict individual events.

We used the model to examine how disturbance regimes and species dynamics interact across a large (500 000-ha), heterogeneous landscape in northern Wisconsin, USA, with six land types having different species environments, and fire disturbance return intervals ranging from 200 to 1000 years. The model showed that there are feedbacks over time between species, disturbance, and environment, and those that these result in the re-emergence of patterns that characterized the landscape before extensive alteration. Landscape equilibrium of species composition and age-class structure developed at three scales from the initial, disturbed landscape. Over 100-150 years, fine-grained successional processes cause gradual disintegration of the initial pattern of relatively homogeneous composition and age classes. Species such as eastern hemlock (*Tsuga canadensis*), largely removed from the landscape by past human activities, only slowly re-invaded. Next, patterns on the various land types diverged, driven by different disturbance regimes and dominant species. Finally, aging of the landscape caused the probabilities of larger and more severe fires to increase, and a coarse-grained pattern developed from the disturbance patches. Influence of adjacent land types is shown as fires spread across land type boundaries, although modified in spread and severity. As found by others, altered landscapes are likely to retain their modified pattern for centuries, suggesting that nonequilibrium conditions between tree species and climate will persist under predicted rates of climate change.

The results suggest that this modeling approach can be useful in examining species-level, broad-scale responses of heterogeneous landscapes to changes in landscape disturbance, such as modified management or land-use scenarios, or effects of global change.

Keywords: WI/ vt, oak forest/ vt, hemlock forest/ vt, hemlock-hardwood forest/ vt, aspen-birch forest/ vt, pine forest/ vt, pine barrens/ vt, maple forest/ windthrow, effects on vegetation/ logging/ wildfire/ landform/ remote sensing/ disturbance ecology/ fire modeling/ succession/ landscape ecology/ maple, sugar/ oak, red/ birch, yellow/ aspen, trembling/ aspen, big tooth/ birch, paper/ pine, white/ pine, red/ pine, jack/ hemlock.

254. Heinselman, Miron L. 1963. Forest sites, bog processes, and peatland types in the glacial Lake Agassiz region, Minnesota. *Ecological Monographs*. 33(4):327-

374.

Note: The relationships between black spruce growth and bog processes, forest sites and peatland types in the Lake Agassiz region are given. Peat characteristics, and hydrology is related to vegetation composition and patterns. Peat cores are examined to determine past vegetation and disturbance history. Charcoal in many layers was noted in a number of samples. The last fire noted in the Lindford area occurred about 1760. While vertical and horizontal water movement explains much of the vegetation patterning in the peat bogs, periodic fires also affect vegetation processes.

Keywords: MN/ vt, swamp forest/ charcoal/ fire regime/ flooding/ hydrology/ spruce, black.

255. ---. 1969. **Diary of the Canoe Country's landscape. *Naturalist*. 20(1):2-13.**

Note: Heinselmann gives a narrative on the fire history of BWCA. While not technical, it gives one a general feel for the pre-European to present fire regime.

Keywords: MN/ BWCAW/ National Forest, Superior/ vt, boreal forest/ vt, pine forest/ vt, conifer-feathermoss forest/ fire history/ fire scar/ pine, white/ pine, red/ pine, jack.

256. ---. 1970. **The natural role of fire in northern conifer forests. *In, The Role of Fire in the Intermountain West, Oct 27-29, 1970, University of Montana, Missoula.***

Keywords: MN/ National Forest, Superior/ BWCAW/ vt, boreal forest/ fire history.

257. ---. 1971. **The natural role of fire in northern conifer forests. *In, Slaughter, C. W.; Barney, R. J., and Hansen, G. M. Fire in the Northern Environment-A symposium, Apr 13-14, 1971, Fairbanks, Alaska. US Forest Service, Pacific Northwest Forest and Range Experiment Station. p. 61-72.***

Note: Originally presented at the Symposium, 'The role of fire in the Intermountain west,' October 27-29, 1970, in Missoula, Montana.

Abstract: The primeval conifer forests of North America, with their associated deciduous components, were largely fire-dependent ecosystems. Fire was a key environmental factor in controlling succession, species composition, and age structure of these forests. An almost universal policy of fire exclusion over the last 50 years is superimposing a vegetation succession which is "unnatural" and is often undesirable in terms of resource management. For most forested areas, a fire policy is advocated which involves selective control of wildfires and managed, prescribed burning to duplicate the natural fire regime.

Keywords: fire, review.

258. ---. 1971. **Restoring fire to the ecosystems of the Boundary Waters Canoe Area, Minnesota, and to similar wilderness areas. *In, Tall Timbers Fire Ecology Conference, Aug 20-21, 1970, Fredericton, New Brunswick. Tall Timbers Research Station, Tallahassee, FL.***

Note: A summary of conclusions from recent fire history research in BWCA; 1) At least 80 to 90% of the virgin forests can be traced to a post-fire origin. 2) Major fires recurred at 5- to 50-year intervals from at least 1600 A.D. to 1920.

Rebound intervals range from 300 to 10 years. 3) There may have been an increase in fire from 1800 to 1910 due to Euro- activities. 4) Very few virgin forest areas have burned since 1920 probably due to fire control. 5) Most stands have a nearly even-aged overstory dating back to the last fire. Some red pine and white pine stands consist of 1 or more age classes, each dating from separate fires. Some stands regenerated slowly and have a mixture of ages. 6) The areas burned most frequently or intensely are large uplands distant from natural firebreaks. Jack pine, black spruce, aspen, birch, other sprout hardwoods, and fir dominate such areas. 7) Area burned least frequently or intensely are sites naturally less subject to fire, such as swamps, ravines, lakeshores, the lower slopes of high ridges, islands, and the east, north, northeast, or southeast sides of large lakes or streams. White pine, red pine, white spruce, and northern white-cedar are relatively more abundant on such sites. 8) Fire was probably frequent enough to prevent succession from proceeding toward the theoretical spruce-fir-birch climax. 9) The vegetation that might develop with fire exclusion is in a sense unnatural and largely unknown to science.

Keywords: MN/ BWCAW/ National Forest, Superior/ vt, boreal forest/ vt, pine forest/ vt, conifer- feathermoss forest/ vt, aspen-birch forest/ vt, spruce-fir forest/ fire history/ fire regime/ fire barriers/ pine, red/ pine, white/ pine, jack/ spruce, black/ aspen, trembling/ birch, paper/ balsam fir/ spruce, white/ northern white cedar .

259. ---. 1973. **Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota. Quaternary Research. 3:329-382.**

Note: Probably most referenced publication in the Great Lakes region on the subject of fire regimes.

Abstract: Fire largely determined the composition and structure of the presettlement vegetation of the Boundary Waters Canoe Area as well as the vegetation mosaic on the landscape and the habitat patterns for wildlife. It also influenced nutrient cycles, and energy pathways, and helped maintain the diversity, productivity, and long-term stability of the ecosystem. Thus the whole ecosystem was fire-dependent.

At least some overstory elements in virtually all forest stands still date from regeneration that followed one or more fires since 1595 A.D. The average interval between significant fire years was about 4 yr in presettlement times, but shortened to 2 yr from 1868 to 1910 during settlement. However, 83% of the area burned before the beginning of suppression programs resulted from just nine fire periods: 1894, 1875, 1863-4, 1824, 1801, 1755-9, 1727, 1692, 1681. The average interval between these major fire years was 26 yr. Most present virgin forests date from regeneration that followed fires in these years. Significant areas were also regenerated by fires in 1903, 1910, 1936, and 1971. Most major fire years occurred during prolonged summer droughts of subcontinental extent, such as those of 1864, 1910, and 1936. Many fires were man-caused, but lightning ignitions were also common. Lightning alone is probably a sufficient source of ignitions to guarantee that older stands burned before attaining climax. Dry matter accumulations, spruce budworm outbreaks, blowdowns, and other

interactions related to time since fire increase the probability that old stands will burn. Vegetation patterns on the landscape were influenced by such natural firebreaks as lakes, streams, wetlands, and moist slopes. Red and white pine are most common on islands, and to the east, northeast, or southeast of such firebreaks. Jack pine, aspen-birch, and sprout hardwood forests are most common on large uplands distant from or west of such firebreaks.

A Natural Fire Rotation of about 100 yr prevailed in presettlement times, but many red and white pine stands remained largely intact for 150-350 yr, and some jack pine and aspen-birch forests probably burned at intervals of 50 yr or less. There is paleoecological evidence that fire was an ecosystem factor before European man arrived, and even before early man migrated to North America. Probably few areas ever attained the postulated fir-spruce-cedar-birch climax in postglacial times. To understand the dynamics of fire-dependent ecosystems fire must be studied as an integral part of the system. The search for stable communities that might develop without fire is futile and avoids the real challenge of understanding nature on her own terms.

To restore the natural ecosystem of the Canoe Area fire should soon be reintroduced through a program of prescribed fires and monitored lightning fires. Failing this, major unnatural, perhaps unpredictable, changes in the ecosystem will occur.

Keywords: MN/ BWCAW/ National Forest, Superior/ vt, boreal forest/ vt, pine forest/ vt, conifer-feathermoss forest/ vt, aspen-birch forest/ fire scar/ fire regime/ fire interval/ GLO/ presettlement vegetation/ pine, red/ pine, jack/ pine, white/ aspen, trembling/ birch, paper.

260. ---. 1981. **Fire and succession in the conifer forests of northern North America.** *In*, West, D. C.; Shugart, Herman H., and Botkin, D. B. *Forest Succession: Concepts and Applications*. Springer-Verlag, New York. p. 374-405.
Note: The interactions between vegetation dynamics and fire regimes in the northern coniferous forests is explained. Many of the authors listed in this bibliography are cited. A good reference.
Keywords: fire, review/ fire regime.
261. ---. 1981. **Fire intensity and frequency as factors in the distribution and structure of northern ecosystems.** *In*, Mooney, H. A.; Bonnicksen, T. M.; Christensen, N. L.; Lotan, J. E., and Reiners, W. A. *Fire Regimes and Ecosystem Properties*, Dec 11-15, 1978. Honolulu, Hawaii. US Forest Service. pp. 7-57.
Note: Heinselman reported that across North America, fire cycles vary with latitude, elevation, and topographic-climate factors. The Great Lakes-Acadian forest had regimes of short cycle crown fires in near-boreal jack pine and spruce forests, combinations of moderate intensity short-interval surface fires and small-scale crown fires at longer intervals in red-white pine forests, and low intensity long-interval fires in hardwoods. Observing these regimes still prevail in the far north, regimes and the forest mosaic are greatly modified by logging, man-caused fires, and fire suppression in the settled regions of the United States. He went on

to note that geologic and topographic variations “exert strong control over fire movements, and the prevailing topography of an ecosystem may account substantially for the scale and pattern of fire-controlled vegetation mosaics. Soils and bedrock are also important because the moisture holding capacity of soils and the local drainage situation relate to drought responses in vegetation, and thus to differences in fire histories. The paper, along with Heinselman (1973) is commonly cited for descriptions of fire regimes in the near boreal forest. Contains good tables and explanations of listed fire regimes.

Abstract: Most presettlement Canadian and Alaskan boreal forests and Rocky Mountain subalpine forests had lightning fire regimes of large-scale crown fires and high-intensity surface fires, causing total stand replacement on fire rotations (or cycles) of 50 to 200 years. Cycles and fire size varied with latitude, elevation, and topographic-climate factors. Some areas had smaller, less-intense surface fires at shorter intervals. The Great Lakes-Acadian forest had regimes of short cycle crown fires in near-boreal jack pine and spruce forests, combinations of moderate intensity short-interval surface fires and small-scale crown fires at longer intervals in red-white pine forests, and low intensity long-interval fires in hardwoods. Fire maintained the structures and pattern of the forest mosaic.

These regimes still prevail in the far north. Elsewhere regimes and the forest mosaic are greatly modified by logging, man-caused fires, and fire suppression.

Keywords: MN/ BWCAW/ National Forest, Superior/ vt, boreal forest/ vt, conifer-feathermoss forest/ vt, pine forest/ vt, maple forest/ vt, hemlock-hardwood forest/ fire frequency/ fire regime/ pine, jack/ pine, red/ pine, white/ spruce, black/ balsam fir/ hemlock/ birch, yellow/ birch, paper/ oak/ aspen, trembling/ aspen, big tooth/ maple, sugar/ maple, red.

262. ---. 1996. *The Boundary Waters Wilderness Ecosystem*. University of Minnesota Press, Minneapolis.

Keywords: MN/ National Forest, Superior/ BWCAW/ wildfire.

263. Henderson, Richard A. 1993. Ten year response of a Wisconsin prairie remnant to seasonal timing of fire. *Restoration & Management Notes*. 11(1):53.

Note: The following is abstract from article in Proc. 12th North American Prairie Conf., pp. 121-125.

Abstract: From 1980 to 1989, Henderson used four experimental plots in south central Wisconsin to test remnant prairie responses to burn treatments in late fall, early spring, late spring and a no-burn control. The late spring plot was the only one that showed significant change in plant composition, and by 1989 its composition was markedly different from the other plots. Most of the change was due to declines in sedge species (*Carex* spp.), Kentucky bluegrass (*Poa pratensis*), flowering spurge (*Euphorbia corollata*) and panic grass (*Panicum leibergii* and *P. oligosanthes*).

Keywords: WI/ vt, prairie/ fire, prescribed/ fire effects/ restoration ecology/ herbs.

264. Henderson, Richard A. and Statz, Sandra H. 1995. *Bibliography of fire effects and related literature applicable to the ecosystems and species of Wisconsin*. 1

ed.. Department of Natural Resources, Madison. Technical Bulletin 187.

Abstract: This bibliography provides 841 literature citations pertinent to the effects of fire and its prescribed use on the ecosystems and species of Wisconsin and the upper Midwest. Three separate subject indexes are provided: one for general topics, one for species (165 headings), and one for geographic location by state or province (51 headings). The general index is divided into 8 broad subject categories, under which there are 28 topic and 58 subtopic headings. The largest subject category, and the main focus of this publication, is Effects of Fire (on soil, water, air, biota, etc.) with 11 topic headings, 41 subtopic headings, and 706 citations. The other categories are Behavior of Fire (2 topics, 5 subtopics, 78 total citations), History of Fire (4 topics, 129 total citations), Effects of Fire Regimes (6 topics, 12 subtopics, 87 total citations), Drought and Fire Interactions (5 citations), Fire Policy (12 citations), Conducting Prescribed Burns (2 topics, 11 total citations), and Other Fire Related Management (2 topics, 54 total citations). Also included is a brief and very general overview of the role of fire in Wisconsin and its effects on the ecosystems and species of the state.

Keywords: WI/ fire effects/ fire behavior/ fire history/ soils/ bibliography.

265. **Henson, Don. 1989. Undertake restoration of Northern Oak-Pine Savanna Complex (Michigan). Restoration & Management Notes . 7(1):30-31.**

Note: An incomplete list of prairie species found a Shakey Lakes Savanna, located 6 km due west of Stephenson, MI, indicating that the area is a true prairie. Two prescribed burns were carried out in 1988. There was no mention of the past fire regime.

Keywords: MI/ vt, prairie/ vt, oak savanna/ fire, prescribed/ restoration ecology/ herbs.

266. **Herriges, Ray P. 1980. Fire on the Prairie: memories of Lac Qui Park. Located at Century College West, MN.**

Keywords: MN/ vt, prairie/ wildfire.

267. **Hibbs, David E. 1983. Forty years of forest succession in central New England. Ecology. 64(6):1394-1401.**

Abstract: The first 40 yr of forest succession on permanent plots at the Harvard Forest in central New England followed the initial floristic composition model of forest succession. After the 1938 hurricane removed the previous white pine (*Pinus strobus*) canopy, species regenerated within 4-6 yr by sprouts, buried seed, and wind-blown seed, with no method of regeneration uniformly contributing more to species success than another. Hemlock (*Tsuga canadensis*) was the only species successfully regenerating after 1948. Pin cherry (*Prunus pennsylvanica*) was the early dominant in size and numbers (5000 stems/ha). At year 10, pin cherry, red maple (*Acer rubrum*), white ash (*Fraxinu americana*), and red oak (*Quercus rubra*) were dominant. Species diversity had reached a maximum. By year 40, red oak and paper birch (*Betula papyrifera*) showed strong canopy dominance, making up only 7.5 and 4.9%, respectively, of total density but 37.5 and 12.5%, respectively, of the size-dominant stems. Red maple and white pine were codominant in 1978. Some evidence for an intermediate stage dominated by

red maple and gray birch (*B. populifolia*) was found. On one previously hardwood plot, the same species were present, and similar trends in species composition and dominance were followed, but there was more surviving hemlock advance regeneration and a lower density of some shade-intolerant early dominant species. The canopy structure was loosely multi-layered, and at any given point in succession, species tended to be found in characteristic layers, although these relative positions could change with time.

Keywords: MA/ Harvard Forest/ eastern United States/ vt, pine-hemlock-hardwood forest/ hurricane / windthrow, effects on vegetation/ succession/ disturbance ecology/ pine, white/ hemlock/ cherry, pin / maple, red / ash, white / oak, red / birch, paper/ birch, gray.

268. **Holbrook, Stewart H. 1943. *Burning an Empire*. Macmillan, New York.**

Note: The events leading up to, during and after many of the great wildfires of the 1800's to early 1900's are described. Wildfires cited are the Miramichi Valley fire (1825), Peshtigo and Michigan fires (1871), Michigan fires of 1881, Hinckley-Baudette and Wisconsin fires (1894), Cloquet-Moose Lake fires (1918) and fires that occurred in Oregon, Washington, the Carolinas, E. Texas and Florida around the same time period. While most of the descriptions center around plight of the human population, a map could be constructed showing fire spread from the times given in the book. Because most of the wildfires began as slash fires, most had multiple starting points. The only one listed as having a single starting point was the Wisconsin fire of 1894. At least a few of the ignition sources for the Michigan fires of 1881 were due to lightning strikes.

Keywords: WI/ MI/ MN/ OR/ WA/ NC / SC / TX/ FL/ wildfire, historic/ wildfire/ fire behavior .

269. **Holla, Teresa A. and Knowles, Peggy. 1988. Age structure analysis of a virgin White Pine, *Pinus strobus*, population. *Canadian Field-Naturalist*. 102(2):221-226.**

Abstract: Age structure characteristics were examined in an undisturbed, mature White Pine (*Pinus strobus*) stand located at Sanford Lake in northwestern Ontario. Sample trees were aged and measured for diameter. The White Pine population showed a multi-aged distribution, a low expectation of life in the lower age classes, a higher one in later years, and a high age/diameter correlation. Fire evidence suggests that a major fire approximately 200 years ago may have stimulated initial establishment, with a more moderate fire 80 years ago contributing to a slight population increase. The multi-aged distribution points to a continual recruitment as the major component of population dynamics, with the role of fire as a minor component. It is suggested that these characteristics, including mass and continual recruitment, are consistent with other White Pine populations.

Keywords: Canada/ Ontario/ vt, pine forest/ age-class structure/ fire history/ pine, white.

270. **Homann, P. S. and Grigal, David F. 1997. Below-ground organic carbon and decomposition potential in a field-forest glacial-outwash landscape. *Biology and Fertility of Soils*. 23(2):207-214.**

Abstract: Variations in the relationships of soil properties to land use and topography exists due to differences in other factors. These were investigated by studying the relationship of below-ground C (as soil organic C + fine-root C) and decomposition potential to site characteristics at Cedar Creek Natural History Area in east-central Minnesota, USA. The landscape, formed in glacial outwash sand, has a complex spatial pattern of grasslands and forests resulting from interactions among cultivation, agricultural abandonment, topography, and fire. Below-ground C was higher in mature forests than in either adjacent abandoned agricultural fields or uncultivated prairie for both the O Horizon (0.57 v. 0.13 kg/m²) and the underlying 0-10 cm of soil (2.1 v. 1.0 kg/m²) but was similar at 10-30 cm (2.0 v. 2.0 kg/m²) and 30-50 cm (1.4 v. 1.5 kg/m²). The higher C in surface soil under forests contrasted with published observations for finer textured substrates. Below-ground C was constant across the forest summit, shoulder, and backslope positions, and increased at the toeslope position. Average fine-root (<2 mm diameter) C at the depth of 0-50 cm was 0.2 kg/m² and represented 4% of below-ground C. In contrast to an expected trend of monotonically increasing decomposition with increased temperature, cellulose decomposition during a 60-day field incubation increased with temperature on cool forest slopes but decreased with temperature in warm fields. Nutrient availability, water availability, and microbial biomass may confound this relationship. The results indicate diverse controls on decomposition in this field-forest landscape.

Keywords: MN/ Cedar Creek Natural History Area/ vt, prairie/ fire, prescribed/ fire effects/ carbon and nitrogen cycling/ landscape ecology/ soil morphology/ land-use/ landform.

271. **Host GE, Pregitzer KS, Ramm CW, Hart JB, and Cleland DT 1987. Landform-mediated differences in successional pathways among upland forest ecosystems in northwestern Lower Michigan. Forest Science 33:445-457.**

Abstract: Seedling and sapling densities were compared with current overstory composition in 30 upland forest stands in northwestern Lower Michigan to study potential successional pathways. The patterns of compositional change were strongly related to topographic and edaphic differences among glacial landforms. Glaciofluvial landforms, currently dominated by oak, have relatively high densities of oak seedlings (4913 stems/ha) that seldom move into the sapling layer (10 stems/ha). Oak-dominated ecosystems on hilly ice-contact stratified drift exhibited relatively high densities of red maple saplings (48 stems/ha). Oak-dominated ecosystems on extremely well drained outwash plains exhibited sparse sapling regeneration of any species; red maple was typically absent, and oak saplings were usually in an apparent state of decline. Differences in the potential for recruitment of saplings into the overstory among these ecosystems may be attributable to differences in fire history or site-dependent effects on the competitive abilities of species. Morainal landforms, currently supporting relatively diverse northern hardwood overstories, showed little potential recruitment of any species other than sugar maple. Glacial landforms in northwestern Lower Michigan direct compositional change by influencing soil moisture and nutrient availability, and historical patterns of disturbance and species establishment.

Keywords: MI/ vt, oak forest/ regeneration, seed/ geology/ landform/ life history

attributes/ oak/ maple, red.

272. **Hull, Melvin K.; O'Dell, Clyde A., and Schroeder, Mark J. 1966. Critical fire weather patterns...their frequency and levels of fire danger. US Forest Service, Pacific Southwest Forest and Range Experiment Station, AD-634 565.**

Note: Weather data from 1951 to 1960 was analyzed to distinguish weather patterns that affect fire danger. These are listed, characterized and illustrated on a map of the continental United States. Supplements with in-depth analysis for each of the 14 regions are published but, I have not been able to track down the one for the Lakes region yet.

Keywords: North America/ fire weather/ fire, review.

273. **Hungerford, R. D.; Frandsen, W. H., and Ryan, K. C. 1995. Ignition and burning characteristics of organic soils. In, Cerulean, S. I. and Engstrom, T. R. Fire in wetlands: a management perspective: proceedings of the Tall Timbers Fire Ecology Conference. Tall Timbers Research Station, Tallahassee, FL. p. 78-91.**

Note: A sedge meadow in Seney NWR, Michigan, was one of the sites used in this research.

Abstract: Surface fires in wetland ecosystems frequently ignite smoldering ground fires. Ground fires often create and maintain open, shallow marshes that contribute to ecosystem diversity. Fire exclusion, drainage, deforestation, and other human activities have altered the landscape patterns and ecosystem processes in wetlands. Land managers who recognize the ecological role of fire want to use it as a management tool in wetlands. Conflicts between concerns such as air quality and ecosystem management objectives limit the range of acceptable fire prescriptions. Land managers need information on ignition and burnout of organic soils to successfully use fire in wetlands and to make decisions about allocating resources for wildfires.

In this paper we review the current state of knowledge on the ignition and burnout of organic soils and present initial results of laboratory ignition and smoldering experiments with soil samples collected from North Carolina pocosins and Alaska black spruce boreal forest. Initial results from a prescribed burn in Alaska are also presented and contrasted with duff from the Northern Rocky Mountains. Ignition tests were applied to black spruce and pocosin soil samples to determine the effect of soil moisture and mineral content on limits to ignition. Initial results for a range of inorganic contents indicate that pocosin soils will ignite at moisture contents from 25% to 100% higher than for peat moss and for feather moss from Alaska.

The data suggest that bulk density and moisture content of organic materials may influence ignition and temperatures more than does soil origin. Temperatures observed in the combustion zone of prescribed fires and in laboratory burns of undisturbed soil cores are quite similar even for different organic materials. Soil temperature profiles (depth and magnitude of heating) are related to the duration

of heating and the amount of organic material consumed. Lab and field data presented here are being used to validate and modify existing physical models that predict consumption of organic material and heat transfer into the soil.

Keywords: NC / AK/ MI/ vt, sedge meadow/ vt, wetland/ fire, review/ fire, prescribed/ fire behavior/ soils, organic .

274. **Hunter, M. L. 1993. Natural fire regimes as spatial models for managing boreal forests. *Biological Conservation*. 65:115-120.**
Keywords: vt, boreal forest/ fire regime/ fire modeling.
275. **Hutnik, R. J. 1952. Reproduction on windfalls in a northern hardwood stand. *Journal of Forestry*. 50:693-694.**
Keywords: vt, northern hardwood forest/ windthrow, effects on vegetation.
276. **Irving, A. D. 1880. Geology of the Eastern Lake Superior District. *In*, *Geology of Wisconsin*, by T.C. Chamberlain. 3:89-91.**
Note: Has reference to the great windfall of 1872 near the Chippewa River, WI. Cited in Stearns (49).
Keywords: WI/ windthrow, occurrence of.
277. **Irving, Frank D. 1981. Fire in Savanna Restoration: A 17-year Record . *Restoration and Management Notes*. 1(1):9.**
Note: An abstract outlining the prescribed fire data that is being collected at Cedar Creek Natural History Area, MN. Further description can be found in Irving, 1970 Tall Timbers Conference.
Keywords: MN/ Cedar Creek Natural History Area/ vt, oak savanna/ fire, prescribed/ fire effects/ restoration ecology.
278. **Irwin, Larry L. 1975. Deer-moose relationships on a burn in northeastern Minnesota. *Journal of Wildlife Management*. 39(4):653-662.**
Note: This study was conducted at the Little Sioux Fire area.
Abstract: A study of habitat selection and distributions of white-tailed deer (*Odocoileus virginianus*) and moose (*Alces alces*) was conducted from July 1972 through December 1973 on a 5,920-ha burn that occurred in spring 1971 in northeastern Minnesota. Most use of coniferous stands within the burn by both moose and deer occurred in late fall and early spring, but they selected deciduous stands above all others ($P < 0.05$), especially in summer and fall. Moose and deer utilized aquatic communities from late May through June. Both species selected postburn communities that produced large amounts of preferred forage. Sites logged prior to the fire and openings along roads were attractive to deer. Association coefficients confirmed moose and deer utilized similar communities in summer and fall, but by December they occurred in similar communities by chance. Aerial and ground observations of animal groups indicated that moose and deer used the burn during summer and the periphery and unburned forest during winter. Coefficients of dietary overlap indicated relatively high overlap occurred during fall, when deer used browse plants more often. This study suggests the large burns, which produce large quantities of woody forage in

boreal forest, allow moose populations to increase despite the presence of deer and the pathogenic nematode parasite *Parelaphostrongylus tenuis*.

Keywords: MN/ National Forest, Superior/ Little Sioux Fire/ vt, boreal forest/ fire effects/ wildfire, historic/ mammals/ deer browsing.

279. **Jakala, Stephen G. 1995. Underburning to reduce fire hazard in the Southern Boreal Transition Forest of Voyageurs National Park, Minnesota. In, Proceedings: symposium on fire in wilderness and park management, Mar 30-1, 1993, Missoula, MT. US Forest Service, General Technical Report INT-320. p. 211-213.**

Note: Pre- and post-burn fuel loading and vegetation results are reported following 2 prescribed burns in red and white pine dominated stands. Fire behavior and weather conditions are given. It was concluded that 1) fire exclusion from the park has allowed for the increase of small trees in the understory of white and red pine stands. 2) The hazardous fuel consists of dead and down woody material, litter and duff and understory trees that create a fuel ladder into the overstory trees. 3) In red and white pine stands, even low intensity fires, when the relative humidity is above 45%, can cause canopy scorch due to understory vegetation.

Keywords: MN/ Voyageur's National Park/ vt, pine forest/ fire behavior/ fire, prescribed/ fuels/ pine, red/ pine, white.

280. **Jakubauskas, M. E.; Lulla, K. P., and Mausel, P. W. 1990. Assessment of vegetation change in a fire-altered forest landscape. PE and RS, Photogrammetric Engineering and Remote Sensing. 56(3):371-377.**

Abstract: Landsat Multispectral Scanner (MSS) data from June 1973 and Landsat Thematic Mapper (TM) data from October 1982 were classified using an unsupervised approach to create pre-fire and post-fire maps of the National Forest in N. Michigan, where an intense fire (Mack Lake Fire in May 1980) had destroyed >9000 ha of pine and broadleaved forest. Using a raster-based geographic information system (GIS), the maps were compared and a map of vegetation change was created. An infrared/red band ratio from a June 1980 Landsat scene was classified to create a map of 3 degrees of burn intensity, which was then compared with the vegetation change map using a GIS. Classification comparisons of pine (*Pinus banksiana*, comprising nearly half the forest destroyed by fire) and broadleaves (mainly *Populus tremuloides*, *Betula papyrifera* and *Quercus* spp.) exhibited increasing change with increasing severity of burn, while the shrub vegetation showed the opposite effect with the greatest change in the lightly burned areas. The dominant class of change by broadleaves was to pine forest in all degrees of burn intensity. The results, from diverse sensors, agreed with vegetation regrowth trends observed in ground-based studies of fire damaged areas. The ability to detect vegetation change using post classification comparison within the context of GIS analysis is discussed.

Keywords: MI/ National Forest, Huron-Manistee/ vt, pine forest/ vt, aspen-birch forest/ remote sensing/ wildfire/ fire effects/ succession/ pine, jack/ aspen, trembling/ birch, paper/ oak.

281. **James, T. D. W. and Smith, David W. 1977. Short-term effects of surface fire on the biomass and nutrient standing crop of *Populus tremuloides* in southern Ontario. Canadian Journal of Forest Research. 7:666-679.**
Keywords: Ontario/ Canada/ vt, aspen forest/ fire, prescribed/ fire effects/ fuels/ vegetation, nutrient analysis/ aspen, trembling.
282. **Jenkins, Jerry. 1995. Notes on the Adirondack Blowdown of July 15th, 1995; Scientific background, observations, and policy issues. Wildlife Conservation Society, Working Paper No. 5.**
Keywords: NY/ northeastern United States/ windthrow, occurrence of.
283. **Johnson, B. G. and Dynesius, M. 1993. Uprooting in boreal spruce forests: long-term variation in disturbance rate. Canadian Journal of Forest Research. 23:2383-2388.**
Keywords: vt, boreal forest/ disturbance ecology/ windthrow, tree damage/ spruce, black.
284. **Johnson, E. A. 1992. *Fire and vegetation dynamics-studies from the North American boreal forest.* Cambridge University Press, Cambridge, UK.**
Keywords: vt, boreal forest/ fire modeling/ fire effects.
285. **Johnson, E. A. and Gutsell, S. L. 1994. Fire frequency models, methods and interpretations. Advances in Ecological Research. 25:239-287.**
Note: This is a very good paper at explaining the linkage between fire history studies and fire regime models. The publication suggests strong points and weak points of other research listed in this bibliography.
Keywords: fire frequency/ methodology/ fire modeling/ fire, review.
286. **Johnson, E. A. and Van Wagner, C. E. 1985. The theory and use of two fire history models. Canadian Journal of Forest Research. 15:214-220.**
Keywords: fire modeling.
287. **Johnson, Paul S. 1974. Survival and growth of northern red oak seedlings following a prescribed burn. US Forest Service, Research Note NC-177.**
Abstract: Mortality of northern red oak seedlings in a spring prescribed burn was related to temperature near the root collar. Most of the 42 percent of seedlings that survived the burn developed new shoots from the root collar.
Keywords: WI/ vt, oak forest/ fire, prescribed/ fire effects/ oak, red.
288. **Johnson, Von J. 1976. Drought and fire in the Lake States. Fire Management Notes. p. 7-10.**
Note: In fall of 1976, the Lake States were in a severe drought that had begun earlier that summer. Acreages are reported for the large fires in the area. The Palmer index was used to indicate the severity of the drought in July and October.
Keywords: WI/ MI/ MN/ fire weather/ fire suppression.
289. **Jones, E. W. 1945. The structure and reproduction of the virgin forest of the north temperate zone. New Phytologist. 44(2):130-148.**

Note: Vegetation dynamics and forest stand structure of many countries of the northern temperate zone are compared. Fire regimes vary but are common factor in all regions.

Keywords: circumpolar/ fire regime.

290. **Kell, Lucille Lora. 1938. The effect of the moisture-retaining capacity of soils on forest succession in Itasca Park, Minnesota. American Midland Naturalist. 20:682-694.**

Note: This paper is referenced by Buell and others in studies investigating the invasion -retreat interactions of maple-basswood and spruce-fir along the tension zone.

Abstract: Soil moisture equivalents (s.m.e.) of 20 different stands of different successional stages, located in an area burned by 1907 wildfires in Itasca Park, were compared. The mean, maximum and minimum s.m.e.'s were different for the different sites. Some examples of dominant tree species (pioneer to climax) of the stands include jack pine with no evident climax, jack pine going to fir-spruce, red pine to fir-spruce, and white pine to maple-basswood. Mean moisture equivalents ranged from 3.1 (jack pine site) to 18.0 (white pine going to maple basswood site). Three climax communities are discussed are ash-elm-fir on peat, sugar maple-basswood on fine-textured mineral soils, and fir-spruce-birch on coarse-textured mineral soils.

Keywords: MN/ Itasca Park/ vt, pine forest/ vt, jack pine forest/ vt, spruce-fir forest/ vt, maple forest/ vt, swamp forest/ fire effects/ succession/ soil moisture/ soil morphology/ pine, jack/ pine, white/ pine, red/ balsam fir/ spruce, white/ maple, sugar/ basswood.

291. **Kent, S. W. 1978. Estimating crown fuel component weights of spruce budworm-killed balsam fir in northeastern Ontario. University of Toronto, Ontario. 58 pages + appendices.**

Keywords: Canada/ Ontario/ vt, boreal forest/ vt, spruce-fir forest/ budworm, spruce/ fuels/ balsam fir.

292. **Kessell, Stephen R. 1976. Gradient modeling: a new approach to fire modeling and wilderness resource management. Environmental Management. 1(1):39-48.**

Abstract: Managers of wilderness resources must maintain, preserve, and sometimes restore pristine ecosystems while providing for public use and enjoyment of these areas. These managers require a resource information system that can store, retrieve and integrate basic data, synthesize components to solve particular problems, and provide simulations and predictions of natural processes and management actions. Traditional information systems based on land classification and type-mapping do not provide these capabilities.

Gradient modeling, a new approach to resource management and forest fire simulation, has been developed to meet these needs in Glacier National Park. The method links four major components: (1) a terrestrial site inventory coded from aerial photographs that offers 10-m resolution; (2) gradient models of vegetation and fuel that derive quantitative stand compositional data from the parameters

stored in the coded inventory; (3) a fuel moisture and microclimate model that extrapolates base-station weather data to remote sites using the parameters stored in the inventory; and (4) fire behavior and fire ecology models that integrate the data from the inventory and models to calculate real-time fire behavior and ecological succession following a fire.

Keywords: MT/ fire modeling/ gradient analysis/ management.

293. ---. 1979. *Gradient modelling: resource and fire management*. Springer-Verlag, New York.

Keywords: MT/ fire, prescribed/ wildfire/ gradient analysis/ management/ fire modeling.

294. Kilburn, Paul D. 1957. *Historical development and structure of the aspen, jack pine and oak vegetation types on sandy soils in northern Lower Michigan*. University of Michigan, East Lansing. Ph.D. dissertation.

Note: Unpublished fire scar data collected by S.H. Spurr and scars from one old red pine by a white pine stand, indicates pre-European settlement fire interval of 1 fire/100 years. There were only a few references to burned areas in the GLO notes. Fires were very frequent from 1880 to 1920. Biologists at station observed major fires at the University of Michigan Biological Station in 1892, 1901, 1911 and 1923. Fires occurred near Carp Creek in 1880, 1886, 1896, 1899, 1907 and 1908. It was estimated that around the turn of the century, fires occurred once every 5 years.

Abstract: This study of the vegetation of Cheboygan County, Michigan, deals specifically with the following three forest types found on the sandy soils in the region: an aspen type dominated by Populus grandidentata, a jack pine type dominated by Pinus banksiana, and an oak type dominated by Quercus rubra and Q. alba.

The specific purpose is threefold: (1) to determine the structure and composition of the above types; (2) to investigate the features determining location of each type; and (3) to describe the course of vegetational development. The general purpose is to determine the role of succession and the continuum in the vegetation.

The investigation was made in four parts. The first describes the development of postglacial vegetation, using the pollen analysis work of others as a basis. The second reconstructs the pre-settlement vegetation from the General Land Office Survey data. The third considers the effect of settlement on the vegetation. The fourth is an analysis of the present vegetation and soils through six one-acre sample plots located in, and 15 soil samples taken from, each of the three types. In addition, a 17-year record from four tenth-acre plots in aspen and jack pine types is considered to show changes in the vegetation.

Postglacial vegetational development began with a period of spruce-fir dominance, followed by a period of pine dominance, and concluded by a deciduous period. The latter period was essentially similar to the pre-settlement

period with five vegetation-complexes distributed along the soil moisture gradient as follows: wet organic soils, bog conifers; wet-moist mineral soils, swamp hardwood-conifer admixture; loams, sugar maple-beech-hemlock forests; sandy loams, transition forests; sands, pine woodlands.

The present aspen, jack pine and oak types represent modified pre-settlement pine-hemlock-aspen, pine-oak and jack pine forest types. These forest types were probably differentiated during the postglacial pine period. The present distribution of the present day types is controlled primarily by the soil texture. The aspen type is on sands with finest texture, the oak and jack pine types on sands of coarsest texture.

The understory of the three types is similar. *Pteridium aquilinum* is the plant with the largest frequency and highest coverage in each of the three types, and the 25 most frequent plants are present in all three types. Differences are present, but they are quantitative.

The general conclusions are as follows: (1) the vegetation-complexes, as well as the three sandy soil forest types, are best described as a continuum of stable vegetation whose composition is governed primarily by soil texture and drainage; and (2) the succession to a beech-maple climax forest is not evidenced by the dry land types, nor by pre-settlement vegetation complexes, although succession is illustrated by those types which have been severely modified by man.

Keywords: MI/ vt, aspen forest/ vt, pine barrens/ vt, pine-oak forest/ vt, pine-hemlock-hardwood forest/ vt, oak forest/ vt, swamp forest/ vt, maple forest/ logging/ land-use/ fire scar/ fire interval/ GLO/ presettlement vegetation/ pollen analysis/ paleoecology/ soil morphology/ aspen, big tooth/ pine, red/ pine, white/ pine, jack/ oak, red/ oak, white/ herbs.

295. ---. 1960. **Effects of logging and fire on xerophytic forests in northern Michigan.** *Bulletin of the Torrey Botanical Club.* **87(6):402-405.**

Note: Comparisons of pre- and post-logging vegetation composition on sandy soils in Cheboygan County, Michigan were made. From the GLO notes, 3 vegetation types were distinguished, hemlock-pine, pine-oak and jack pine-red pine-pin oak. After logging and slash fires, stands were converted from hemlock-pine, pine-oak and jack pine-red pine-pin oak types to bigtooth aspen, red oak-white oak and jack pine-pin oak types, respectively.

Keywords: MI/ vt, pine-hemlock-hardwood forest/ vt, pine-oak forest/ fire, late 19th century logging/ logging/ GLO/ presettlement vegetation/ hemlock/ pine, white/ pine, red/ pine, jack/ aspen, big tooth/ oak, pin.

296. **Kimmins, J. P. 1987. Fire: A pervasive and powerful environmental factor. In, Kimmins, J. P. *Forest Ecology*. Macmillan Publishing Company, New York. p. 287-303.**

Note: A general description of fire ecology. The text describes types and occurrence of fires. And, describes of the effects of fire on soils, vegetation, animals, ecosystems and ecosystem processes.

Keywords: fire, review/ fire effects.

297. **King, D. A. 1986. Tree form, height growth, and susceptibility to wind damage in *Acer saccharum*. *Ecology*. 67:980-990.**

Keywords: maple, sugar/ windthrow, tree damage.

298. **Kittredge, Joseph, Jr. 1934. Evidence of the rate of forest succession of Star Island, Minnesota. *Ecology*. 15(1):24-35.**

Note: A study of forest succession was carried out on Star Island, a 1200 acre island, surrounded by Cass Lake. Fire scars were found on red and white pine for the years of 1808, 1818, 1865, 1871 and 1872. A 100 year old jack pine originated after a fire in 1824. Jack pine stands were an equal mix of jack pine and red pine. In the smaller size classes (0.5 to 4.5 feet), red pine was more numerous than jack pine. White pine was also present (100 tpa) in the 0.5 to 4.5 feet size class, as was paper birch, red maple and balsam fir. Within the red pine stands 98% of trees greater than 8" dbh were red pine. The red pine were close to 200 years old and will probably maintain their dominance for at least another 50 years. There was red pine reproduction but, white pine seedlings were 3 times as abundant. The 250 year old white pine stand consisted of almost equal numbers of white pine and red pine. Reproduction is mostly sugar maple, along with a few white pine, basswood and red oak seedlings. It was hypothesized that this stand represented a successional stage that was at least 220 years older than the 200 year old red pine stand. The white pine-maple-basswood type indicates a transition from pine to hardwood. A few old (greater than 300 years) red and white pine remain. Sugar maple, paper birch, red maple and basswood are more common than the pines in the overstory and, sugar maple dominates the reproduction. The maple-basswood type consists of sugar maple, basswood, elm and red oak. Regeneration consists of almost solely sugar maple. The stand was affected by a wildfire about 60 years ago. Basswood resprouted and sugar maple did not. The previous stand was probably over 200 years old and similar in composition. Soils are Cass Lake fine sand. See Alway and McMiller (1933) and Alway et al. (1933) for a description of island soil and topography, vegetation, etc.

Keywords: MN/ National Forest, Chippewa/ island/ vt, pine forest/ vt, maple forest/ fire interval/ fire scar/ succession/ age-class structure/ pine, jack/ pine, red/ pine, white/ maple, sugar/ basswood/ birch, paper/ maple, red.

299. **Kittredge, Joseph Jr. and Chittenden, A. K. 1929. Oak forests of northern Michigan. Michigan Agricultural Experiment Station, East Lansing. Special Edition 190.**

Note: The emphasis of this paper is to describe 1) the vegetation composition of the oak forests on different soil types, 2) post-harvest regeneration, and 3) growth characteristics of the 4 most common oaks growing in sandy soils of northern Michigan. The effect of fire was also explained. The pre-logging vegetation was described by examining stumps found throughout the area and by the few stands that had not been logged and burned. Red pine and white pine were common dominants and oaks were subdominants prior to logging. After logging and slash

fires, most of the conifer seed trees were removed and the oaks resprouted. Of the 77 plots sampled with as little evidence of fire as possible, 66 still showed evidence of one or more fires. The average fire interval was 9 years. Many trees survived multiple fires indicating most were surface fires rather than crown fires.
Keywords: MI/ vt, oak forest/ vt, pine forest/ fire interval/ logging/ regeneration, vegetative/ soil morphology/ pine, red/ pine, white/ pine, jack/ oak, red/ oak, white/ oak, scarlet/ oak, black.

300. **Kline, V. M. and Cottam, Gordan. 1979. Vegetational response to climate and fire in the Driftless Area of Wisconsin. Ecology. 60:861-868.**

Keywords: WI/ fire effects/ weather, effects on vegetation.

301. **Knighton, M. Dean. 1977. Hydrologic response and nutrient concentrations following spring burns in an oak-hickory forest. Soil Science Society of America Journal. 41:627-632.**

Abstract: Annual spring burns were applied for 1 to 3 years on a 25 to 50% slope in an oak-hickory forest (*Quercus-Carya*) in southwestern Wisconsin. Overland flow and sedimentation did not increase, although no severe storms occurred during the study.

Fires of light to moderate intensities, consumed most of the fresh litter and sometimes all of the fermentation layer. Mean weight of litter plus fermentation layers were significantly reduced ($\alpha = 0.05$) from 15,800 kg/ha by three annual burns. Bulk density, total pore volume, organic carbon content, and water permeability of the mineral soil were unaltered. Stems < 5 cm in diameter at breast height were killed, but shrubs sprouted vigorously and herbaceous vegetation was not altered.

Mean concentrations of both anions [$\text{PO}_4\text{-P}$ and $(\text{NO}_3 + \text{NO}_2)\text{-N}$] and cations (Ca, Mg, K) in the soil leachate collected at 15-cm depth appeared to increase after burning although the differences were small and highly variable. Significant changes ($\alpha = 0.05$) in the concentrations of both anions were measured through the growing season. Concentrations of $(\text{NO}_3 + \text{NO}_2)\text{-N}$ peaked 6 weeks after the mid-April fires, which reflects increased nitrification following burning. Sodium concentrations were not affected by burning. Although it was increased by burning nutrient loss to deep leaching appeared to be approximately equivalent to, or less than, estimated annual input from precipitation.

Keywords: WI/ vt, oak forest/ fire, prescribed/ fire effects/ soil drainage/ soils, nutrient analysis/ hydrology/ oak, red/ oak, bur/ hickory, shagbark.

302. **Komarek, E. V., Sr. 1966. The meteorological basis for fire ecology. In, Komarek, Roy. Proceedings of the Annual Tall Timbers Fire Ecology Conference, Mar 24-25, 1966. Tall Timbers Research Station, Tallahassee, FL. p. 85-126.**

Note: Meteorological events that cause lightning to occur are explained. A case study of meteorological events and lightning caused fires of 1965 is presented.

Keywords: fire weather/ wildfire.

303. ---. 1968. **Lightning and lightning fires as ecological forces. In, Proceedings of the Annual Tall Timbers Fire Ecology Conference. Tall Timbers Research Station, Tallahassee, FL. p. 169-198.**
Note: A description of the extent and effect of lightning on wildland fire regimes is presented. Seven lightning bio-climatic regions are proposed. They are 1) southern pine forest, 2) eastern deciduous forest, 3) central grasslands, 4) boreal forest, 5) tundra, 6) western mountain complex, 7) tropical evergreen forest (rain forest). The Great Lakes area is included with the boreal forest region.
Keywords: fire weather/ vt, boreal forest/ vt, southern pine forest/ vt, deciduous forest/ vt, grassland/ vt, tundra/ vt, western mountain complex/ vt, rain forest/ classification.
304. **Krefting, Laurits W. and Ahlgren, Clifford E. 1974. Small mammals and vegetation changes after fire in a mixed conifer-hardwood forest. Ecology. 55(6):1391-1398.**
Note: Located in Lake County, MN-Heart Lake, and Keeley Creek burns.
Abstract: Following wild fire in northeastern Minnesota small mammals were snap-trapped on two burned and one unburned area for three nights each fall from 1955 to 1967. The deer mouse (*Peromyscus maniculatus*) was the most abundant species on the two burns the first 7 yr. Later the vegetation changes apparently produced a habitat less attractive to the deer mouse, while the red-backed vole (*Clethrionomys gapperi*) increased. Numbers of meadow voles (*Microtus pennsylvanicus*), jumping mice (*Zapus hudsonius*), and cinereus shrews (*Sorex cinereus*) were low and erratic on all areas. Eastern chipmunks (*Tamias striatus*) were abundant most years on only one of the burns.
Keywords: MN/ National Forest, Superior/ vt, mixed conifer hardwood forest/ fire, prescribed/ fire effects/ mammals.
305. **Kruger, Eric L. 1992. Survival, growth and ecophysiology of northern red oak (*Quercus rubra* L.) and competing tree regeneration in response to fire and related disturbance. University of Wisconsin, Madison. Ph.D. dissertation. 215 pp.**
Abstract: I examined the potential role of fire in the reestablishment of northern red oak (*Quercus rubra* L.) on productive forest sites by monitoring the response of red oak and competing tree regeneration to repeated burning in mesic forest openings in southwestern Wisconsin. In separate experiments I also studied the response to red oak seedlings to top-kill (stem destruction), a common consequence of fire. Measures of plant response to fire and top-kill included survival, height and biomass growth, leaf gas exchange, and whole-plant, carbohydrate and nitrogen relations. In general, fire appeared to enhance the competitive status of northern red oak regeneration on mesic sites. Repeated spring surface fires had little impact on oak survival, growth and ecophysiology in mesic forest openings. However, fire adversely affected the survival and growth of several of oak's competitors on mesic sites, including sugar maple (*Acer saccharum* Marsh.) and white ash (*Fraxinus americana* L.). There was evidence that the deleterious impact of fire on several species may have been related primarily to the action of top-kill. In contrast, oak was little affected by top-kill,

and in separate studies it was found to fully compensate in terms of biomass for initial stem loss through slightly increased growth rates. The differential effects of fire on biomass growth of oak, ash and maple were attributed to fire-induced changes in two co-determinants of relative growth rate (RGR), leaf area ratio (LAR) and leaf photosynthesis rate. Fire stimulated photosynthesis but reduced LAR for maple. For ash and oak, fire increased LAR and had a modest positive influence on photosynthesis. Treatment and species differences in RGR were associated primarily with variation in leaf area ratio (LAR), as the two were significantly and positively correlated. The influences of fire on leaf photosynthesis and LAR may have been interrelated, in that fire appeared to stimulate leaf photosynthesis via an increase in root:leaf ratio. The increase in root:leaf ratio was thought to result from a fire-induced decrease in the production of leaf area. Studies on oak indicated that top-kill could in certain instances reduce subsequent canopy size, and in turn alter leaf photosynthetic performance through changes in root-leaf balance.

Keywords: WI/ fire effects/ physiology/ oak, red/ ash, white/ maple, sugar.

306. **Kruger, E. L. and Reich, Peter B. 1997. Responses of hardwood regeneration to fire in mesic forest openings. I. Post-fire community dynamics. Canadian Journal of Forest Research. 27:1822-1831.**
Keywords: WI/ vt, oak forest/ fire, prescribed/ fire effects/ regeneration, vegetative/ maple, sugar/ oak, red/ hop hornbeam/ hickory, bitternut/ herbs.
307. ---. **1997. Responses of hardwood regeneration to fire in mesic forest openings. II. Leaf gas exchange, nitrogen concentration, and water status. Canadian Journal of Forest Research. 27:1832-1840.**
Keywords: WI/ vt, oak forest/ vt, maple forest/ fire, prescribed/ fire effects/ physiology/ regeneration, vegetative / oak, red/ maple, sugar/ ash, white.
308. ---. **1997. Responses of hardwood regeneration to fire in mesic forest openings. III. Whole-plant growth, biomass distribution, and nitrogen and carbohydrate relations. Canadian Journal of Forest Research. 27:1841-1850.**
Keywords: WI/ vt, oak forest/ vt, maple forest/ fire, prescribed/ fire effects/ physiology/ regeneration, vegetative / oak, red/ maple, sugar/ ash, white.
309. **Lapham, I. A. 1965. The great fires of 1871 in the northwest. Wisconsin Academy Review. 12(1):6-9.**
Note: This article was originally published in the 1871 War Department Report of the Chief Signal Officer. Lapham was the first scientist/naturalist in Wisconsin (forester, botanist, meteorologist). He was one of the first to publish works on botany, forestry, windthrow from the surveyors notes, etc..

The weather conditions that caused the Chicago, Peshtigo and other large fires of 1871 are explained. There are ideas on how to live on the edge of a prairie and not lose everything in a fire (homes not made of wood, etc.).

Keywords: WI/ IL/ wildfire/ wildfire, historic.

310. **Leak, William B. and Smith, Marie-Louise. 1996. Sixty years of management and natural disturbance in a New England forested landscape. *Forest Ecology and Management*. 81:63-73.**

Abstract: Changes in species composition of overstory trees (percent of basal area) and size class were monitored over 60 years on 441 cruise plots located on the Bartlett Experimental Forest, a 1052 ha experimental forest in the White Mountains of New Hampshire. The plots were analyzed by elevation class, landtype (deciduous and coniferous), and year (1931-1932, 1939-1940, and 1991-1992) within managed and unmanaged stands. The primary changes in species composition over the 60-year period were due to natural succession, which resulted in marked increases (doubling) of the eastern hemlock (*Tsuga canadensis* (L.) Carr.) component, and consistent decreases in paper birch (*Betula papyrifera* Marsh.), yellow birch (*B. alleghaniensis* Britton) (at medium to low elevations), and aspen (*Populus* spp.). Timber management resulted in small decreases in the beech (*Fagus grandifolia* Ehrh.) and red spruce (*Picea rubens* Sarge.) component and slight increases in sugar maple (*Acer saccharum* Marsh.). Natural disturbances (beech-bark disease and hurricane damage) had only minor effects on species occurrence. No consistent evidence of red spruce (*Picea rubens* Sarg.) decline was detected. Eastern hemlock, a climatically sensitive species in northern New England with a limited elevational range, increased dramatically at moderate to low elevations, but showed little tendency to invade the highest elevation class; apparently, the warming trend reported elsewhere in New Hampshire is not occurring, or the species are not responding in terms of changes in elevational distribution. The results emphasize the resilience of New England forests and their resistance to exogenous disturbance.

Keywords: NH/ northeastern United States/ hurricane/ windthrow, effects on vegetation/ disease/ succession/ logging/ disturbance ecology/ hemlock/ birch, paper/ birch, yellow/ aspen/ beech/ spruce, red/ maple, sugar.

311. **LeBarron, R. K. 1939. The role of forest fires in the reproduction of black spruce. *The Minnesota Academy of Science, Proceedings*. 7:10-15.**

Note: Even-aged spruce stands frequently establish after wildfire as evidenced by charred stumps in many spruce stands. In Koochiching, St. Louis, Lake, and Cook counties, charcoal was found in peat samples taken from black spruce swamps. In some cases, charcoal was found in many different levels. Black spruce seed does not travel very far, thus seed must stay viable through fire. To determine black spruce seeding distances, a seed rain study was initiated by Ely. Within stand density was 300,000 seeds/acre; at 100 feet from edge of stand, it was 18,000 seeds/acre and at 200 feet the seed rain was only 8,000 seeds/acre (no mention of tree density or age). The attributes that enable black spruce to reestablish after a fire are as follows: 1) Consistent seed crops. At the same site, from 1931 to 1938, there was never a year that was a complete seed crop failure. 2) Seeds viable for many years. Viable seeds took at least 2 or 3 years to drop to the ground. Viability of seeds collected in 1936 ranged from 60% to 36% to 30% for new, 1 year old, and older cones, respectively. In 1937, the new and 1 year old seed viability was 76%. 3) Cone serotiny is indicated. After the Markham fire of 1936, dead black spruce trees would shower seeds when struck with an

axe. Two years later, area had good stocking of 2 year old spruce seedlings.

Keywords: MN / vt, conifer-feathermoss forest/ wildfire/ charcoal/ life history attributes/ regeneration, seed/ spruce, black.

312. **LeBlanc, Henri. 1954. A new approach to the northern spruce regeneration problem. Forestry Chronicle.; 30(4):372-379.**

Note: The focus of this paper is the comparison of humus between two vegetation types. Of interest in terms of fire regime is the account of stand history. The black spruce stand originated after a catastrophic fire in 1865, and clearcut in 1941. A few patches of unburned lowlands indicate the previous stand consisted of trees between 120 and 180 years old. There were also scattered patches of jack pine in areas where the litter layer was removed completely. On the upper slopes, the regeneration was to hardwoods.

Abstract: Lack of reproduction of black spruce, *Picea mariana*, in pure black spruce stands in old cut-over areas, has always been a great subject of discussion and one for intensive work among forester. Many reasons such as the absence of an adequate seed supply stored on top of humus, or adverse germination conditions are said to be partly responsible.

This study on the humus of this unregenerated cut-over area, indicates clear cutting of this stand will influence the normal concentration of definite micro-nutrients such as manganese and magnesium.

The augmentation of manganese in the soil has a detrimental effect on the growth of plants when its concentration is too high. The diminution of magnesium, which is a element necessary to stimulate the growth, must create abnormal nutritive conditions of the habitat. This visible lack of equilibrium might be the cause of the absence of seedlings of *Picea mariana* on certain parts of the cut-over area.

Keywords: Quebec/ Canada/ vt, conifer-feathermoss forest/ wildfire/ litter and duff/ regeneration, seed/ spruce, black.

313. **Leininger, Theodor D.; Wilson, A. Dan, and Lester, Donald G. 1997. Hurricane Andrew damage in relation to wood decay fungi and insects in bottomland hardwoods of the Atchafalaya Basin, Louisiana. Journal of Coastal Research. 13(4):1290-1293.**

Abstract: Hurricane Andrew caused damage to more than 780 sq. km of bottomland hardwood and cypress-tupelo forests in the Atchafalaya Basin of Louisiana in August 1992. Trees in bottomland hardwood sites were examined, in early May 1994, for signs and symptoms of wood decay fungi, and for insect damage, ostensibly present before the hurricane, which may predispose trees to windthrow or breaks in the bole or top. Three sites with severe wind damage and three sites with minor wind damage were studied along the path of the hurricane. Surveying for wood decay fungi and insects on trees, and evaluating damage to crowns, stems, and roots was done on 25-m diameter point-sample plots.

Evidence of wood decay fungi and insects, or the damage they cause, was rare at all sites, in part because of flooding during the evaluation, so that predisposition

to wind damage by these agents was not established. Crown damage rating classes and d.b.h. classes were positively correlated for sites with severe wind damage indicating that larger diameter trees were more susceptible to wind damage than smaller diameter trees. Chinese tallow, swamp cottonwood, pumpkin ash, American sycamore, and swamp dogwood showed greater wind damage on sites with severe wind damage than other species.

Keywords: LA/ vt, bottomland hardwood forest/ hurricane/ windthrow, tree damage/ insects/ disease/ Chinese tallow/ cottonwood, swamp/ ash, pumpkin / sycamore/ dogwood, swamp.

314. **Leitner, L. A.; Dunn, Christopher P.; Guntenspergen, Glenn R.; Stearns, Forest W., and Sharpe, D. M. 1991. Effects of site, landscape features, and fire regime on vegetation patterns in presettlement southern Wisconsin. *Landscape Ecology*. 5:203-217.**

Keywords: WI/ GLO/ presettlement vegetation/ fire regime/ landscape ecology.

315. **Lemon, Paul C. 1961. Forest ecology of ice storms. *Bulletin of the Torrey Botanical Club*. 88(1):21-29.**

Abstract: Glaze storms of destructive intensity, caused by certain frontal conditions, visit northern and eastern parts of the United States periodically; ice thickness occasionally exceeds 2 in. Resistance to glaze breakage is a complex matter, not simply related to one factor such as green wood strength, crown pattern, taxonomic group, exposure, and nature of the stand. The more resistant tree species are some of the dominants of climax forest communities. Several of the more susceptible species belong to early stages in succession, causing a slight acceleration of the rate of succession. A plea is made for improved and standardized glaze observations.

Keywords: weather, effects on vegetation/ review.

316. **Lewis, Henry T. 1980. Indian fires of spring. *Natural History*. 89(1):76-83.**

Note: Past use of fire by Indians inhabiting Canadian boreal forests is described. Most of the information comes from interviewing older individuals who were alive prior to the enforcement of existing fire laws. The natives did most of their burning in the spring in the openings or prairies surrounded by forest. They knew that a variety of habitat was required for many of the species they were interested in harvesting.

Keywords: Canada/ vt, boreal forest/ vt, prairie/ fire, Native American use of.

317. **---. 1982. A time for burning. Boreal Institute for Northern Studies, University of Alberta, Edmonton, Alberta, Canada. Occasional Publication number 17.**

Keywords: Canada/ vt, boreal forest/ fire, Native American use of.

318. **Liechty, H. O.; Jurgensen M.F.; Mroz, G. D., and Gale, M. R. 1997. Pit and mound topography and its influence on storage of carbon, nitrogen, and organic matter within an old-growth forest. *Canadian Journal of Forest Research*. 27:1992-1997.**

Note: Taken from Gerlach, Gilmore, Zasada.

Abstract: Pit and mound microtopography created by tree windthrow is a dominant feature in many old-growth forests in the Great Lakes Region. This study investigated whether stand-level quantities, or processes which control quantities of carbon, nitrogen, and organic matter in forest floor and mineral soil, have been altered by changes in microtopography caused by windthrow. Comparison of flat or relatively undisturbed surfaces with the areas that contained mounds, pits, and flat features combined indicated no changes in the amounts of carbon, nitrogen, or organic matter in the forest floor or mineral soil as a result of pit and mound microtopography. However, there was an increased mixing of forest floor organic matter within mineral soils of mounds as compared to pits. Decomposition potential after 10 weeks, as indicated by cotton strip assay method, was 116% greater within the mineral soils of mounds than in pits. The decomposition rates in the mineral soil in the mounds were related to greater amounts of organic matter, temperatures, and moisture contents within this feature. Changes in sink sizes related to organic matter mixing or alteration in decomposition were minimal. Thus long-term stand-level storage of carbon, nitrogen, or organic matter in forest floor or mineral soil pools was not found to be significantly altered by changes in microtopography resulting from windthrow disturbance levels found within this study area.

Keywords: microsite/ pit and mound/ windthrow, effects on soil.

319. **Loomis, Robert M. and Blank, Richard W. 1981. Summer moisture content of some northern Lower Michigan understory plants. US Forest Service, Research Note NC-263.**

Note: Roscommon County, MI.

Abstract: Summer moisture contents and factors for converting fresh plant weights to oven-dry weights were determined for selected herbs, ferns, and small shrubs commonly found on upland sites in northern Lower Michigan. Sampling was done weekly from mid-June through early September 1978, following the period of major plant growth. Average summer moisture contents ranged from 120 percent for blueberry (*Vaccinium* spp.) to 370 percent for wild lily-of-the-valley (*Maianthemum canadense*). Generally, moisture content averages and trends were similar for plant groups sampled in both northern Lower Michigan and northeastern Minnesota. Herbaceous fuel moisture percentages computed using the 1978 National Fire Danger Rating System for the same time period showed a similar general trend but were significantly lower than observed values.

Keywords: MI/ fuels/ blueberry/ lily of the valley, wild/ herbs/ shrubs.

320. **Loomis, Robert M.; Roussopoulos, Peter J., and Blank, Richard W. 1979. Summer moisture contents of understory vegetation in northeastern Minnesota. US Forest Service, Research Paper NC-179. 7 pp.**

Keywords: MN/ fuels.

321. **Loope, Walter L. 1991. Interrelationships of fire history, land use history, and landscape pattern within Pictured Rocks National Lakeshore, Michigan. Canadian Field-Naturalist. 105(1):18-28.**

Abstract: Forest fire history in Upper Michigan was studied using cross-sections

from living fire scarred trees and 100 year old fire scarred stumps from Pictured Rocks National Lakeshore (PRNL). Prior to the late 19th century, surface fires were common within pine-dominated patches of very well-drained soils with an average fire occurrence rate of one per 21.8 years. Since the era of European settlement, there have been no significant forest fires within PRNL. This difference in fire occurrence likely involves changes in the influence of native peoples upon the landscape, in land use patterns and in the public policy and technology of fire control. Changes in vegetation structure attributable to patterns of fire and land use history are evident upon comparison of present vegetation characteristics and 19th century land line survey records. Patterns of fire occurrence for specific areas within PRNL possibly suggest that large scale landscape connectivity may also play a role in the fire regime.

Keywords: MI/ vt, pine forest/ fire interval/ fire scar/ soil morphology/ land-use/ fire, Native American use of/ pine, red/ pine, white/ pine, jack.

322. **Lorimer, Craig G. 1977. The presettlement forest and natural disturbance cycle of northeastern Maine. *Ecology* . 58:139-148.**

Keywords: ME/ northeastern United States/ disturbance ecology/ presettlement vegetation

323. ---. 1980. **The use of land survey records in estimating presettlement fire frequency. In, Stokes, M. A. and Dieterich, John H. Proceedings of the Fire History Workshop, Oct 20-24, 1980, Laboratory of Tree-Ring Research, University of Arizona, Tucson. Rocky Mountain Forest and Range Research Station, Fort Collins, CO. p. 57-62.**

Abstract: Records from early government land surveys can be used to estimate the proportion of stands killed by fire in a 15-25 yr period preceding the survey for vast areas of presettlement forest. Identification of post-fire stands is possible in some regions. Assumptions and problems of interpretation are discussed.

Keywords: fire history/ GLO/ methodology.

324. ---. 1985. **Methodological considerations in the analysis of forest disturbance history. *Canadian Journal of Forest Research*. 15:200-213.**

Abstract: A number of nondestructive techniques for analyzing the timing, frequency, and magnitude of natural disturbances in forest stands are discussed in this paper. Intensive age determination of trees is desirable for reconstructing forest disturbance history, but age distribution alone is not always a sufficient basis for a disturbance chronology. Frequently all-aged forests have undergone severe past disturbance which cannot be readily identified from the distribution of trees among age-classes. Radial growth patterns provide more direct evidence of past canopy tree deaths. In cases where a large sample of tree ages and growth records is not feasible, structural attributes of forests can provide valuable supplementary evidence. Evidence of the effects of disturbance history and age structure on diameter distributions is examined, and principles of valid interpretation proposed. Crown area distributions and diameter distributions of non-suppressed trees potentially appear to be more reliable structural indicators of past canopy disturbance than simple size distributions. For regional studies of

disturbance frequency, random dispersal of medium to large plots across large landscape units is recommended as a sample design.

Keywords: disturbance ecology/ methodology.

325. ---. 1989. **Relative effects of small and large disturbances on temperate hardwood forest structure. Ecology. 70(3):565-567.**

Note: This publication is part of a special Ecology issue on treefall gaps and forest dynamics. Lots of references on the subject.

Keywords: vt, northern hardwood forest/ windthrow, review/ disturbance ecology/ windthrow, effects on vegetation/ canopy gap.

326. ---. 1993. **Causes of oak regeneration problems. In, Oak regeneration: serious problems, practical recommendations: Symposium Proceedings, Sep 8-10, 1992. Knoxville, Tennessee. Southeastern Forest Experiment Station. p. 14-39.**

Abstract: Historical records indicate that oak species dominated much of the central hardwood forest at the time of settlement. However, many oak stands harvested in the past 40 years on average or good sites are now dominated to various degrees by other hardwood species. Several possible causes are discussed, including acorn predation, climatic change, damage to seedlings by insects and deer, and excessive competition resulting from decreased fire frequency. A number of these factors appear capable of reducing the success of oak regeneration or causing nearly complete failures. However, mature oak stands usually have several hundred to several thousand oak seedlings per acre present in the understory. The crux of the problem often appears to be the failure of these seedlings to survive and increase in vigor, even when released from competition. Slow juvenile growth occurs even where deer browsing is uncommon and appears to be an inherent trait of northern red oak and white oak on mesic and dry-mesic sites. Experimental evidence shows that the dense understory of shade-tolerant species on mesic sites is a major limiting factor to adequate oak seedling development, and that seedling development is markedly improved if the understory is removed. Historical evidence suggests that many of our existing oak stands on mesic sites either developed after fire or were periodically subjected to fire and other disturbances removing understory and subcanopy trees. Historical evidence on changes in fire frequency is reviewed, and problems with the fire hypothesis are discussed.

Keywords: vt, oak forest/ fire effects/ fire, Native American use of/ regeneration, seed/ oak, red/ oak, white/ oak/ review.

327. ---. 2001. **Historical and ecological roles of disturbance in eastern North American forests: 9,000 years of change. Wildlife Society Bulletin. 29:425-439.**

Keywords: fire effects/ wildlife/ paleoecology/ presettlement vegetation/ windthrow, effects on vegetation/ disturbance ecology/ land-use.

328. Lorimer, Craig G. and Frelich, Lee E. 1989. **A methodology for estimating canopy disturbance frequency and intensity in dense temperate forests. Canadian Journal of Forest Research. 19:651-663.**

Abstract: Analysis of the frequency of past moderate and high-intensity disturbances has been hindered in forests of complex age structure by methodological problems. A methodology is proposed for developing a disturbance chronology in such stands by identifying the probable date of canopy accession for each sample tree. Canopy accession dates are based on an evaluation of radial growth pattern and early growth rates of existing canopy trees. Canopy disturbance intensity is defined as the percentage of sample trees with canopy accession events in each decade. Rotation periods for disturbances of various intensities are calculated from the chronology. The method was evaluated using 893 increment cores from 70 plots in northern hardwood stands of western Upper Michigan. The estimated average disturbance rate for all plots and decades was 5.7-6.9% of land area per decade, with an implied average canopy tree residence time of 145-175 years. These estimates are similar to those obtained by on-site estimates of canopy tree residence time and studies in the literature on the rate of gap formation. Problems in radial increment analysis and possible solutions are discussed.

Keywords: MI/ Porcupine Mountains/ Huron Mountains/ Sylvania Recreation Area/ vt, maple forest/ vt, hemlock-hardwood forest/ disturbance ecology/ disturbance frequency/ succession/ canopy gap/ maple, sugar/ hemlock/ birch, yellow.

329. ---. 1994. **Natural disturbance regimes in old-growth Northern Hardwoods. Journal of Forestry. 92(1):33-38.**

Note: Results of research on disturbance regimes and landscape structure of the Northern Hardwood region is reviewed and, the value to hardwood restoration is explained.

Keywords: vt, northern hardwood forest/ vt, maple forest/ vt, hemlock-hardwood forest/ vt, hemlock forest/ old-growth/ fire, review/ windthrow, effects on vegetation/ restoration ecology/ disturbance ecology/ review/ hemlock/ maple, sugar/ beech/ birch, yellow/ basswood.

330. **Lorimer, Craig G., Frelich Lee E., and Nordheim, E. V. 1988. Estimating gap origin probabilities for canopy trees. Ecology. 69:778-785.**

Abstract: A method is presented for estimating the probability that existing canopy trees were growing in gaps during the sapling stage, given observed mean 5-yr radial growth rates starting when the trees were 4 cm d.b.h. Required calibration data are frequency distributions of radial growth rate for existing saplings that are currently suppressed in the forest understory vs. those of saplings growing in gaps. Threshold growth rates for high confidence of gap origin are calculated in an iterative fashion using growth rate data and interpretation of radial increment patterns. The method is illustrated with data from sugar maple (*Acer saccharum*) and eastern hemlock (*Tsuga canadensis*) in mature and old northern hardwood forests of western Upper Michigan. The proportion of canopy trees that had been growing in gaps during the sapling stage ranged from 35 to 67% in different stands. This wide range suggests the adaptability of these two late-successional, shade-tolerant species to a variety of stand microenvironments.

Keywords: MI/ canopy gap/ disturbance ecology/ methodology/ age-class

structure/ maple, sugar/ hemlock.

331. **Lorimer, Craig G. and Gough, William R. 1988. Frequency of drought and severe fire weather in north-eastern Wisconsin. *Journal of Environmental Management*. 26:203-219.**
Abstract: A daily record of drought was calculated with the Keetch-Byram drought index from temperature and rainfall data from the period 1864-1979. Historic fire records indicate that most fires >120 ha in size have occurred at levels exceeding the 80th percentile of 10-day mean drought index observations. Unusually large conflagrations, such as the Peshtigo Fire of 1871, occurred at levels at, or exceeding, the 95th percentile on days with $\leq 40\%$ relative humidity. Days with moisture conditions conducive to the spread of large fires in slash, windfall, and pine forest fuels are common; 36% of the years had at least 15 days with suitable conditions. Weather conditions similar to those at the time of historic conflagrations are much less frequent, but years with at least 10 days of extreme burning conditions have occurred at average intervals of 18 years. A comparison of drought severity in each year suggests that 1976 had by far the most severe drought conditions in the 116-year period, and that many droughts in recent decades were as severe as those at the time of post-settlement conflagrations. Lightning fire frequency is highest during drought years, apparently because of higher ignition probability during dry periods.
Keywords: WI/ fire weather.
332. **Lovejoy, P. S. 1920. The effect of forest fires upon the soil of the North Lake states. *Michigan Academy of Science*; 22:9-20.**
Note: The report is a discussion among scientists on the effects of fire on the humus layer of the soil.
Keywords: MI/ fire effects/ litter and duff.
333. **Lyford, W. H. and MacLean, D. W. 1966. Mound and pit micro-relief and tree distribution in New Brunswick, Canada *In, Harvard Forest Paper*. Harvard University, Cambridge, MA. p. 1-18.**
Keywords: windthrow, effects on soil/ microsite/ Canada.
334. **Lynham, Timothy J.; Curran, T.R. 1998. Vegetation recovery after wildfire in old-growth red and white pine. Canadian Forestry Service, Great Lakes Forestry Centre. *Frontline Technical Note 100*.**
Note: Wildfire was in Quetico Provincial Park, Ontario on August 1995.
Keywords: Canada/ Ontario/ vt, pine forest/ wildfire/ fire effects/ regeneration, seed/ pine, red/ pine, white/ pine, jack/ balsam fir.
335. **MacCleery, Doug. 1994. Understanding the role the human dimension has played in shaping America's forest and grassland landscapes. Is there a landscape archaeologist in the house? *Eco-Watch*.**
Note: Examples of Native American use of fire before European settlement are presented and, how our perception of "natural" has been distorted by authors who portray the pre-European landscape as "wilderness", untouched by human hands.

Poses some good arguments as to why we need to understand the human element and nature in landscape dynamics.

Keywords: fire, Native American use of/ presettlement vegetation.

336. **MacDonald, B. 1995. The case for boreal mixedwood management: an Ontario perspective. *Forestry Chronicle*. 71:725-735.**
Keywords: Canada/ Ontario/ fire/ logging/ silviculture/ management.
337. **Main, William A. and Haines, Donald A. 1974. The causes of fires on northeastern National Forests. US Forest Service, Research Paper NC-102. 7 pp.**
Note: Tabulation of wildfire cause data collected from 1960 to 1969 including all the forests in Region 9. The data indicate that lightning caused fires are significant.
Keywords: wildfire statistics.
338. **Maissurow, D. K. 1935. Fire as a necessary factor in the perpetuation of white pine. *Journal of Forestry*. 33:373-378.**
Note: One of the first publications to indicate that fire may be important in the perpetuation of white pine. The paper is a summary of forest survey data (600 square miles) in pine territory located in the southwestern part of Pontiac County, Quebec (Lat. 46-40 N; Logn. 78-48 W). A few observations on the locations of pine reproduction include: 1) small openings (2-5 trees) as a result of surface fires, 2) steep slope and ravines (erosion), 3) low streambanks or dry ponds subject to inundation, 4) small lake islands, 5) rocky ridges where trees are subject to windthrow. Pine reproduction was usually absent in very young stands but became noticeable 10 to 25 years after a fire. Pure stands of white pine were observed in 40+ year old post-burn areas. Most of the white pine reproduction was established after forest fires and not after logging. Logging removed the seed trees thus, regeneration could not occur.
Keywords: Quebec/ Canada/ vt, boreal forest/ vt, pine forest/ fire effects/ pine, white.
339. ---. 1941. **The role of fire in the perpetuation of virgin forests of northern Wisconsin. *Journal of Forestry*. 39:201-207.**
Note: The composition, age structure, and origin of 22 virgin stands of the mixed hardwood type on the Nicolet N.F. are reported. Most of the stands had evidence of fire and most originated after fire (95%). Uneven aged stands were common and seemed to be perpetuated by surface fires. Types included in the study were mixed hardwoods (loamy soils, various mixtures of sugar maple, yellow birch, basswood, some white pine, hemlock, white spruce and balsam fir), and hemlock-hardwood mixtures (hemlock with varying mixtures of hardwoods and softwoods).
Keywords: WI/ National Forest, Chequamegon-Nicolet/ vt, maple forest/ vt, hemlock-hardwood forest/ fire history/ fire effects/ pine, white/ hemlock/ maple, sugar/ birch, yellow/ basswood/ spruce, white/ balsam fir.
340. **Manni, Edwin E. 1978. Kettle River, Automba, Kalevala, and surrounding area**

history: also 1918 forest fire stories.

Keywords: MN/ wildfire/ wildfire, historic.

341. **Marks, John B. 1942. Land use and plant succession in Coon Valley, Wisconsin. Ecological Monographs. 12(2):113-133.**

Note: Past and present land-use influencing vegetation dynamics in Coon Valley, Wisconsin, is described. The early prairie-oak scrub dominant landscape is associated with burning by Native Americans. After the migration European settlers, the changes in vegetation composition and structure due to the reduction of burning and the increase in grazing, logging and haying is also presented.

Keywords: WI/ vt, prairie-oak scrub/ vt, oak forest/ vt, maple forest/ logging/ soil drainage/ fire, Native American use of/ land-use/ succession/ presettlement vegetation/ oak, red/ oak, white/ pine, white/ maple, sugar/ basswood/ elm/ maple, black/ oak, bur.

342. **Marshall, John David. 1980. Factors affecting jack pine regeneration on the sand plains of northern Lower Michigan. Michigan State University, Ann Arbor. Masters thesis. 66 pp.**

Abstract: Factors exercising greatest control over success of planting and natural regeneration techniques were identified. Seedling stocking was related to physical and chemical soil properties and to understory and overstory vegetation.

Partial cut areas studied included shelterwood, seed tree, and strip cut areas. Seedling stocking averaged 1346 trees/hectare. Seedling numbers were positively related to bearberry and sweet-fern cover, and inversely related to overstory basal area and several measures of B horizon fertility.

Burned areas studied included prescribed burns and wildfires through standing trees. Seedling stocking averaged 7123 trees/hectare. Regeneration was inversely related to sedge cover, pre-fire stand density, and soil profile thickness. Post-fire seedling establishment was found to reach a maximum two to five years after burning.

An average of 75.4% survival was found on the plantations, with no significant differences among the site types studied.

Keywords: MI/ vt, pine barrens/ soils, nutrient analysis/ soil morphology/ sand plains/ fire effects/ regeneration, seed/ logging, shelterwood/ logging, seed tree/ logging, strip cut/ pine, jack/ sedge .

343. **Martin, Calvin. 1973. Fire and forest structure in the aboriginal eastern forest. The Indian Historian. 6(3):23-26.**

Note: The author relates how authors of the 1800's perpetuated the misconception of the American wilderness as wild and untouched but, which was described by early settlers and explorers as "park-like" and generally modified by climate, animals, humans and insects. He cites diaries written by European explorers as evidence of fire use by Native Americans.

Keywords: eastern United States/ fire, Native American use of/ presettlement

vegetation.

344. **Martin, J. Lynton. 1955. Observations on the origin and early development of a plant community following a forest fire. *Forestry Chronicle*. 31(2):154-160.**
Abstract: The origin of the species on a burned-over area in southwestern Nova Scotia was determined by means of covered plots, and the early stages of succession were followed closely for two years. All of the herbaceous and shrub species which appeared on the area during the first two years were survivors of the fire. Bracken fern showed unquestionable dominance the first year, but its position was severely contested by other herbaceous species and the heath plants during the second year. Seedlings of grey birch and large-toothed aspen appeared the second year and were restricted to patches of bare mineral soil. Sucker growth of red oak, red maple and grey birch was rapid, but it was pruned heavily by deer feeding.
Keywords: Nova Scotia/ Canada/ vt, boreal forest/ vt, spruce forest/ vt aspen-birch forest/ fire effects/ fern, bracken/ maple, red/ spruce, red/ birch, grey/ oak, red/ aspen, big tooth.
345. **Martin, Michael. 1983. Peshtigo: the fire a nation forgot . *American Forests*. 89(9):14-16, 53-55.**
Note: The events and weather conditions that led to the Peshtigo fire are described. A map of the fire perimeter is included.
Keywords: WI/ wildfire/ fire weather/ wildfire, historic.
346. **Martin, N. D. 1959. An analysis of forest succession in Algonquin Park, Ontario. *Ecological Monographs*. 29(3):187-218.**
Note: Succession, species composition and stand origin of forest stands from wet bog to dry upland in Algonquin Park, an ecotone between the boreal and the eastern deciduous forests, are described. The most common upland species of the present forest are trembling aspen, paper birch and red maple. Other common species are balsam fir, white spruce, black spruce, sugar maple, and hemlock. Red pine and white pine occur in small patches as well. In the bog sites, black spruce, paper birch, white cedar and white pine occur. Shrubs and herbaceous vegetation was also listed. The stand history for each plot is noted, including logging, wildfires, windthrow and insect mortality. Then, a time scale of forest succession is given for each sere (hydro and xero).

This paper contrasts with Cwynar (1977, 1978) indicating the white pine-aspen forest is more common than the species listed above.
Keywords: Ontario/ Canada/ vt, boreal forest/ vt, aspen-birch forest/ vt, spruce-fir forest/ vt, maple forest/ vt, hemlock-hardwood forest/ vt, conifer-feathermoss forest/ vt, pine forest/ fire effects/ windthrow, occurrence of/ insects/ succession/ aspen, trembling/ birch, paper/ maple, red/ maple, sugar/ balsam fir/ spruce, white/ spruce, black/ hemlock/ pine, red/ pine, white/ northern white cedar/ shrubs/ herbs.
347. **Maycock, Paul F. 1961. The spruce-fir forests of the Keweenaw Peninsula, Northern**

Michigan. Ecology. 42(2):357-365.

Note: Boreal forest vegetation was quantified at 4 sites on the Keweenaw Peninsula. The most important of the 18 tree species include balsam fir, trembling aspen, paper birch, white spruce, mountain maple, red maple, and sugar maple. Because of the moderate climate, the plant diversity of the area is 20% greater than comparable mainland boreal sites. Three of the 4 sites showed evidence of either fire, wind or a combination of fire and wind disturbances.

Keywords: MI/ vt, boreal forest/ vt, spruce-fir forest/ vt, maple forest/ vt, aspen-birch forest/ fire history/ windthrow, occurrence of/ aspen, trembling/ birch, paper/ balsam fir/ spruce, white/ maple, sugar/ maple, mountain/ maple, red/ shrubs/ herbs .

348. **McAndrews, John H. 1966. Postglacial history of prairie, savanna and forest in northwestern Minnesota. Memoirs of the Torrey Botanical Club. 22(2):1-72.**

Note: Effects of soil texture, geology, topography and climate on vegetation prior to European settlement is described along a transect from prairie to forest. Vegetation descriptions are derived from GLO notes for the recent vegetation composition and pollen counts for the earlier vegetation composition. The effects of fire regime on vegetation types is discussed in general terms.

Keywords: MN/ Itasca Park/ vt, prairie/ vt, oak savanna/ vt, maple forest/ vt, pine forest/ vt, aspen forest/ paleoecology/ pollen analysis/ GLO/ presettlement vegetation/ fire regime/ climate change/ maple, sugar/ basswood/ pine, red/ pine, white/ pine, jack/ aspen/ spruce.

349. ---. 1968. **Pollen evidence for the protohistoric development of "Big Woods" in Minnesota (U.S.A.). Review of Palaeobotany and Palynology. 7:201-211.**

Summary

When the presettlement deciduous forest, as described from land-survey notes of 1854-1860, is compared with relict forest stands of today, it is clear that mesic succession has taken place. The "Big Woods", dominated by *Acer* and *Tilia*, has developed from a forest dominated by *Ulmus* and *Quercus* with some *Tilia* and *Acer*. Two pollen diagrams spanning the past 1,000 years show that this succession was initiated several hundred years before settlement. Three pollen diagrams from the adjacent oak forest suggest a concurrent succession from *Quercus* savanna, as well as a later increase in mesic elements at the time of settlement. An area that was oak barrens (a type of *Quercus* savanna) at the time of settlement, now has relict stands of oak forest; the two pollen diagrams from this area suggest the formation of oak forest since settlement.

The mesic successions are probably a culmination of a long-term change toward a cooler and moister climate, but a postulated decrease in Indian populations and fires after European contact about 1650 and before settlement could have accelerated the vegetation successions.

Keywords: MN/ vt, Big Woods/ vt, oak savanna/ paleoecology/ pollen analysis/ climate change/ fire, Native American use of/ GLO/ presettlement vegetation/ maple, sugar/ basswood/ elm/ oak.

350. **McColl, John G. and Grigal, David F. 1975. Forest fire: effects of phosphorus movement to lakes. *Science*. 188:1109-1111.**
Abstract: After a wildfire in the virgin forest of a lake-watershed region in northeastern Minnesota, the phosphorus concentration in the runoff was elevated for 2 years and decreased in the third year. However, there was no increase in the phosphorus concentrations of a lake and its input stream. This indicates that, under similar circumstances, controlled burning will not damage streams or lakes by elevating phosphorus levels.
Keywords: MN/ National Forest, Superior/ Little Sioux fire/ fire effects/ wildfire, historic/ lake/ water chemistry/ hydrology.
351. ---. **1977. Nutrient changes following a forest wildfire in Minnesota: effects in watersheds with differing soils. *Oikos*. 28:105-112.**
Abstract: The concentrations of nutrient elements in water were monitored in the unburned watershed of Dogfish Lake and in the burned watersheds of Lamb and Meander Lakes for three years following the 1971 Little Sioux Wildfire in the Superior National Forest, northeastern Minnesota. Lamb Lake watershed contains fine-textured soils of glacial lacustrine origin, whereas the other two watersheds contain coarse-textured soils derived from glacial till or granite bedrock. Nutrient concentrations of various hydrologic components were determined largely by soil type rather than by the effect of fire. Nutrient concentrations of lake waters and input streams were unaffected by the fire, due to immobilization of nutrients in the soil and to uptake by prolific post-fire revegetation.
Keywords: MN/ National Forest, Superior/ Little Sioux fire/ wildfire, historic/ fire effects/ lake/ hydrology/ water chemistry.
352. **McComb, A. L. and Loomis, W. E. 1944. Subclimax prairie. *Bulletin of the Torrey Botanical Club*. 71(1):46-76.**
Note: The prairie vegetation of Iowa is described and associated with soil characteristics. Fire is considered secondary in prairie maintenance.
Keywords: IA/ vt, prairie/ fire, general reference to stand structure/ soil morphology.
353. **McCullough, D. G.; Werner, R. A., and Neumann, D. 1998. Fire and insects in northern and boreal forest ecosystems of North America. *Annu. Rev. Entomol.* 43:107-127.**
Keywords: vt, boreal forest/ fire effects/ insects.
354. **McCune, Bruce and Cottam, Grant. 1985. The successional status of a southern Wisconsin oak woods. *Ecology*. 66(4):1270-1278.**
Note: This publication is frequently cited as one showing how vegetation composition can change with changes in fire regime.
Abstract: We examined the applicability of concepts of succession to 27 yr of tree growth and demographic data from an oak woods. From 1956 to 1983 tree population dynamics in Noe Woods, a black oak-white oak woods in southern Wisconsin, were heavily influenced by oak wilt disease. Between 15 and 20% of

the black oaks, many of them large, died in each 5-yr period; much of this mortality was due to oak wilt. White oak increased in basal area but declined slowly in numbers. Regeneration was dominated by black cherry, boxelder, and American elm; these species are either short-lived and small-statured or threatened by disease, and are, therefore, unlikely to form a new canopy. None of the species in the woods seems capable of filling the role of a self-replacing climax species in the classical sense. We hypothesize that the absence of a climax species in Noe Woods and other areas of the prairie-forest transition is due to the changed disturbance regime. Decreased fire frequency has created an unprecedented opportunity for shade-tolerant species in dry woods. This opportunity had apparently been met by expansion of shade-tolerant native species from other habitats, invasion of exotic species, and increased abundance of some short-lived and small-statured native species.

Keywords: WI/ vt, oak forest/ vt, prairie-forest ecotone/ succession/ regeneration, seed/ disturbance ecology/ disease/ fire regime/ oak, black/ oak, white/ cherry, black/ boxelder/ elm.

355. **McIntosh, R. P. 1961. Windfall in forest ecology. Ecology. 42:834.**

Keywords: windthrow, effects on vegetation/ windthrow, review.

356. **McKenzie, Donald; Peterson, David L., and Alvarado, Ernesto. 1996. Predicting the effect of fire on large-scale vegetation patterns in North America. US Forest Service, Research Paper PNW-489. 38 pp.**

Abstract: Changes in fire regimes are expected across North America in response to anticipated global climatic changes. Potential changes in large-scale vegetation patterns are predicted as a result of altered fire frequencies. A new vegetation classification was developed by condensing Kuchler potential natural vegetation classification types into aggregated types that are relatively homogeneous with respect to fire regime. Transition rules were developed to predict potential changes from one vegetation type to another because of increased fire frequency. In general, vegetation currently associated with warmer or drier climates could replace existing vegetation in most biomes. Exceptions are subalpine forests and woodlands at the Arctic treeline, which are predicted to become treeless. The transition rules provide an ecological perspective on possible new configurations of vegetation types, a set of constraints for steady-state models, and a potential method of calibration for dynamic models of large-scale vegetation change.

Keywords: fire regime/ fire frequency/ climate change/ fire effects/ landscape ecology/ biome scale/ fire modeling.

357. **McRae, Douglas J.; Lynham, Timothy J., and Frech, Robert J. 1994. Understory prescribed burning in red pine and white pine. Forestry Chronicle. 70(4):395-401.**

Abstract: The alarming loss of forested areas containing red pine (*Pinus resinosa* Ait.) and eastern white pine (*Pinus strobus* L.) in eastern Canada is a situation that must be addressed promptly by changing management approaches. Since the ecological role of fire in the regeneration and perpetuation of these pines is well known, it makes sense to use fire to maintain pine ecosystems through forest

management that uses an understory prescribed burn program. Fears of fire escape and a poor knowledge of applying fire correctly to these ecosystems are the result of poor training in the use of prescribed fire, which concentrates solely on post-harvest slash sites; this has prevented extensive use of understory prescribed burning in the past. However, research in Canada, principally using the Canadian Forest Fire Behavior Prediction (FBP) System coupled with the Canadian Forest Fire Weather Index (FWI) System, allows forest managers to develop burning prescriptions that are safe and economical while meeting objectives for seedbed preparation, natural seeding and control of competing vegetation.

Keywords: Canada/ vt, pine forest/ fire, prescribed/ management/ pine, red/ pine, white/ fire, review.

358. **Mergen, F. 1954. Mechanical aspects of wind-breakage and windfirmness. Journal of Forestry. 52:119-125.**

Keywords: windthrow, tree damage.

359. **Methven, Ian R. 1973. Fire, succession and community structure in a red and white pine stand. Petawawa Forest Experiment Station, Information Report PS-X-43.**

Note: Tree mortality occurs up to three years after a fire, at least. This would be a much better study if plots were replicated and sampling was done a few more years. Stand origin was a fire approximately 90 years ago.

Abstract: Two consecutive annual, low intensity experimental fires were conducted in a 90-year-old red and white pine stand. Damage to the overstory and consumption of the organic layer were minimal, the balsam fir understory was eliminated and shrubs and herbaceous species were considerably reduced. However changes one year after the fires, relative to the prefire condition three years earlier, amounted largely to changes in species density and biomass rather than changes in species composition. Thus changes were largely quantitative rather than qualitative, indicating no radical alteration of the ecosystem but merely creation of an environment more conducive to pine regeneration.

Keywords: Canada/ Ontario/ vt, boreal forest/ vt, pine forest/ fire, prescribed/ fire effects/ pine, red/ pine, white/ balsam fir/ shrubs/ herbs.

360. **Methven, Ian R. and Murray, W. G. 1974. Using fire to eliminate understory balsam fir in pine management. The Forestry Chronicle. 50:77-79.**

Abstract: A major problem in the management of red (*Pinus resinosa* Alt.) and white pine (*Pinus strobus* L.) is obtaining satisfactory pine regeneration where undesirable understory species such as balsam fir (*Abies balsamea* (L.) Mill.) and beaked hazel (*Corylus cornuta* Marsh.) are plentiful. Both pines are essentially subclimax species (Maissurow 1935, Candy 1939, Horton and Bedell 1960), with regeneration and perpetuation being dependent on disturbance, such as fire, to reduce understory competition and prepare a seedbed. Since the ecological role of fire in the regeneration and perpetuation of pine species is well recognized, it makes both biological and economic sense to harness this natural force if at all possible, and apply it in forest management.

Studies were undertaken to evaluate fire as an agent for the control of balsam fir understories in pine and pine-mixedwood cover types. Although this study was not large enough to produce definitive prescriptions for the use of fire to control balsam fir, the results were sufficient to be worth reporting as a step toward this goal.

The work was carried out on the Petawawa Forest Experiment Station, Chalk River, Ontario as part of a continuing prescribed burning program in red and white pine stands (Van Wagner 1963, Kayll 1963, Methven 1971).

Keywords: Canada/ Ontario/ vt, pine forest/ fire effects/ fire, prescribed/ pine, red/ pine, white/ balsam fir/ hazel/ shrubs.

361. **Meyers, N. L. and McSweeney, K. 1995. Influence of treethrow on soil properties in Northern Wisconsin. Soil Science Society of America Journal. 59(3):871-876.**

Abstract: The uprooting of trees (treethrow) creates major changes in some soil properties. This study was conducted to document both the extent of treethrow activity and its influence on soil properties in northern Wisconsin. We determined the extent of treethrow at 12 localities and studied 10 of those localities in detail. We determined bulk density, particle-size distribution, P, K, pH, and moisture status of knolls, cradles, and linear areas where recent disturbance was not obvious. The terms *knoll* and *cradle* refer to the mound and depression or pit created by treethrow disturbance. We use the term *linear area* to identify portions of the landscape not identified as knoll or cradle. Knolls have significantly lower bulk densities throughout the upper 90 cm, compared with adjacent cradles and linear areas. Differences in particle-size distribution are evident to a depth of 90 cm. Potassium contents are significantly higher in cradles than knolls or linear areas. No differences in P levels or pH are evident. Monthly determinations of moisture content during two growing seasons show knolls are drier than cradles or linear areas. In light of these sizable significant differences, it seems appropriate that disturbance in these landscapes should be identified within map units and considered in both interpretations for use and taxonomic classification.

Keywords: WI/ soils, nutrient analysis/ soil morphology/ microsite/ windthrow, effects on soil.

362. **Milfred, Clarence J.; Olson, Gerald W.; Hole, Francis D.; Baxter, F. P.; Goff, F. G.; Creed, W. A., and Stearns, Forest W. 1967. Soil resources and forest ecology of Menominee County, Wisconsin. The University of Wisconsin Geological and Natural History Survey, Soil Series 60, Bulletin 85. 203 pp.**

Note: References to fire regime and the effects on soil characteristics are given. Some very nice soil and vegetation maps of county are also included.

Abstract: Menominee County, located in northeastern Wisconsin, is the land formerly designated as the Menominee Indian Reservation (1854-1961). The county has an area of 234,000 acres and had a population of about 3,300 in 1961. It is remarkable for its large block of timber which has never been clear-cut, and which has increased in volume under a program of conservative selective cutting.

Stands more than 100 feet tall of white and red pine, hemlock, and sugar maple trees are impressive. Unregulated hunting by the Menominees in the days of the reservation has kept the deer population to a low figure, which explains in part the excellent reproduction of the forest.

Land-surface altitudes range from about 625 to 1,425 feet. Except for scattered outcrops of granitic bedrock in the Wolf River Valley the Precambrian bedrock is buried beneath glacial deposits of Middle to Late Wisconsinian age. Glacial drumlins, standing about 50 feet high above outwash and till plains, are prominent in the landscape as viewed from a fire-tower or from an airplane. Peat bogs are extensive and there are more than 100 lakes.

The soils range from sands in the southeast to silt loams in the northwest. The county lies in a transition zone grading from coniferous forest lands on the north, southwestward toward deciduous forest and prairie lands. This is reflected in the character of the soils, which include weakly developed dark soils under prairie vegetation in open jack pine and Hill's oak forest, weakly developed forest soils under hardwood-coniferous forest, and strongly developed podzol soils under hemlock forest. Most of the forest floor is characterized by pits and mounds ("cradle-knolls") made by blowdown of timber during violent storms over many centuries. The present composition of the forest in many parts of the county has been influenced by local forest fires of thirty or more years ago. The county presents unusual opportunities for study of forest and wildlife ecology, for recreation as well as for harvesting of wood products on a sustained yield basis.
Keywords: WI/ vt, deciduous forest/ vt, coniferous forest/ vt, jack pine forest/ vt, oak forest/ vt, prairie/ soil classification/ fire and soils/ windthrow, effects on soil/ logging, selection/ pine, red/ pine, white/ hemlock/ maple, sugar/ pine, jack.

363. **Miller, Roswell K. 1978. The Keetch-Byram Index and three fires in Upper Michigan, 1976. In, The 5th National Conference on Fire and Forest Meteorology, American Meteorological Society. p. 63-67.**
Note: The paper describes the weather conditions preceding, during and following 3 Upper Michigan wildfires that occurred in 1976. Problems with management decisions are also discussed. The prescribed and wildfires had final sizes of 5, 200 and 72,500 acres.
Keywords: MI/ fire weather/ wildfire.
364. **Mitchell, J. A. 1927. Forest fires in Minnesota. Forest Service, State of Minnesota. 73 pp.**
Note: This report describes fire occurrence, location, seasonality, damage, risk, causes, cost and effectiveness of protection from 1916 through 1925 in Minnesota. There is also a section on the relationship of vegetation, soils, topography, climate and land ownership patterns to fire occurrence.
Keywords: MN/ fire suppression/ wildfire statistics.
365. **--. 1954. Mortality from fire in jack pine stands. US Forest Service, Lake States Forest Experiment Station, Technical Note 416. 2 pp.**

Note: Jack pine mortality following fire was measured in 72 stands throughout northern Michigan, Wisconsin and Minnesota. Variables that affected mortality rates were tree size class, wind speed and stand stocking.

Keywords: WI/ MN/ MI/ vt, conifer-feathermoss forest/ vt, jack pine forest/ fire effects/ pine, jack.

366. **Mitchell, J. A. and LeMay, Neil. 1952. Forest fires and forest-fire control in Wisconsin. Wisconsin State Conservation Commission. 75 pp.**

Note: Wildfire statistics reported include acreage burned, cause, and damage between 1914 and 1950. A history of fire control in Wisconsin is included.

Keywords: WI/ fire suppression/ wildfire statistics.

367. **Mitchell, J. A. and Sayre, H. R., Forester. 1929. Forest fires in Michigan. Michigan Conservation Department. 65 pp.**

Note: A description of Michigan's fire record from 1918 to 1927. The report lists causes, fire size, seasonality and location. There is also a description of the soils, topography, climate, forest types and land ownership patterns. The authors state "More important from the standpoint of forest fires than temperature perhaps, is the average date of last killing frost in the spring and that of the first killing frost in the fall since this, to a large extent, limits the growing season and hence has an important bearing on the fire season." They also asserted "From the standpoint of forest protection, the character of the soil is important since within a given climatic region it very largely determines the forest type prevailing. It also influences the moisture condition and hence the inflammability of the forest fire fuels overlaying it." Lying as it does within the glaciated regions, Michigan has a great variety of soil very much intermingled. From a protection standpoint, however, but three broad types need be recognized. (1) Sandy and gravelly soils which dry out quickly after rains and favor more or less pure stands of pine, chiefly jack and Norway. (2) Loam and clay soils which tend to retain moisture and favor broadleaved trees or mixed stands of hardwoods and conifers. Such soils tend to retard the drying-pout of the forest litter and by doing so reduce the fire hazard appreciably. (3) Swamp soils, rich in organic matter and normally wet, which favors trees as black spruce, tamarack, cedar, and swamp hardwoods – types of relatively low hazard."

Keywords: MI/ fire suppression/ wildfire statistics.

368. **Mitchell, Val L. 1979. Drought in Wisconsin. Wisconsin Academy of Sciences, Arts and Letters. 67:130-134.**

Abstract: Drought in Wisconsin is not as uncommon as the abundant agriculture and the beautiful greenery of the state might suggest. Both agricultural and hydrologic droughts, as defined by a simple precipitation criterion, occur in some part of the state on the average of once in about seven years. Statewide drought occurs less frequently. There appears to be no cyclical pattern to drought occurrence in Wisconsin.

Keywords: WI/ weather.

369. **Mladenoff, David J.; He, Hong S., and Baker, William L. 1999. Design, behavior and**

application of LANDIS, an object-oriented model of forest landscape disturbance and succession. Cambridge University Press, Cambridge, UK.

Abstract: An account is given of LANDIS, a spatial forest landscape computer simulation model that integrates forest succession, windthrow, fire and management. The behavior of the model is demonstrated with a created random landscape, and the a fuller application given by simulating a large heterogeneous landscape with multiple components covering a large portion of northern Wisconsin, USA.

Keywords: WI/ succession/ windthrow, effects on vegetation/ wildfire/ fire modeling/ modeling/ landscape ecology.

370. **Mladenoff, David J.; White, M. A.; Pastor, John., and Crow, Thomas R. 1993. Comparing spatial pattern in unaltered old-growth and disturbed forest landscapes. Ecological Applications. 3:294-306.**
Keywords: landscape ecology/ disturbance ecology.
371. **Mokma, D. L. and Vance, G. F. 1989. Forest vegetation and origin of some spodic horizons, Michigan. Geoderma. 43:311-324.**
Keywords: MI/ soil morphology/ fire and soils.
372. **Moore, B. 1933. Unusual wind and soil effects. Journal of Forestry. 31:97-98.**
Keywords: windthrow, effects on soil/ soil morphology.
373. **Moore, C. T. 1972. Man and fire in the central North American grassland 1535-1890: a documentary historical geography. University of California, Los Angeles. Ph.D. dissertation.**
Keywords: MN/ vt, prairie/ fire, Native American use of.
374. **Motzkin, G.; Wilson, P.; Foster, David R., and Allen, A. 1999. Vegetation patterns in heterogeneous landscapes: the importance of history and environment. Journal of Vegetation Science. 10(6):903-920.**
Abstract: Throughout the eastern United States, plant species distributions and community patterns have developed in response to heterogeneous environmental conditions and a wide range of historical factors, including complex histories of natural and anthropogenic disturbance. Despite increased recognition of the importance of disturbance in determining forest composition and structure, few studies have assessed the relative influence of current environment and historical factors on modern vegetation, in part because detailed knowledge of prior disturbance is often lacking. In the present study, we investigate modern and historical factors that control vegetation patterns at Harvard Forest in central Massachusetts, USA. Similar to the forested uplands throughout the northeastern United States, the site is physiographically heterogeneous and has a long and complex history of natural and anthropogenic disturbance. However, data on forest composition and disturbance history collected over the past >90 years allow us to evaluate the importance of historical factors rigorously, which is rarely possible on other sites. Soil analyses and historical sources document four categories of historical land use on areas that are all forested today: cultivated

fields, improved pastures/mowings, unimproved pastures, and continuously forested woodlots. Ordination and logistic regressions indicate that although species have responded individually to a wide range of environmental and disturbance factors, many species are influenced by three factors: soil drainage, land use history, and C:N ratios. Few species vary in accordance with ionic gradients, damage from the 1938 hurricane, or a 1957 fire. Contrary to our expectation that the effects of disturbance will diminish over time, historical land use predicts 1992 vegetation composition better than 1937 composition, perhaps because historical woodlots have become increasingly differentiated from post-agricultural stands through the 20th century. Interpretations of modern vegetation must consider the importance of historical factors in addition to current environmental conditions. However, because disturbances such as land use practices and wind damage are complex, it is often difficult to detect disturbance effects using multivariate approaches, even when the broad history of disturbance is known.

Keywords: MA/ Harvard Forest/ eastern United States/ landscape ecology/ disturbance ecology/ windthrow, effects on vegetation/ carbon and nitrogen cycling/ land-use/ soil drainage/ hurricane.**NO VT**

375. **Murn, Thomas J. 1988. Flooding to substitute for fire, and historical studies in wooded acidic lowlands (Wisconsin). Restoration & Management Notes. 6(1):39.**

Note: Flooding was used to simulate the effects of fire by causing woody species mortality at Twin Lakes Bog, Portage county, WI. Results have yet to be reported.

Keywords: WI/ vt, swamp forest/ vt, wetland/ flooding/ fire, mimicking effects/ restoration ecology.

376. **Niemi, Gerald J. and Pershing, B. Hofslund. A final report for the study of Fire: its impact on avian composition and habitat selection. The University of Minnesota, Duluth, Biology Department; submitted to USFS, North Central Forest Experiment Station.**

Note: Changes in bird composition through habitat selection following habitat changes due to fire and logging is described. Study areas were selected in three vegetation types. They were: uncut jack pine, burned and cut jack pine, and recently cut aspen. The burned study areas were part of the Little Sioux fire. Bird census techniques were used to document species distribution, population density, diversity and biomass levels. Bird territory was mapped. Species found include white-throated sparrow, dark-eyed junco, mourning warbler, chestnut-sided warbler, song sparrow, common flicker, American robin, house wren and many others.

Keywords: MN/ National Forest, Superior/ Little Sioux fire/ vt, pine forest/ vt, aspen forest/ wildfire/ wildfire, historic/ logging, salvage/ pine, jack/ aspen, trembling/ birds. **SEND**

377. **Niemuth, N. D. and Boyce, Mark S. 1998. Disturbance in Wisconsin pine barrens: implications for management. Transactions of the Wisconsin Academy of**

Sciences, Arts and Letters. 86:167-176.

Abstract: Oak savannas and woodlands: 1997 Midwest oak savanna and woodland conference, University of Wisconsin Madison.

A study was conducted during July 1993 and 1994 in Burnett, Douglas and Bayfield counties to compare cover, structure and diversity of woody vegetation in 3 types of early successional habitat patches in the pine barrens of northwestern Wisconsin. Predominant tree species included *Pinus banksiana*, *P. resinosa*, *Populus tremuloides*, *P. grandidentata*, *Quercus rubra* and *Q. macrocarpa*. Patch disturbance types included repeated prescribed burning, crown fire and clearcutting. All three disturbances set back succession, but with distinct differences in vegetation structure and composition. Vegetation in patches created by crown fire had greatest tree density, diversity of structure and composition, and cover by *P. banksiana* and large woody debris. It is suggested that differences in woody vegetation among disturbance types may influence the success of savanna restoration and landscape management projects at providing habitat for savanna wildlife species in the pine barrens.

Keywords: WI/ vt, pine barrens/ vt, oak savanna/ succession/ restoration ecology/ fire, prescribed/ fire effects/ wildfire/ management/ logging, clearcut/ pine, jack/ pine, red/ aspen, trembling/ aspen, big tooth/ oak, red/ oak, bur.

378. **Noble, Mark G.; DeBoer, Linda K.; Johnson, Kenneth L.; Coffin, Barbara A.; Fellows, Lucia G., and Christensen, Neil A. 1977. Quantitative relationships among some *Pinus banksiana* - *Picea mariana* forests subjected to wildfire and postlogging treatments. Canadian Journal of Forest Research. 7:368-377.**

Abstract: Numerical classifications are used to compare vegetation and soil characteristics at virgin, logged, slash-burned, wildfire burned, and rock-raked sites in northeastern Minnesota and western Ontario. Virgin sites are dominated by *Pinus banksiana* Lamb. and *Picea mariana* (Mill.) BSP, and adjacent disturbed sites were previously dominated by these species. The vegetation of each study site is related to regional upland community types by discriminant analysis and canonical analysis.

A relationship between predisturbance and postdisturbance vegetation is indicated, regardless of the type of disturbance. Sites disturbed by logging or logging followed by slash burning are more similar to virgin sites than to wildfire or rock-raked sites, which are generally more similar to one another than to any of the other sites. The wildfire and rock-raked sites have undergone significant vegetational changes, but the difference in invader species indicates that the types of changes have not been the same. The number of invader species present is influenced by the type of disturbance experienced by a site. An important consequence of rock-raking is the movement of nutrients from timber producing areas to windrows.

Keywords: MN/ Ontario/ Canada/ vt, boreal forest/ vt, conifer-feathermoss forest/ fire, prescribed/ fire effects/ wildfire/ logging/ logging, rock rake/ pine, jack/ spruce, black.

379. **Nordin, John Olof. 1974. The mapping and characterization of the soils and vegetation of the Little Sioux Burn Area in northeastern Minnesota. University of Minnesota, St. Paul. Masters thesis. 122 pp.**

Abstract: The Little Sioux Fire was first detected on 14 May 1971. During the next three days the fire burned approximately 5900 ha (14,600 acres). A large portion (about 40%) of the burned area was virgin forest. Maps were constructed of fire intensities, forest cover types in 1970, and soils of the Little Sioux Burn Area (LSBA). These three maps, a 1948 U S Forest Service cover map and a US Geological Survey topographic map for the area were randomly sampled by 997 points and thirteen classifications were analyzed using chi-squares and measures of association. Highest association was found between 1948 and 1970 cover types, with relationships between soil units, soil groups, topographic classes, and cover types also being relatively high. Fire intensity was most closely related to topographic class.

Analysis of vegetation change from 1948 to 1970 showed an 80% decrease in balsam-fir cover types. This decrease was accompanied by a nearly equal increase in aspen cover types. This balsam fir to aspen cover type reversal was attributed primarily to the spruce budworm epidemic, which occurred from about 1955 to the mid-1960's. Decreases in jack pine, red pine, and white pine cover types were attributed to commercial logging.

Soils in the LSBA are diverse, due to a wide range of parent materials and rugged topography. Clayey lacustrine sediments located in the northwestern portion of the burn area appear to have been deposited during a high stage of glacial Lake Agassiz. Soils developed in varying thicknesses of Rainy Lobe till occupy the majority of the LSBA, and bedrock ridges are common. Surface horizons of many till and lacustrine soils are high in silt-sized material, presumably of aeolian origin. Well-drained water-lain soils are infrequent, with alluvial soils more frequent than soils developed in glacial outwash. Hemists of varying depths occur throughout the burn area.

Keywords: MN/ Superior N.F/ Little Sioux fire/ vt, balsam fir forest/ vt, pine forest/ wildfire/ wildfire, historic/ logging/ soil classification/ landform/ budworm, spruce/ balsam fir/ pine, red/ pine, jack/ pine, white/ aspen, trembling.

380. **Nordin, John Olof and Grigal, David F. 1976. Vegetation, site, and fire relationships within the area of the Little Sioux fire, northeastern Minnesota . Canadian Journal of Forest Research. 6:78-85.**

Abstract: The relationships among various landscape features were examined in an area in northeastern Minnesota that burned in a forest fire in May 1971. Maps based on fire intensity, cover types in 1948 and 1970, soils, and topography were randomly sampled. A total of 34 comparisons were made between pairs of classifications based on the mapped characteristics. The closest relationship was between dominant vegetation in 1948 and that in 1970. Relationships between soil mapping units and slope position and between vegetation and soils were also relatively high. The vegetation-soil relationships were influenced by the close associations of lowland vegetation to lowland soils and of upland vegetation to

upland soils. However, specific categories of upland vegetation were not well related to specific categories of upland soils. Fire intensity was most closely related to slope position. An 80% decrease in balsam-fir cover types occurred in 1948 to 1970. This decrease was accompanied by a nearly equal increase in aspen cover types. This balsam-fir to aspen cover type change is attributed to the spruce budworm epidemic, which occurred from the mid-1950's to the mid-1960's. Decreases in jack pine, red pine, and white pine cover types are attributed to commercial logging.

Keywords: MN/ Little Sioux fire/ National Forest, Superior/ vt, balsam fir forest/ vt, aspen forest/ vt, pine forest/ vt, jack pine forest/ logging/ fire behavior/ wildfire/ wildfire, historic/ soil classification/ landform/ budworm, spruce/ balsam fir/ aspen, trembling/ pine, jack/ pine, red/ pine, white.

381. **Nowacki, Gregory J.; Abrams, Marc D., and Lorimer, Craig G. 1990. Composition, structure, and historical development of northern red oak stands along an edaphic gradient in north-central Wisconsin. Forest Science. 36(2):276-292.**

Abstract: Forty-six relatively undisturbed northern red oak (*Quercus rubra* L.) stands in north-central Wisconsin were surveyed during the summers of 1986 and 1987. Detrended correspondence analysis (DCA) and overstory importance values were used to separate stands into four groups: *Q. rubra*-*Acer saccharum*, *Q. rubra*-*A. rubrum*-*A. saccharum*, *Q. rubra*-*Q. alba*-*A. rubrum*, and *Q. rubra*-*A. rubrum*-*Betula papyrifera*. Stand position along DCA axis 1 was significantly correlated with soil texture, which was interpreted as an edaphic gradient from rich, mesic to poorer, dry mesic sites. All groups were dominated by overstory northern red oak; however, changes in understory dominance from sugar maple (*Acer saccharum* Marsh.) to red maple (*Acer rubrum* L.) occurred from mesic to dry mesic groups. Moreover, basal area and age decreased and shrub cover increased from mesic to dry mesic sites. Most of north-central Wisconsin was completely logged and physical evidence of fires was found within or near two-thirds of the stands surveyed. These disturbances are thought to have created conditions favorable to northern red oak establishment, leading to its increased dominance in the region. Age and diameter data indicated that northern red oak were consistently the oldest and largest individuals in all stands and formed an even-aged canopy. Substantial northern red oak recruitment into the tree size class seemed to last for only 25-30 years after disturbance (probably until canopy closure), after which only shade-tolerant species were successful in the understory. Under today's low disturbance regime, northern red oak may be restricted to a single generation with a strong likelihood of being replaced by sugar maple on mesic sites, a combination of sugar and red maple on transitional sites and red maple on dry mesic sites.

Keywords: WI/ vt, oak forest/ vt, maple forest/ logging/ fire, general reference to stand structure/ soil morphology/ succession/ oak, red/ maple, red/ maple, sugar.

382. **Nuzzo, Victoria A. 1986. Extent and status of midwest oak savanna: presettlement and 1985. Natural Areas Journal. 6(2):6-36.**

Abstract: Oak savanna covered some 11,000,000 to 13,000,000 hectares of the Midwest at the time of settlement, extending over portions of Minnesota, Iowa,

Missouri, Illinois, Wisconsin, Michigan, Indiana, and Ohio. Definitions for the community vary between states, due in part to different concepts of the presettlement appearance and structure of the community, a general lack of phytosociological data about oak savanna, and difficulty in interpreting historical data. Community definitions, a map of the real or potential extent of presettlement oak savanna, and location and description of high-quality savanna remnants are presented for each state. In 1985, 113 sites totaling more than 2,607 hectares of relatively high-quality oak savanna were located in the Midwest, approximately 0.02 percent of the presettlement extent of the community.

Keywords: MN/ WI/ MI/ IL/ IN/ OH/ IA/ MO/ vt, oak savanna/ review/ fire effects/ oak.

383. **Oelfke, Jack G. 1995. Prescription for a Wilderness: Isle Royale National Park. In, Brown, James K.; Mutch, Robert W.; Spoon, Charles W., and Wakimoto, Ronald H. Symposium on fire in wilderness and park management, Mar 30-Apr 1, 1993, Missoula, MT. US Forest Service, Intermountain Research Station. p. 247-249.**

Note: The fire management program of Isle Royale is described. It also discusses why it is possible to have a prescribed natural fire program on the island.

Keywords: MI/ Isle Royale/ island/ fire, prescribed/ management.

384. **Ohman, Lewis F.; Cushwa, Charles T., and Lake, Roger E. 1973. Part I. The upland plant communities. Wilderness ecology: the upland plant communities, woody browse production, and small mammals of two adjacent 33-year-old wildfire areas in northeastern Minnesota. US Forest Service, General Technical Report NC-7. 22 pp.**

Abstract: The present upland vegetation of two adjacent wildfire areas that burned 33 years ago consists of four plant community types: aspen, aspen-birch, jack pine-birch, and jack pine. These types were identified through cluster and canonical analysis of species frequency of occurrence data from 33 sample stands located randomly over the two areas. Present vegetation differences appear to relate better to the type and condition of vegetation present before the fire than to measured environmental parameter differences found between the types.

Keywords: MN/ National Forest, Superior/ BWCAW/ vt, aspen forest/ vt, aspen-birch forest/ vt, jack pine forest/ fire effects/ soils/ classification/ mammals/ aspen, trembling/ birch, paper/ pine, jack/ shrubs/ herbs.

385. **Ohman, Lewis F. and Grigal, David F. 1979. Early revegetation and nutrient dynamics following the 1971 Little Sioux forest fire in northeastern Minnesota. Forest Science Monograph. 21 ed.**

Abstract: Three virgin plant communities dominated by *Pinus banksiana*, three by *Populus-Betula*, and one mixed community were studied over five growing seasons after burning in the 1971 Little Sioux Fire. From 1971 through 1975 tree and tall shrub reproduction generally decreased in density and increased in biomass. Low shrub cover and biomass increased for 3 years and then leveled off as tree and shrub competition increased. Herb cover and biomass increased most rapidly through 1972 and then slowed substantially. By 1975 total net primary

productivity averaged 850 g/m²/yr for all seven stands, and over 1,200 g/m²/yr in the broadleaf-dominated stands. The forest floor 01 horizon increased in mass through 1974, and then apparently stabilized at about 620 g/m². The 02 horizon averaged about 1,000 g/m² and was still increasing in 1975. By the 1975 growing season the total amount of nutrients in aboveground vegetation on burned plots ranged from 33 percent of the N to 65 percent of the K found in nearby unburned forest communities. By 1973 the nutrients in the aboveground vegetation and the 01 horizon of the forest floor were greater than the quantity estimated to have been mobilized by the fire. The vegetation was an effective sink for the released nutrients.

Keywords: MN/ National Forest, Superior/ Little Sioux fire/ vt, aspen-birch forest/ vt, jack pine forest/ wildfire, historic/ fire effects/ vegetation, nutrient analysis / pine, jack/ aspen, trembling/ birch, paper/ pine, white.

386. **Ohman, Lewis F. and Ream, Robert R. 1971. Wilderness ecology: virgin plant communities of the Boundary Waters Canoe Area. US Forest Service, Research Paper NC-63.**

Note: The objective of this study was to inventory, analyze and develop a classification of the upland virgin plant communities in the BWCA.

Abstract: Index values for moisture, heat, nutrient, environmental (an average of the previous 3), and fire disturbance were used to evaluate and describe stands. Fire disturbance index was a rating from 1 to 5, with 1 being the shortest time interval since last fire and 5 being the longest time since last fire. Twelve plant communities were identified by sampling 106 stands. The plant communities were lichen, jack pine (fir), jack pine (oak), black spruce-jack pine, white pine, jack pine-black spruce, maple-aspen-birch, aspen-birch, red pine, budworm damage, fir-birch, and white cedar. Of all the index values, the one that seemed to be the best plant community indicator was fire disturbance.

Keywords: MN/ National Forest, Superior/ Little Sioux fire/ vt, boreal forest/ vt, lichen woodland/ vt, conifer-feathermoss forest/ vt, pine forest/ vt, spruce forest/ vt, aspen-birch forest/ vt, balsam fir forest/ vt, white cedar forest/ fire effects/ wildfire, historic/ soil morphology/ classification/ insects/ budworm, spruce/ pine, jack/ balsam fir/ oak/ spruce, black/ pine, white/ maple, red/ aspen, trembling/ pine, red/ birch, paper/ northern white cedar/ shrubs/ herbs.

387. **Oliver, Chadwick Dearling. 1981. Forest Development in North America following major disturbances. Forest Ecology and Management. 3:153-168.**

Abstract: Large-scale, man-created or natural disturbances play a major role in determining forest structure and species composition in many areas of North America and probably other temperate and tropical forests. Trees begin growth by a variety of mechanisms - each of which can respond to disturbances of a different severity. Studies suggest: a single group of species is not predestined to inhabit an area; forest physiognomic appearances assumed to imply all-aged succession often occur in single-age class stands; and recruitment of new stems into a forest often follows a disturbance rather than being a constant occurrence. After disturbances, forests develop through general physiognomic stages: "stand initiation", "stem exclusion", "understory reinitiation", and "old growth".

Disturbance severity determines which species will dominate the forest afterward. The frequency of disturbances is also important in determining the general forest type over a large area, because species dominance and stand physiognomy change with time following disturbance.

Keywords: disturbance ecology/ modeling.

388. **Overpeck, Jonathon; Rind, David, and Goldberg, David. 1990. Climate-induced changes in forest disturbance and vegetation. *Nature*. 343:51-53.**

Note: Using stand-simulation model FORENA, the authors compare biomass fluctuations due to climate change with and without probable changes in disturbance regimes. They noted that the changes in predicted biomass occurred much more quickly and reductions were much greater when disturbances, such as fire, were added to the model. Sites used in modeling were in N. Wisconsin, S. Quebec, N.E. Michigan, S. Illinois.

Keywords: WI/ MI/ IL/ Quebec/ Canada/ climate change/ disturbance ecology/ fire regime/ modeling/ fire modeling.

389. **Palik, Brian J. and Pregitzer, Kurt S. 1992. A comparison of presettlement and present-day forests on two bigtooth aspen-dominated landscapes in northern Lower Michigan. *American Midland Naturalist*. 127:327-338.**

Note: The two sites are located in the extreme northwestern and in northeastern Lower Michigan. The estimated fire rotation for the northeastern site is 114-127 years (a mix of predominantly jack pine, red pine and white pine). The estimate was derived using vegetation stage described in survey notes as an approximation of time since last fire. The vegetation present on the other site was homogeneous and did not show any signs of fire presence (mostly hemlock, beech, white pine).

Abstract: Forest composition within a local landscape is influenced by physical site characteristics and prevailing disturbance regime. In many areas of eastern North America, the natural disturbance regimes that influenced presettlement forest composition have been altered by human activities associated with European settlement. These alterations have led to substantial changes in composition and the development of successional pathways markedly different from presettlement conditions. In this study we examined presettlement and present-day forest composition of two bigtooth aspen-dominated landscapes in northern Lower Michigan. Our objectives were to : (1) reconstruct and relate presettlement forest composition to the potential natural disturbance regime of each landscape; (2) compare presettlement and present-day forest composition of each landscape; and (3) assess the influence of post-settlement disturbance history on the development of the current forests and the potential successional pathways of the two landscapes.

Presettlement forest composition, reconstructed using General Land Office survey records, differed substantially between the two landscapes. Landscape 1 was dominated by fire-sensitive eastern hemlock and American beech, while landscape 2 was dominated by fire-dependent red pine, white pine and jack pine. Compositional differences may have been related to differences in presettlement fire frequency, or to differences in physical site characteristics or regional

climates. The present-day overstories of both landscapes were dominated by bigtooth aspen, red oak and red maple species that were of minor importance in the presettlement forests of the study areas. Compositional convergence was attributed to the similar influence of post settlement disturbance history on each landscape. Logging and wildfires eliminated advanced regeneration and many remnant seed sources of hemlock, beech and pines and favored the development of forests dominated by bigtooth aspen, red oak and red maple. Individuals of the latter species survived the disturbance and proliferated vegetatively in the postsettlement landscape. Differences in seed source availability in the present-day forests have led to marked differences in species recruitment in the understories of the two landscapes. Changes in seed rain and fire exclusion in the two landscapes are apparently leading to development of forest types markedly different from the presettlement conditions. The results illustrate how human-induced changes in disturbance regimes can have important, long-lasting effects on forest composition.

Keywords: MI/ vt, hemlock-hardwood forest/ vt, pine forest/ fire interval/ age-class structure/ logging/ regeneration, seed/ succession/ disturbance ecology/ land-use/ GLO/ presettlement vegetation/ hemlock/ beech/ pine, red/ pine, white/ pine, jack/ aspen, big tooth/ oak, red/ maple, red.

390. **Palik, Brian J. and Robl, James. 1999. Structural legacies of catastrophic windstorm in a mature Great Lakes aspen forest. US Forest Service, Research Paper NC-37. 11 pp.**

Note: Blowdown occurred July 15, 1995 on the Chippewa NF near Trout Lake. Tree mortality, coarse woody debris, residual trees and saplings are reported.

Abstract: We report on biological legacies resulting from a major windstorm in a Minnesota aspen forest and suggest guidelines for managing legacies with silvicultural disturbance.

Keywords: MN/ National Forest, Chippewa/ vt, aspen forest/ windthrow, effects on vegetation/ silviculture/ aspen/ maple, sugar/ birch, paper/ oak, red/ maple, red.

391. **Pare, D.; Bergeron, Yves, and Camire, C. 1993. Changes in the forest floor of Canadian southern boreal forest after disturbance. Journal of Vegetation Science. 3:811-818.**

Keywords: Canada/ Quebec/ vt, boreal forest/ fire effects/ shrubs/ herbs.

392. **Pastor, John and Post, W. M. 1986. Influence of climate, soil moisture, and succession on forest carbon and nitrogen cycles. Biogeochemistry. 2:3-27.**

Keywords: weather/ soil morphology/ succession/ carbon and nitrogen cycling.

393. **Patterson, William Albert III. 1978. The effects of past and current land disturbances on Squaw Lake, Minnesota and its watershed. University of Minnesota, St. Paul. Ph.D. dissertation. 254 pp.**

Note: The objective of the study was to evaluate the ecological significance of man-caused disturbance presently occurring in Itasca State Park relative to natural and man-caused disturbances that occurred in the past. In Squaw Lake Basin vegetation, a mix of jack pine, red pine and white pine, response to logging,

wildfire and prescribed fire is measured. Water chemistry measurements were taken on lakes to determine influence of disturbance on the aquatic environment. The fire frequency of the basin corresponds closely with the results of Frissell (1973). Wildfires occurred in the early 1700's (many stands originated in 1730), 1759, 1772, 1796, 1803, 1811, 1820, 1864, 1891 1907, 1910, 1918, and 1922. The jack pine stands originated after the 1907 fire(s). Since that time, there have been at least 3 other fires (1910, 1918, and 1920) in these stands. Pollen counts indicate a decrease in white pine and increase in red pine and jack pine over the last 1000 years. Charcoal analysis indicates an increase in fire frequency with the charcoal: pollen ratio. The author contrasts these results with those of Cwynar that show an increase in fire frequency and no decrease in white pine abundance. **Keywords:** MN/ Itasca Park/ fire/ vt, pine forest/ fire interval/ fire scar/ fire, prescribed/ land-use/ paleoecology/ pollen analysis/ charcoal analysis/ climate change/ hydrology/ water chemistry/ pine, red/ pine, white/ pine, jack.

394. **Patterson, William Albert III; Edwards, Kevin J., and Maquire, David J. 1987. Microscopic charcoal as a fossil indicator of fire. Quaternary Science Reviews. 6:3-23.**

Note: Discusses work by Swain.

Abstract: Charcoal preserved in lake sediments, peat, and soils provides a record of past fire occurrence. An understanding of fire history is important in evaluating interactions between vegetation, climate and human disturbances through at least the last several millennia. In this paper we review information concerning the production, dispersal, sedimentation and preservation of charcoal. We present examples of studies that have used charcoal analysis in paleoecological reconstructions, with special emphasis on analytical techniques and problems of interpretation.

Unlike pollen, which is produced continuously in fairly constant amounts, charcoal is produced in large quantities but at irregular intervals. These are a function of fire regimes that are often unique to specific vegetation types and/or climatic regions. Charcoal particles vary in size from sub-microscopic to macroscopic, with small particles presumably being transported further by wind and water than large particles. Charcoal preserves well, but it may be subject to breakage, especially when transported by water. We present theoretical models of dispersal and discuss potential problems associated with post-depositional mixing.

A variety of charcoal analysis techniques have been employed during the past four decades. Most involve microscopic identification and quantification of numbers or size of individual fragments occurring in samples prepared for pollen analysis. The most commonly used method-estimating charcoal area by categorizing particles in several size classes-is both tedious and time consuming, and recently introduced techniques attempt to estimate past fire occurrence based upon point count estimation, elemental carbon analysis, magnetic measurement of sediments, electron microscope, and spectrographic analyses. A lack of standardization both within and among analysis techniques has hampered

interpretation of charcoal profiles. Taphonomic processes affecting charcoal are less well understood than for pollen, and as a result interpretations of historic interactions between vegetation and fire based upon pollen and charcoal analyses are difficult. We review several studies through which advances have been made and suggest questions for future study.

Keywords: charcoal analysis/ fire, review.

395. **Patterson, William Albert III and Sassaman, Kenneth E. 1988. Indian fires in the prehistory of New England. In, Nicholas, George P. *Holocene Human Ecology in Northeastern North America*. Plenum Publishing. p. 107-135.**
Note: Ecological, cultural, archaeological, paleoecological evidence is given to verify the use of fire by Native Americans in agricultural areas of New England prior to European settlement. Citations include past explorers and authors who describe communities, and associated economies, in New England at the time of European settlement. While groups in the north were mostly hunters and gatherers, the groups in southern New England were hunters, gatherers and agriculturalists. More human set fires were observed in the south than in the north.
Keywords: ME/ MA/ NY/ northeastern United States/ eastern United States/ fire, Native American use of.
396. **Peart, D. R.; Cogbill, Charles V., and Palmiotto, P. A. 1992. Effects of logging history and hurricane damage on canopy structure in a northern hardwoods forest. *Bulletin of the Torrey Botanical Club*. 119:29-38.**
Keywords: vt, northern hardwood forest/ logging/ windthrow, effects on vegetation/ hurricane.
397. **Peek, James M. 1974. Initial response of moose to a forest fire in northwestern Minnesota. *American Midland Naturalist*. 91(2):435-438.**
Abstract: Density of moose (*Alces alces*) in northwestern Minnesota increased from less than 0.5 per sq mile prior to a large fire to over 2 per sq mile two growing seasons following the fire. The increase was related to immigration, especially of yearlings, rather than in increased production and survival of calves.
Keywords: MN/ National Forest, Superior/ Little Sioux fire/ fire effects/ wildfire/ wildfire, historic/ mammals.
398. **Perala, Donald A. 1974. Growth and survival of northern hardwood sprouts after burning. US Forest Service, Research Note NC-176. 4 pp.**
Abstract: Root collar sprouting of nine hardwoods was measured annually after a prescribed burn. Basswood, red oak, and paper birch were the most vigorous sprouters; sugar maple and yellow birch the least; and American elm, bur oak, ironwood and red maple were intermediate. Parent tree diameter influenced sprouting. Consumption energy of slash given.
Keywords: MN/ National Forest, Chippewa/ fire, prescribed/ fire effects/ basswood/ oak, red/ birch, paper/ maple, sugar/ birch, yellow/ elm/ oak, bur/ ironwood/ maple, red .

399. ---. 1974. **Prescribed burning in an aspen-mixed hardwood forest. Canadian Journal of Forest Research. 4:222-228.**
Keywords: vt, aspen forest/ fire, prescribed/ fire effects/ aspen, trembling.
400. --. 1995. **Quaking aspen productivity recovers after repeated prescribed fire. US Forest Service, Research Paper NC-324. 11 pp.**
Note: Post-harvest prescribed burn treatments were done on aspen sites with a strong hardwood component to determine if burning might reduce the hardwood composition. The treatments were no burn, single burn in cured slash fuels, single spring burn plus another spring burn 2 years later, single spring burn plus a fall burn 2 years later. Fuel removal was very high in the first spring burn plots and, after 25 years, the yield was still 22% less than unburned control. The repeat burn units favored the aspen component by reducing the hardwood composition. The fall burn units had an increase in productivity (111%) over the control. Flame heights and fire line intensity for each of the burns is given.
Keywords: MN/ vt, aspen forest/ fire, prescribed/ fire effects/ aspen, trembling.
401. **Pernin, Peter Rev. 1999. The Great Peshtigo Fire. The State Historical Society of Wisconsin, Madison.**
Note: First published in 1971.
Keywords: Wisconsin/ wildfire, historic.
402. **Peterson, Chris J.; Carson, W. P.; McCarthy, B. C., and Pickett, S. T. A. 1990. Microsite variation and soil dynamics within newly created treefall pits and mounds . Oikos. 58:39-46.**
Keywords: windthrow, effects on soil/ soils, nutrient analysis/ microsite.
403. **Peterson, Chris J. and Pickett, S. T. A. 1990. Microsite and elevational influences on early forest regeneration after catastrophic windthrow. Journal of Vegetation Science. 1:657-662.**
Abstract: We compared vegetation establishment in 25 treefall pits and mounds along a hillside elevational gradient in a fourth-year catastrophic windthrow in eastern North America. Plant communities differed greatly between pits and mounds, with pit microsites having significantly greater species richness, total biomass, and total tree stem density.
- Species richness in pits and on mounds decreased with increasing elevation from the bottom of the hillside, although the effect of elevation on mound species richness was less than that of elevation on pit species richness. Biomass of *Erechites hieraciifolia* decreased significantly, while that of *Betula alleghaniensis* increased significantly with elevation. However, total biomass of both pit and mound microsites was unrelated to elevation. Total stem density decreased with elevation in pits, but was unaffected by elevation on mounds.

This study shows that both small-scale (microsite) effects and intermediate-scale effects influence the reestablishment of plant communities within this catastrophic windthrow. Consideration of both microsite and position along intermediate-scale

gradients may allow more precise prediction of plant community composition and dynamics in recovery of disturbed areas.

Keywords: PA/ eastern United States/ windthrow, effects on vegetation/ microsite/ fireweed/ birch, yellow.

404. ---. 1991. **Treefall and resprouting following catastrophic windthrow in an old-growth hemlock-hardwoods forest.** *Forest Ecology and Management*. 42:205-217.

Abstract: We surveyed the type of treefall (snapped and uprooted), and for snapped trees the height of break and sprouting tendency, in a catastrophic windthrow in an old-growth hemlock-hardwoods forest. Two-thirds of the 630 trees sampled were uprooted and one-third snapped. Trunk size (diameter at breast height) was more important than species in determining whether trees snapped or uprooted. Tree characteristics interacted with storm meteorology to determine the overall pattern of treefalls.

We found that only 25% of the snapped trees sprouted in the four growing seasons after the tornado, and that the tendency to sprout varied significantly among species. Of those snapped trees that sprouted, only 68% were alive at the end of the fourth growing season. In contrast to small gaps in the tropics, where sprouted trees contribute a substantial portion of the post-disturbance canopy, sprouting will be of little importance in the re-establishment of forest in this catastrophic windthrow.

Keywords: PA/ eastern United States/ vt, hemlock-hardwood forest/ tornado/ windthrow, tree damage/ beech/ hemlock/ birch, yellow/ maple, sugar.

405. ---. 1995. **Forest reorganization: a case study in and old-growth forest catastrophic blowdown.** *Ecology*. 76(3):763-774.

Keywords: PA/ eastern United States/ windthrow, effects on vegetation.

406. Pickett, S. T. A.; Amesto, J. J., and Collins, S. L. 1989. **The ecological concept of disturbance and its expression at various hierarchical levels.** *Oikos*. 54:129-136.

Keywords: disturbance ecology/ theory.

407. Pickett, S. T. A and White, P. S. 1985. *The ecology of natural disturbance and patch dynamics.* Academic Press, Orlando, FL.

Keywords: fire effects/ patch dynamics.

408. Pierce, R. L. 1954. **Vegetation cover types and land use history of the Cedar Creek Natural History Reservation, Anoka and Isanti Counties, Minnesota .** University of Minnesota, St. Paul.

Keywords: MN/ Cedar Creek Natural History Area/ vt, oak savanna/ fire effects/ fire, prescribed/ land-use.

409. Plummer, Fred G. 1912. **Forest fires: their causes, extent and effects, with a summary of recorded destruction of loss.** Government Printing Office,

Washington D.C., Bulletin 117. 39 pp.

Note: Wildfire occurrence, locations, sizes and causes for the United States from approximately 1880 to 1910 are reported. The Baudette, Chisholm, Hinkley, Peshtigo, Michigan and a large unnamed fire in Michigan were listed among the greatest fires in the United States since 1800 (to 1912). A map showing locations of wildfires in Minnesota and Wisconsin during 1910 is shown.

Keywords: MI/ WI/ MI/ wildfire/ wildfire, historic/ management/ wildfire statistics.

410. **Potzger, J. E. 1941. The vegetation of Mackinac Island, Michigan: an ecological survey. American Midland Naturalist. 25:298-323.**

Note: Vegetation composition, and its relationship with soil acidity, and wind, as well as land-use is described for Mackinac Island, MI.

Keywords: MI/ island/ vt, pine forest/ vt, swamp forest/ vt, spruce-fir forest/ vt, maple forest/ soil morphology/ land-use/ windthrow, effects on vegetation/ classification/ balsam fir/ spruce, red/ northern white cedar/ birch, paper/ pine, white/ maple, sugar/ beech.

411. **Price, David Lynn. 1994. An ecological study of the composition structure and disturbance regimes of the pre-European settlement forests of western Chippewa County, Michigan. Michigan State University, Ann Arbor. Ph.D. dissertation.**

Note: Fire, windthrow, beaver flooding and insect mortality return intervals are estimated by forest type for the county from the GLO notes. The intervals when compared with Whitney and others tends to be a little longer.

Abstract: To successfully implement ecosystem management an understanding must be achieved regarding how different forest communities and ecosystems function and interrelate at the landscape level. This study explores the composition, structure and disturbance patterns of the pre-European settlement forests of eastern upper Michigan, by reconstruction of the forests from General Land Office Survey notes. Results suggest that the pre-European settlement landscape was a vast array of irregular patches, composed of different successional stages and forest associations of different age and size classes. The composition and structure of the forest was driven by fire, windthrow, insect related mortality and beaver (*Castor canadensis*) floodings. Hemlock (*Tsuga canadensis*) was a dominant species in the landscape. The results of the study provide a foundation for understanding how today's forests differ from those that dominated the landscape before Europeans began to harvest timber.

Keywords: MI/ vt, wetland/ vt, swamp forest/ vt, pine forest/ vt, jack pine forest/ vt, maple forest/ vt, hemlock-hardwood forest/ vt, hemlock forest/ vt, balsam fir forest/ fire interval/ windthrow, frequency/ flooding/ budworm, jack pine / insects/ mammals/ GLO/ presettlement vegetation/ disturbance ecology/ maple, sugar/ ash/ balsam fir/ birch/ hemlock.

412. **Putz, Francis E.; Coley, Phyllis D.; Lu, Karen; Montalvo, Arlee, and Aiello, Annette. 1983. Uprooting and snapping of trees: structural determinants and ecological consequences. Canadian Journal of Forest Research. 13:1011-**

1020.

Abstract: The influence of mechanical and architectural properties of trees on growth rates, mortality rates, and relative probabilities of snapping and uprooting were examined on Barro Colorado Island, Republic of Panama. Of 310 fallen trees, 70% snapped, 25% uprooted, and 5% broke off at ground level. Stepwise discriminant analysis between snapped and uprooted trees indicated that of the variables measured, wood properties were the most important factors in determining the type of death in trees. Uprooted trees tended to be larger, shorter for a given stem diameter, and to have denser, stiffer, and stronger wood than snapped trees. There were no significant differences between trees that snapped and trees that uprooted in the extent of buttress development or in the slope of the ground upon which they grew. Trees with low density wood grew faster in stem diameter than those with high density wood but also suffered higher mortality rates. After damage, many of the snapped trees sprouted; small trees sprouted more frequently than large trees. Sprouting is proposed as a means by which weak-wooded fast-growing trees partially compensate for being prone to snapping.

Keywords: Panama/ other countries/ windthrow, tree damage.

413. **Quinby, Peter A. 1991. Self-replacement in old-growth white pine forests of Temagami, Ontario. *Forest Ecology and Management*. 41:95-109.**

Note: Evidence of windthrow or fire scarring was indicated for each plot but not quantified. Seventy-two percent of the plots had evidence of windthrow and, 61% of the plots recorded fire scarred trees.

Abstract: Surveys of both live and dead vegetation were conducted to examine long-term successional trends in old-growth white pine forest. The forest successional trend, for a period of possibly up to seven centuries, shows that white pine has been the dominant species over this time period indicating that these old-growth white pine forests have been self-replacing. Size-class analysis was used as an indicator of age-class structure. Results of this analysis show that the old-growth white pine stands are at least partially uneven-aged. The uneven-aged condition, resulting from continuous recruitment, was most likely facilitated by local disturbances such as small surface fires, windthrown trees and the death of large individual trees through biological or other agents. These findings cast some doubt on the silvicultural theory that catastrophic fire is the only primary facilitator of natural white pine regeneration. Selection logging in white pine forest may make better use of the various non-catastrophic mechanisms of natural white pine regeneration. It is unlikely, however, that the old-growth condition can be maintained or enhanced under any cutting regime. In addition to the production of fiber, old-growth forests are valuable components of the landscape from both a functional ecological perspective and a scientific perspective.

Keywords: Ontario/ Canada/ vt, pine forest/ fire history/ fire scar/ fire effects/ logging, selection/ succession/ windthrow, occurrence of/ age-class structure/ regeneration, seed/ disturbance ecology/ pine, white.

414. **Radeloff, Volker C. 2000. Effects of multiple interacting disturbances on landscape patterns: budworm defoliation and salvage logging. *Ecological Applications*.**

10:233-247.

Abstract: Prior to European settlement, the 450,000-ha Pine Barrens region in northwestern Wisconsin, USA, was characterized by a landscape mosaic of large, open patches, savannas, and closed forest stands of jack pine (*Pinus banksiana*). Crown-fires created large open patches that persisted on the droughty soils, providing important habitat for a number of area-sensitive, open-habitat species. Insect outbreaks may have contributed to periodic fires by increasing the fuel load. Today, fires are suppressed in the managed landscape, but insect defoliation remains a major disturbance. Salvage logging commonly follows insect outbreaks. Our objective was to evaluate landscape pattern changes caused by this interaction of natural disturbances and forest management. We examined changes in landscape pattern during the most recent (1990-95) outbreak of jack pine budworm (*Choristoneura pinus pinus*) in northwestern Wisconsin using four Landsat TM satellite images (1987, 1991, 1993, and 1995). The 1987 image provided the basis for a species-level forest classification identifying mature jack pine and open habitat prior to the budworm outbreak. Each subsequent image was used to identify clearcuts in mature jack pine. The 1995 image was also used to classify stand development in the open habitat of the 1987 image so that the overall availability of open habitat in 1995 could be assessed. GIS data layers were used to analyze logging rates and clearcut sizes separately for different classes of land ownership and soils. Approximately 12,500 ha were salvage logged during the 1990-1995 outbreak. Logging rates were highest on the most infertile soils, and on private, industrial forest land. Annual logging rates of different owners were 3-6 times higher during the outbreak than previous to it. Salvage cut sizes were larger than clearcuts prior to the outbreak. New cuts were mostly located next to previous cuts, thus increasing the size of openings on the landscape. Initial survey results by N. Niemuth show that populations of one area-sensitive open-habitat species (Sharp-tailed Grouse, *Tympanuchus phasianellus*) thrive on the salvage cuts. Insect defoliation and subsequent salvage logging did create new habitat for open-habitat species that were declining. Landscape pattern changes due to multiple interacting disturbances have rarely been studied. The interaction of jack pine budworm defoliation and salvage logging substantially changed landscape pattern in the Pine Barrens. We speculate that interaction between insect defoliation and fire may have significantly shaped the presettlement landscape.

Keywords: WI/ National Forest, Chequamegon-Nicolet/ disturbance ecology/ landscape ecology/ remote sensing/ budworm, jack pine/ logging, salvage/ GIS/ insects/ birds/ pine, jack.

415. ---. 2000. **A historical perspective and future outlook on landscape scale restoration in the northwest Wisconsin Pine Barrens. Restoration Ecology. 8(2):119-126.**
Abstract: The environmental history, early restoration projects, and current plans to restore landscape patterns at broader scales in the 450 000 ha NW Wisconsin Pine Barrens, USA, are reviewed. The Pine Barrens are a landscape shaped by fire in the past. These barrens were a mosaic of open prairie, savanna, and pine forests on very poor, sandy soils. The surrounding region of better soils was otherwise heavily forested. Six restoration sites have been managed since the mid 1900s

using prescribed burns to maintain the open, barrens habitat. However, these sites are not extensive enough to mimic the shifting mosaic of large open patches previously created by fire. Extensive clear felling may be used as a substitute for these large fire patches so that presettlement landscape patterns are more closely approximated in the current landscape. Such silvicultural treatments may be suitable to restore certain aspects of presettlement landscapes, such as landscape pattern and open habitat for species such as grassland birds. The effects of fire and clear felling differ in many aspects and additional management, such as prescribed burning after harvesting, may assist in further approximating the effect of natural disturbance. However, the restoration of landscape pattern using clear felling may provide an important context for smaller isolated restoration sites even without the subsequent application of fire, in this formerly more open landscape.

Keywords: WI/ vt, pine barrens/ vt, prairie/ vt, oak savanna/ fire, prescribed/ fire, general reference to stand structure/ logging, clearcut/ soil morphology/ landscape ecology/ restoration ecology/ pine, red/ pine, jack/ pine, white/ oak, red/ oak, bur/ oak, pin/ aspen, trembling.

416. **Radeloff, Volker C.; Mladenoff, David J.; He, Hong S., and Boyce, Mark S. 1999. Forest landscape change in the northwestern Wisconsin Pine Barrens from pre-European settlement to the present. Canadian Journal of Forest Research. 29(11):1649-1659.**

Abstract: Natural disturbance patterns can provide useful information for ecosystem management. Our objective of this study was to provide a detailed spatial picture of the pre-European settlement vegetation cover for the northwestern Wisconsin Pine Barrens and to compare it with the present vegetation cover. We analyzed the presettlement conditions using an extensive data set comprised of US General Land Office surveyor records from the mid-19th century and related to the vegetation cover in 1987 as depicted in a Landsat satellite forest classification. Changes were quantified by calculating differences in abundance and relative importance of tree species at presettlement time and today. Our results revealed a strong decline of jack, red, and white pine (*Pinus banksiana* Lamb., *Pinus resinosa* Ait., and *Pinus strobus* L., respectively), accompanied by an increase of oak (*Quercus* spp.), trembling aspen (*Populus tremuloides* Michx.), and other hardwood species. Certain vegetation types, e.g., red pine and oak savannas, were removed from the landscape. The forest density gradient of the presettlement landscape with open savannas and woodlands in the South and denser forests in the North disappeared. These changes, especially the increase in forest cover, are ecologically significant because numerous species are adapted to open habitat, which was previously created by fire, and their populations are declining.

Keywords: WI/ vt, pine barrens/ vt, oak savanna/ remote sensing/ landscape ecology/ succession/ presettlement vegetation/ GLO/ fire, general reference to stand structure/ pine, red/ pine, jack/ pine, white/ oak, red/ oak, bur/ oak, pin/ aspen, trembling.

417. **Radeloff Volker C.; Mladenoff David J.; Manies, K. L., and Boyce, Mark S. 1998.**

Analyzing forest landscape restoration potential: pre-settlement and current distribution of oak in the northwest Wisconsin Pine Barrens. Transactions of the Wisconsin Academy of Sciences, Arts and Letters. 86:189-206.

Note: Oak savannas and woodlands: 1997 Midwest oak savanna and woodland conference, University of Wisconsin Madison.

Abstract: A study was undertaken to reconstruct the historical, large-scale pre-European landscape of the Pine Barrens in northwestern Wisconsin and to compare the extent and abundance of the oak component to its current importance. The study addressed 2 main questions; (i) does the current distribution of oak resemble pre-settlement conditions and (ii) did oak savannas exist during pre-settlement times, which would indicate a high frequency but low intensity fire disturbance regime. A species-level satellite image classification was utilized to map the current distribution of oak, while pre-settlement conditions were reconstructed using the U.S. General Land Office (GLO) surveyor notes dating from 1847-59 in a geographical information system (GIS). Oak has increased in the Pine Barrens landscape over the last 150 years, the increase being particularly strong where nineteenth-century surveyors mentioned oak understory. It is suggested that fire suppression may have contributed to the oak increase by permitting these understory oaks to reach canopy height. Oak savannas were not widespread in the pre-settlement landscape, but probably existed in the south-central part of the Pine Barrens, where larger, dispersed burr oaks were noted by the surveyors. The value of GLO data for the broad scale reconstruction of pre-settlement vegetation and disturbance characteristics was highlighted. The role of historical data in assisting restoration management is discussed.

Keywords: WI/ vt, oak savanna/ vt, pine barrens / fire regime/ wildfire/ fire suppression/ fire, prescribed/ GIS/ remote sensing/ land-use/ landscape ecology/ GLO/ presettlement vegetation/ restoration ecology/ oak/ oak, bur.

418. **Rauscher, H. Michael. 1984. Homogeneous macroclimatic zones of the Lake States. US Forest Service, Research Paper NC-240.**

Note: The Lake States is stratified using NOAA weather station data into homoclines, areas of similar climate. The variables used for stratification are heat, light and moisture, that influence plant species composition.

Keywords: MN/ WI/ MI/ weather.

419. **Raymond, Randall Eugene. 1975. Postglacial lakes and recent forest fire history as exhibited in inland lake sediments on Isle Royale National Park, Michigan. Michigan Technological University, Houghton. Masters thesis. 42 pp.**

Abstract: Study of the forest fire history of Isle Royale National Park reveals that the inland lakes sampled for charcoal analysis have different origins with respect to the higher water levels of ancestral Lake Superior. The basal reddish-brown silty clay found in 10 of the 12 sites cored on Isle Royale places the origin of these basins at Valdres age (approx. 11,000 years B.P.). The key stratigraphic feature which differentiates the sites is the homogenous gray clay which overlies the basal reddish-brown clays in many lakes. This feature indicates whether or not a particular basin was affected by the high water levels of the postglacial lakes of the Minong-Nipissing interval. Comparing the diagrams of the sediment

sequences and the diagrams of the Isle Royale shoreline at the Minong and Nipissing high water stages, makes it possible to separate those basins covered by only Lake Minong from those covered by both Lakes Minong and Nipissing. It appears that the band of gray sand found in the sediment cores from Chickenbone and Eva Lakes are the result of Lake Houghton low water stage that existed between postglacial Lakes Minong and Nipissing.

The record of charcoal influx to the lake sediments indicates that fire has been an important ecological factor in the forest history of Isle Royale for at least the past 1,000 years. The average frequency between peak periods of charcoal influx does not vary significantly in three of the four lakes selected for charcoal analysis. Angleworm, Siskiwit, and Wallace Lakes each have 19, 18, and 18 peaks respectively, with the average number of years between the peaks being 58, 60, and 60 years. However, problems with radiocarbon age determinations and low rates of sediment accumulation make it difficult to say whether these peaks represent one fire or a series of fires at close time intervals.

Keywords: MI/ Isle Royale/ island/ vt, balsam fir forest/ paleoecology/ charcoal analysis/ soil morphology/ fire history.

420. **Reeder, C. J. and Jurgensen, M. F. 1979. Fire-induced water repellency in forest soils of upper Michigan. Canadian Journal of Forest Research. 9:369-373.**
Keywords: MI/ fire effects/ soils, hydrophobic.
421. **Reich, Peter B.; Abrams, Marc D.; Ellsworth, David S.; Kruger, Eric L., and Tabone, Tom J. 1990. Fire affects ecophysiology and community dynamics of central Wisconsin oak forest regeneration. Ecology. 71(6):2179-2190.**
Abstract: In order to understand better the ecophysiological differences among competing species that might influence competitive interactions after, or in the absence of, fire, we examined the response to fire of four sympatric woody species found in intermediate-sized gaps in a 30-yr-old mixed-oak forest in central Wisconsin. Selected blocks in the forest were burned in April 1987 by a low-intensity controlled surface fire. The fire had significant effects during the following growing season on community structure, foliar nutrient concentrations, and photosynthesis. *Acer rubrum* seedling density declined by 70% following the fire, while percent cover increased several-fold in *Rubus allegheniensis*. In general, leaf concentrations of N, P, and K were increased by the fire in all species, although the relative enhancement decreased as the growing season progressed. Daily maximum photosynthetic rates were 30-50% higher in burned than unburned sites for *Prunus serotina*, *Quercus ellipsoidalis*, and *R. allegheniensis*, but did not differ between treatments for *A. rubrum*. Mean sunlit photosynthetic rates and leaf conductances were stimulated by the burn for all species, with the greatest enhancement in photosynthesis measured in *Q. ellipsoidalis*. Leaf gas exchange in *R. allegheniensis* was most sensitive to declining leaf water potential and elevated vapor pressure gradient, with *Q. ellipsoidalis* the least sensitive. Fire had no discernable effect on water status of these plants during a year of relatively high rainfall. In comparison with other species, *A. rubrum* seedlings responded negatively after fire-both in terms of

survival/reproduction (decline in the number of individuals) and relative leaf physiological performance. Fire enhanced abundance of *R. allegheniensis* and the potential photosynthetic performance of *R. allegheniensis*, *P. serotina*, and particularly *Q. ellipsoidalis*. We conclude that post-fire stimulation of net photosynthesis and conductance was largely the result of enhanced leaf N concentrations in these species.

Keywords: WI/ vt, oak forest/ fire, prescribed/ fire effects/ physiology/ regeneration, seed/ maple, red/ cherry, black/ oak, pin/ shrubs.

422. **Reuter, D. Dayton. 1986. Effects of prescribed burning, cutting and torching on shrubs in a sedge meadow wetland. In, Prescribed Burning in the Midwest: State of the Art., Mar 3-6, 1986, Stevens Point, WI. Wisconsin Department of Natural Resources, Fire and Science Center. pp. 108-115.**
Note: Location of study was Endeavor Marsh of the Fox River watershed.
Abstract: This study compares treatments of early spring prescribed burning, early and late summer manual cutting, and early and late summer manual torching for their effects on shrubs and ground layer plants and their implementation costs. All treatments produced a temporary reduction in shrub dominance, but few plants were actually killed. No major differences were observed between shrub species in response to the treatments (although *Cornus stolonifera* Michx. and *Salix* spp. exhibited more vigorous vegetative behavior after treatment than the other shrub species), nor were major differences observed between treatments in their effects on shrubs. Early treatments favored ground layer plants more than later treatments, with prescribed burning showing the most vigorous ground layer plant response. Prescribed burning was also found to be substantially less costly to implement, costing less than 15% as much as the other treatments (including the cost of firebreak construction).
Keywords: WI/ vt, wetland/ fire, prescribed/ fire effects/ restoration ecology/ sedge/ shrubs/ willow.
423. ---. 1988. **Management of prescribed burns in fen and sedge meadow wetlands. In, Wetlands '88: Urban wetlands and riparian habitat. p. 290-297.**
Note: Planning a prescribed burn is explained and, an example of how a prescribed burn was done at the Summerton Bog Nature Preserve in Marquette county, WI is given.
Keywords: WI/ vt, wetland/ fire, prescribed/ methodology.
424. **Richardson, H. W. 1919. The northeastern Minnesota forest fires of October 12, 1918. The Geographical Review. 7:220-232.**
Note: Statistics such as location of fires, fire weather and damage that occurred on October 12, 1918 in northeastern Minnesota by the famous wildfires are given. The Cloquet fire is the most famous of the fires.
Keywords: Minnesota/ wildfire/ wildfire, historic.
425. **Richardson, J. L. and Hole, Francis D. 1978. Influence of vegetation on water repellency in selected western Wisconsin soils. Soil Science Society of America Journal. 42:465-467.**

Abstract: Water repellency in several western Wisconsin soils was characterized by three tests: wetting angle (θ), wetting drop penetration-time (WDPT), and 90° -surface tension (γ). It appears that the high contents of organic matter in the A horizon of Mollisols and Alfisols are associated with slight repellency as measured by (θ) and WDPT. Frequent burning of a prairie on a Mollisol increased persistence (WDPT) and γ (90° -surface tension) as compared with soil at a nearby control sites, but had no influence on (θ), indicating that repellency is present at initial water contact but is unstable and disappears with prolonged water contact.

Mor litter layers having observable fungal mycelia had repellent surfaces as measured by all three of the above tests. These repellent materials were observed in Spodosols under red pine (*Pinus resinosa*), hemlock (*Tsuga canadensis*), and under a mixed hard and soft wood stand with dense ericaceous shrub understory. The repellency of mor horizons of Spodosols may relate in some significant way to process of genesis of Spodic horizon.

Keywords: Wisconsin/ vt, prairie/ fire, prescribed/ fire effects/ soils, hydrophobic/ pine, red/ hemlock.

426. **Roberts, Charles F. 1974. Weather and Forest Fires. Weatherwise. 27(3):100-105, 115.**

Note: The changes in fuel moisture of small to large fuels with changes in relative humidity and the influence of wind speed on rate of fire rate of spread are described.

Keywords: fire behavior.

427. **Rogers, Paul. 1996. Disturbance ecology and forest management: a review of the literature. US Forest Service, General Technical Report INT-336. 16 pp.**

Note: The report defines disturbance ecology and outlines forest dynamics and disturbance agents (biotic and abiotic). Methods for quantifying disturbance ecology and modeling procedures are explained.

Keywords: disturbance ecology/ review/ modeling.

428. **Rogers, Robert S. 1978. Forests dominated by hemlock (*Tsuga canadensis*): distribution as related to site and postsettlement history. Canadian Journal of Botany. 56:843-854.**

Note: Only 8% of the hemlock stands sampled were even-aged therefore, very few of the hemlock stands in the northern part of their range were initiated after a catastrophic event such as a wildfire. A good description of soils and moisture under hemlock stands.

Abstract: Along a transect of mature forests from Wisconsin to Nova Scotia, hemlock attains dominance most frequently where soil is thin or low in stored nutrients. Very probably, soil is also dependably moistened either by climate or seepage. The inability of shade-tolerant competitors to survive suppression on thin or infertile soil may explain hemlock's success, even though hemlock maintains understory populations at very low densities. Hemlock also grows well on moist uplands with richer soil but does not often attain dominance or form

large aggregates in a continuously varying mixed forest. This is in contrast to hemlock's codominance on a wide variety of upland sites in the presettlement forest. Recent history, then, may best explain the rarity of hemlock-dominated stands on richer sites: (1) hemlock is sensitive at all stages of its life cycle to disturbances that were intensified after European settlement as well as to the kinds of animal consumption that increase with disturbance; (2) disturbance has been most frequent on sites with richer soils; and (3) hemlock does not compete well with shade-tolerant trees such as sugar maple, beech, and red spruce that are better adapted to disturbance. These species can increase at the expense of hemlock because they have less rigorous requirements for seedling establishment, are not as palatable to consumers, or, in the case of sugar maple and beech, have deeper root systems and can sucker or sprout after extensive root damage.
Keywords: WI/ MN/ Canada/ Ontario/ vt, hemlock forest/ vtm hemlock-hardwood forest/ soil morphology/ soils, nutrient analysis/ presettlement vegetation/ disturbance ecology/ hemlock/ maple, sugar/ beech/ spruce, red.

429. **Rogers, W. E. 1922. Ice storms and trees. *Torreyia*. 22:61-63.**
Note: Two ice storms that occurred in central Wisconsin, 1922 are documented. The effect of ice on twigs and the weight of twig to ice ratio is explained.
Keywords: WI/ weather, effects on vegetation.
430. **Roussopoulos, Peter J. A decision aid for wilderness fire prescriptions in the Boundary Waters Canoe Area. In. 5th National Conference on Fire and Forest Meteorology, Boston, MA. American Meteorological Society. p. 52-58.**
Keywords: MN/ National Forest, Superior/ BWCAW/ fire, prescribed/ management.
431. **Rowe, J. S. and Scotter, G. W. 1973. Fire in the boreal forest. *Quaternary Research*. 3:444-464.**
Keywords: vt, boreal forest/ fire regime/ fire effects.
432. **Runkle, James Reade. 1982. Patterns of disturbance in some old growth mesic forests of eastern North America. *Ecology*. 63(5):1533-1546.**
Abstract: To characterize the disturbance regime of one type of vegetation, study areas in which relatively small-scale disturbance predominates were chosen in several old-growth mesic forests in the eastern United States. Canopy openings covered 9.5% of total land area. New gaps were formed at an average rate of 1% of total land area per year; old gap area closed at a similar rate primarily by sapling height growth.

With increased gap size, vegetation within the gaps increased in woody species diversity, total basal area, and total number of stems. Stems also showed accelerated growth into larger size classes. As gaps aged, stems grew into larger size classes and basal area increased.

Species responses to canopy gaps varied. Some species survived and became established in fairly small gaps (50-100 m²). Although in large gaps (up to 2009

m² in the present study) these species usually increased in total number of stems and basal area, they declined in importance relative to species which rarely survived in small gaps but grew rapidly in large gaps. The disturbance regimes in the forests studied favored tolerant species but allowed opportunists to persist at low densities.

Keywords: eastern United States/ vt, hemlock-hardwood forest/ windthrow, occurrence of/ disturbance ecology/ canopy gap/ hemlock/ maple, sugar/ beech/ birch, yellow.

433. **Runkle, James Reade and Yetter, Todd C. 1987. Treefalls revisited: gap dynamics in the southern Appalachians. Ecology. 68(2):417-424.**

Abstract: In 1976-1977, 284 gaps (canopy-opening sizes 1-1490 m²) were sampled (age, size, species composition) from old-growth mesic forests in Great Smoky Mountains National Park, Joyce Kilmer Wilderness Area and Walker Cover Research Natural Area. In 1983, the woody vegetation (stems \geq 1 cm dbh) of 273 of these gaps was resampled, rates of gap closure by canopy tree branch growth and sapling height growth were estimated, and incidences of disturbances occurring since 1976-1977 were noted. The average yearly crown extension growth rate was 18 cm/yr, with much variation among species and individuals. Some individual crowns grew into the canopy opening as much as 4 m in the 7 yr. Saplings grew an average of 30 cm/yr in height, again with much variation. Overall, taller saplings grew somewhat faster than smaller ones and saplings in large gaps grew faster than those in small gaps. These two rates of gap closure together suggest that most samplings will require two or more gap episodes to reach the forest canopy.

For woody vegetation, basal area per unit gap area was originally highest in small gaps, though it increased between sampling dates most in large gaps. Stem density had been highest in small old gaps, but decreased the most in old gaps. *Tsuga canadensis*, *Fagus granifolia*, *Acer saccharum*, and *Halesia carolina* were the most important species in the gaps studied. Most species did not change in relative density or dominance between the two sampling dates and showed no significant correlations between those parameters and gap size and age. Overall, *Tsuga* and *Fagus* decreased and *Acer saccharum* increased in importance. High rates of repeat disturbance favor species able to grow in intermediate light levels and to survive several periods of suppression before reaching the canopy.

Keywords: NC/ vt, hemlock-hardwood forest/ vt, maple forest/ canopy gap/ windthrow, occurrence of/ disturbance ecology/ maple, sugar/ beech/ hemlock.

434. **Sando, Rodney W. 1969. Prescribed burning weather in Minnesota. US Forest Service, Research Paper NC-28. 8 pp.**

Keywords: MN/ fire, prescribed.

435. **Sando, Rodney W. and Haines, Donald A. 1972. Fire weather and behavior of the Little Sioux Fire. US Forest Service, Research Paper NC-76. 6 pp.**

Note: The fuel conditions of the forest, synoptic weather and fire behavior that occurred prior to and during the Little Sioux fire.

Keywords: Minnesota/ National Forest, Superior/ Little Sioux fire/ fire weather/ fire behavior/ wildfire, historic.

436. **Sauer, C. O. 1950. Grassland climax, fire, and man. Journal of Range Management. 3:16-21.**
Note: Cited by Curtis (1959) on the subject of Indians setting fire to the prairie.
Keywords: vt, prairie/ fire, Native American use of.
437. **Schaetzl, Randall J. 1986. Complete soil profile inversions by tree uprooting. Physical Geography. 7(2):181-189.**
Keywords: soil formation/ windthrow, effects on soil.
438. ---. 1987. **The effects of tree-tip microtopography on soil genesis, northern Michigan. University of Illinois, Urbana.**
Keywords: MI/ soil formation/ microsite/ windthrow, effects on soil.
439. ---. 1990. **Longevity of treethrow microtopography: Implications for mass wasting. Geomorphology. 3:113-123.**
Keywords: windthrow, effects on soil/ microsite/ soil formation.
440. **Schaetzl, Randall J.; Burns, S. F.; Johnson, D. L., and Small, T. W. 1989. Tree uprooting: review of impacts on forest ecology. Vegetatio. 79:165-176.**
Keywords: windthrow, effects on soil/ windthrow, review.
441. **Schaetzl, Randall J.; Burns, S. F., and Small, T. W. 1989. Tree uprooting: Review of terminology, process, and environmental implications. Canadian Journal of Forest Research. 19:1-11.**
Abstract: Floralturbation, the mixing of soil by the action of plants, is an important pedologic process in forested areas. The uprooting of trees, the most obvious form of floralturbation, is a natural process found in nearly all forested landscapes. The term uprooting is distinct from such terms as treethrow, treefall, and blowdown, which imply processes that may occur without soil disturbance, as in bole snap. Uprooting is exacerbated by shallow rooting, topographic exposure, weakened condition of the tree, certain cutting practices, and (or) low soil cohesion and shear strength. The root plate of an uprooted tree may deteriorate into a pit-mound pair, the size and shape of which depends on the characteristics of the root plate and the amount of backward displacement during uprooting. This paper (i) provides a synthesis of related terminology on the topics of treefall and uprooting, (ii) examines various lines of evidence for the widespread occurrence of uprooting, (iii) summarizes disturbance cycles for catastrophic uprooting events in different environments, (iv) discusses several examples of the economic import and scale of widespread uprooting events, and (v) reviews environmental factors and silvicultural practices that may lead to increased uprooting or can be used to minimize its likelihood.
Keywords: windthrow, effects on soil/ windthrow, review.
442. **Schaetzl, Ronald J. 1994. Changes in O horizon mass, thickness and carbon content**

following fire in northern hardwood forests. Vegetatio. 115:41-50.

Keywords: MI/ vt, aspen-birch forest/ vt, hemlock-hardwood forest/ fire effects/ litter and duff/ pine, white/ maple, sugar/ hemlock/ birch, paper/ aspen, trembling.

443. **Scheiner, Samuel M.; Sharik, T. L.; Roberts, M. R., and Kopple, R. Vande. 1988. Tree density and modes of tree recruitment in a Michigan pine-hardwood forest after clear-cutting and burning. Canadian Field Naturalist. 102(4):634-638.**

Abstract: Changes in stem density and the relative amount of recruitment by both vegetative reproduction and seedling establishment were assessed for 5 yr following clear felling and burning of slash in northern lower Michigan. Prior to disturbance, the community consisted primarily of a mixture of *Quercus rubra*, *Populus grandidentata*, and *Pinus strobus*. Following disturbance, *Populus grandidentata* and *Acer rubrum* comprised 66% and 25%, respectively, of all stems. Stem density declined by 41% in the first 5 yr following fire. There was no change in the relative number of stems of each species during this time. Animal- and wind-dispersed species had different rates of seedling recruitment. *Populus grandidentata*, *P. tremuloides*, and *Acer rubrum* were recruited exclusively by vegetative means. *Q. rubra*, *Amelanchier arborea*, and *Betula papyrifera* were recruited both vegetatively and by seed. *Prunus pennsylvanica* was recruited only by seed. No recruitment of *Pinus strobus* and *P. resinosa* occurred in the first 4 yr following disturbance and any future recruitment would have to be from seed.

Keywords: MI/ vt, pine-oak forest/ fire effects/ fire, prescribed/ logging, clearcut/ regeneration, seed/ regeneration, vegetative/ oak, red/ aspen, big tooth/ pine, white/ pine, red/ maple, red/ aspen, trembling/ serviceberry/ birch, paper.

444. **Scheiner, Samuel M. and Teeri, James A. 1981. A 53-year record of forest succession following fire in northern lower Michigan. The Michigan Botanist. 20:3-14.**

Abstract: A 53-year record of forest succession following fire was analyzed for five experimentally or naturally burned plots in northern Michigan. After a fire the species diversity increased gradually for 25 years and remained level thereafter. This finding contrasts with studies which have found an early peak in species diversity with a subsequent decrease within the first 10 years of succession. Immediately following fire, *Populus grandidentata* became the dominant tree species. During the 53-year period *Acer rubrum* and *Pinus strobus* replaced *Populus grandidentata* in abundance. In contrast with other investigations, the importance of annual species did not decrease during the period of succession.

Keywords: MI/ vt, aspen forest/ vt, pine forest/ succession/ fire effects/ fire, prescribed/ wildfire/ aspen, big tooth/ maple, red/ pine, white.

445. **Schindler, D. W.; Newbury, R. W.; Beaty, K. G.; Prokopowich, J.; Ruszczynski, T., and Dalton, J. A. 1980. Effects of a windstorm and forest fire on chemical losses from forested watersheds and on the quality of receiving streams. Canadian Journal of Fisheries and Aquatic Sciences. 37:328-334.**

Note: The windstorm occurred on July 7, 1973. The hydrographs for the

windthrow/fire influenced watersheds were back to normal 3 years after the fire. **Abstract:** A severe natural windstorm followed by a high intensity forest fire caused significant increases in runoff and in losses in nitrogen, phosphorus, and potassium from two small Precambrian watersheds. Both the windstorm and the fire had significant effects on water and chemical yields. Water yields in the two basins were 1.6 and 1.8 times the pre-impact means, respectively, in the year after the burn. Maximum chemical losses we observed for nitrate, with values of 3.4 and 9 times the pre-impact means for the two basins in the year after the burn. Increases in yields of most chemical parameters were 1.1 to 2.9 times the background. Both increased concentrations and increased flow volumes appear to be responsible for the increased nutrient losses.

Keywords: Ontario/ Canada/ vt, boreal forest/ vt, conifer-feathermoss forest/ fire effects/ soil drainage/ hydrology/ soils, nutrient analysis/ water chemistry/ windthrow, effects on hydrology.

446. **Schroeder, Mark J. 1950. The Hudson Bay High and the spring fire season in the Lake States. Fire Control Notes. 11(1):1-8.**

Note: Burning index data from 1945 to 1948 for the month of May was used to determine what weather patterns are associated with severe fire weather. The Hudson Bay High, almost always present during severe fire weather, is described. **Keywords:** MI/ MN/ WI/ fire weather.

447. **Schulte, Lisa. 2002. Northern Wisconsin forests: pattern and process on a historical landscape. University of Wisconsin, Madison.**

Abstract: I characterize regional patterns in northern Wisconsin (USA) forests and disturbance regimes for the period prior to Euro American settlement (ca. 1850). This period offers an informative ecological baseline for both science and natural resources management because it represents conditions just prior to rapid and unprecedented land use change. Pre-Euro American forest patterns, heavy windthrow dynamics, and stand-replacing fire disturbance can be represented by the U.S. General Land Office's original Public Land Survey (PLS) records.

My work shows much more regional-scale variability than previous studies of historical northern Wisconsin vegetation. Whereas yellow birch (*Betula alleghaniensis*) was previously thought to be only subdominant or co-dominant within northern Lakes States hemlock– northern hardwoods forests (primarily *Tsuga canadensis*, *Acer saccharum*, *Betula alleghaniensis*, and *Tilia americana*), my quantitative analysis reveals that this species prevailed on many of the glacial moraines. Maps also show broad areas dominated by white pine (*Pinus strobus*), and that jack pine (*P. banksiana*) had a more limited distribution than previously suggested.

Patterns of both heavy windthrow and stand-replacing fire were not random at any scale, and environment had a strong influence on this. The top-down control of climate exerted its influence on the distribution of both wind and fire disturbance, while bottom-up controls of forest type and physiography were respectively important. Topographic factors were not significant in explaining the distribution

of wind or fire in this region where gradients are subtle. Together these factors worked to maintain complex historical forest patterns in northern Wisconsin. Heavy windthrow was the predominant disturbance dynamic structuring forests across the majority of the region, but fire was of strong sub-regional importance, largely on glacial sandy outwash and along the prairie-forest border. An uncommon positive feedback existed between wind and fire at a patch scale, where heavy windthrow increased the potential for fire disturbance on mesic sites. This was combined with a persistent negative feedback at the regional scale that made fire-prone areas less susceptible to windthrow.

My research paints a new view of ecological patterns and processes within northern Wisconsin's historical forests, and can be used as a baseline for current day forest management and ecological restoration.

Keywords: WI/ presettlement vegetation/ GLO/ GIS/ fire interval/ windthrow, frequency.

448. Shay, Creighton Thomas. 1965. Postglacial vegetational development in northwestern Minnesota and its implications for prehistoric human ecology. University of Minnesota, St. Paul. Masters thesis. 112 pp.

Note: Postglacial vegetation change in the Red River Valley, Minnesota, is described by pollen and charcoal analysis from 3 sites. The information is associated with anthropological and faunal findings from the same area. The data indicates that the high fire frequency of the prairie was at least partially dependent upon the use of fire by Native Americans for buffalo drives. The woodland expansion into the prairie seems to correspond with the changing patterns of native Americans from nomadic hunting groups to less mobile groups with less dependence upon buffalo and increased use of other foods such as fish, berries, etc.

Keywords: MN/ vt, prairie/ paleoecology/ pollen analysis/ charcoal analysis/ climate change/ fire, Native American use of.

449. Simard, Albert J. and Blank, Richard W. 1982. Fire history of a Michigan jack pine forest. Michigan Academician. 15(1):59-71.

Note: The Mack Lake Fire (May 5, 1980), burned in mostly mature jack pine forest with scattered red pine throughout. Fire scars from red pine in eight different locations (groups of 2 to 3 trees) within the boundaries of the fire were analyzed for past fire interval. The mean group fire interval was 29 years with a range of 15.1 to 33.2 years. For the time periods associated with presettlement (1830-1849), settlement (1850-1909), early suppression (1910-1929), and recent (1930-1969), the mean fire intervals were estimated to be 27 years, 10 years, 18 years, 8 years and 31 years, respectively (There was only one fire scar to represent the presettlement interval thus, the interval may have been shorter.). The large fire interval (10,000+ acres) at Mack Lake was 27.5 years over the past 165 years. There are six probable large fires (1815, 1862, 1874, 1886, 1946, and 1980). There is a downward trend in large fire interval from 35 years (presettlement) to 27 years (settlement and early suppression) to 25 years (recent). The fire size-

class distribution for the Huron-Manistee National Forest is typical with 98.7% of fires less than 100 acres in size. Seasonal distribution of area burned by jack pine crown fires from 1964 to 1975 from the 4 county area surrounding Huron National Forest can be summarized as follows: 1) Four times more area was burned during the second week of May than in any other week of the year. 2) There have been no crown fires during June and the first three weeks of July. 3) Throughout the remainder of the fire season, crown fires have occurred in about half of the weeks.

Keywords: Michigan/ National Forest, Huron-Manistee/ vt, pine barrens/ wildfire, historic/ fire, prescribed/ wildfire/ fire interval/ fire scar/ pine, jack/ pine, red.

450. **Simard, Albert J.; Haines, Donald A.; Blank, Richard W., and Frost, John S. 1983. The Mack Lake Fire. US Forest Service, General Technical Report NC-83. 37 pp.**

Note: This report describes the weather, fuels, and the fire chronology of the Mack Lake fire.

Describes the Mack Lake Fire near Mio, Michigan. Few documented wildfires have exceeded its average spread rate (2 mi/hr) and energy release (8,800 Btu/ft/sec). The extreme behavior resulted from high winds, low humidity, low fuel moisture, and jack pine fuels. Horizontal roll vortices may have contributed to the death of one firefighter.

Keywords: Michigan/ National Forest, Huron-Manistee/ vt, pine barrens/ wildfire/ fire behavior/ fire weather/ wildfire, historic/ pine, jack.

451. **Simiu, Emil and Filliben, James J. 1979. Probability distributions of extreme wind speeds. Journal of the Structural Division, Proceedings of the American Society of Civil Engineers. 102:1861-1877.**

Note: A model for estimation of extreme wind speeds is presented.

Keywords: weather/ modeling.

452. **Slaughter, Kent Wesley. 1994. Succession following forest fire in northeastern Minnesota; changes in biomass and stand composition. University of Minnesota, St. Paul. Masters thesis. 141 pp.**

Note: Changes in biomass and stand composition that has occurred between 1975 and 1993 on 5 permanent plots located with the perimeter of the Little Sioux fire (see pubs by Grigal, Ohman, Kernik, Botkin and Simpson) are described. Results show an increase in tree biomass and forest floor biomass confirming the model proposed by Ohman and Grigal (1979). Species specific data was reported.

Keywords: Minnesota/ BWCAW/ National Forest, Superior/ Little Sioux fire/ vt, boreal forest/ succession/ fire effects/ wildfires, historic/ maple, red/ birch, paper/ spruce, black/ pine, jack/ pine, red/ pine, white/ aspen, big tooth/ aspen, trembling/ oak, red/ shrubs/ herbs.

453. **Slaughter, Kent Wesley, Grigal, David F. and Ohman, Lewis F. 1998. Carbon storage in southern boreal forests following fire. Scandinavian Journal of Forest Research. 13:119-127.**

Note: I suspect this paper is taken from thesis studies located in BWCAW, Little Sioux fire area.

Keywords: Minnesota/ National Forest, Superior/ BWCAW/ Little Sioux fire/ vt, boreal forest/ fire effects/ wildfire, historic/ aspen, trembling/ aspen, big tooth.

454. **Smith, David W. and Sparling, John H. 1966. The temperatures of surface fires in jack pine barren, I. The variation in temperature with time. Canadian Journal of Botany. 44:1285-1292.**

Abstract: The temperatures of 18 fires in an open jack pine barren near Timmins, Ontario, have been recorded. The maximum temperature recorded was 545°C, although in the other determinations fire temperatures in excess of 1000°C were reached. The mean temperature of all fires was 340.6±133.2°C. Three fires at 230, 345, and 545°C were considered in detail.

The maximum temperature of a fire was normally recorded at heights of 5 cm or 10 cm above the surface. Maximum temperatures of hotter fires usually occurred at greater heights than cooler ones. Duration and the temperature ("intensity") of the fire are important aspects of fire studies.

Keywords: Ontario/ Canada/ vt, boreal forest/ vt, pine barrens/ fire, prescribed/ fire behavior/ pine, jack.

455. **Soper, E. K. 1919. The peat deposits of Minnesota: University of Minnesota, Geological Survey, Bulletin 16.**

Keywords: MN/ charcoal/ soils, organic.

456. **Sprugel, Douglas G. 1991. Disturbance equilibrium, and environmental variability: What is 'Natural' vegetation in a changing environment. Biological Conservation. 58:1-18.**

Note: This article characterizes the problems with ecological classification and, it emphasizes the need to describe the range of natural variation within ecosystems.

Abstract: To the most early ecologists, the 'natural' ecosystem was the community that would be reached after a long period without large-scale disturbance (fire, windstorm, etc.). More recently, it has been realized that in most areas some type of large-scale disturbance is indigenous, and must be included in any realistic definition of 'naturalness'. In some areas an equilibrium may exist in which patchy disturbance is balanced by regrowth, but in others equilibrium may be impossible because (1) individual disturbances are too large or infrequent; (2) ephemeral events have long-lasting disruptive effects; and/or (3) climate changes interrupt any movement toward equilibrium that does occur. Examples of non-equilibrium ecosystems include African savannas, the Big Woods of Minnesota, the lodgepole pine forests of Yellowstone National Park, and possibly the old-growth Douglas-fir forests of the Pacific Northwest.

Where an equilibrium does not exist, defining the 'natural' vegetation becomes more challenging, because the vegetation in any given area would not be stable over long periods of time even without man's influence. In many areas it may be unrealistic to try to define the natural vegetation for a site; one must recognize

that there are often several communities that could be the 'natural' vegetation for any given site at any given time.

Keywords: MN/ MT/ WA/ Africa/ other countries/ vt, Big Woods/ fire, general reference to stand structure/ windthrow, effects on vegetation/ climate change/ disturbance ecology/ review.

457. **Spurr, Stephen H. 1953. Forest fire history of Itasca State Park. Minnesota Forestry Notes 18. 2 pp.**

Note: Fire scar analysis on red pine slab from Itasca State Park indicates many fires had occurred after its origin (after a wildfire in 1725). Wildfire data was corroborated with increment cores from nearby trees. Wildfires occurred, at least, in 1772, 1803, 1811, 1820, 1865, and 1886. Red pine and white pine stands regenerated after the 1772 fire and, the 1803, 1811, and 1820 fires gave rise to red pine stands. Thousands of acres of jack pine and aspen became established after a very severe fire in 1886 in the northeast section of the park.

Keywords: MN/ Itasca Park/ vt, pine forest/ fire scar/ fire interval/ pine, red/ pine, white/ pine, jack/ aspen, trembling.

458. ---. 1954. **The forests of Itasca in the nineteenth century as related to fire. Ecology. 35(1):21-25.**

Note: This publication is very similar to Spurr (1953) except there is more detail on extent of large fires, as well as, small fire locations. The frequency of witness trees by species recorded on the GLO notes is summarized, and logging history detail within the park is given.

Keywords: MN/ Itasca Park/ vt, pine forest/ fire scar/ fire interval/ pine, red/ pine, white/ pine, jack/ aspen, trembling/ GLO/ presettlement vegetation/ logging.

459. ---. 1956. **Natural restocking of forests following the 1938 hurricane in central New England. Ecology. 37:443-451.**

Note: Tree regeneration is compared across soil types in Harvard Forest, MA, 10 years after the 1938 hurricane. There is also some comparison with salvage operations in other areas affected by blowdown. Factors that affected stand composition are: "1) soil type, 2) composition of former stand, 3) advance growth present at the time of blowdown, 4) whether the down timber was logged or not.". Released late-successional understory trees made up stands that were not logged and had advanced growth present prior to the blowdown. If logging occurred, the late successional species are mixed with pioneer species that seeded in. If advanced growth was not present, pioneer species were the dominant regeneration. Red oak and red maple typically dominant species found on all sites, although, in many cases pioneer species density was higher. White pine was associated with outwash sands and till soils. White ash and other mesic site species were found on till soils, especially areas with imperfect drainage or more fertile. Pioneer species are grey birch, pin cherry, black cherry, and paper, black, and yellow birches. In almost all cases, the species composition of the stand was evident after the second growing season.

Keywords: MA/ eastern United States/ Harvard Forest/ vt, pine-hemlock-hardwood forest/ vt, hemlock-hardwood forest/ vt, maple forest/ windthrow,

effects on vegetation/ hurricane/ regeneration, seed/ succession/ soil morphology/ logging, salvage/ pine, white/ ash, white/ birch, grey/ birch, paper/ birch, black/ birch, yellow/ cherry, pin/ cherry, black/ oak, red/ maple, red.

460. **Stallard, Harvey. 1929. Secondary succession in the climax forest formation of northern Minnesota. Ecology. 10(4):476-547.**

Note: Secondary succession for vegetation found in northern Minnesota is described. Data was collected from Beltrami, Koochiching, St. Louis, Cook, Hubbard, Cass, Crow Wing, Itasca, Aitkin, Carlton, Pine, Wadena, and Ottertail counties. Secondary succession for pine-hemlock, maple-beech climaxes are listed by soil types. Evidence of fire was common in stands that were at one time red and white pine although, the current dominant vegetation was jack pine, aspen, birch, spruce, or tamarack. Frequently, white and red pine seedlings were found in the understory of the pioneer stands. Locations of red and white pine stumps, mature jack pine, and seedlings (especially red and white pine) within 10-meter quadrant is shown. Descriptions of many plant communities, such as the 1 listed above are given and fire is listed as an agent of change. While windthrow, flooding and logging are mentioned frequently, wildfire is the disturbance given the most attention. Comparisons of summer soil moisture of some soils with differing vegetation composition are compared.

Keywords: MN/ vt, pine forest/ vt, pine-hemlock-hardwood forest/ vt, maple forest/ fire effects/ logging/ succession/ soil morphology/ pine, white/ pine, red/ pine, jack/ hemlock/ maple, sugar/ beech/ shrubs/ herbs .

461. **Stearns, Forest W. 1949. Ninety years change in a northern hardwood forest in Wisconsin. Ecology. 30:350-358.**

Note: Forest composition in 1946 is compared to that of the mid-1800's, as described in the GLO notes (1857-59), of a stand in southeast Forest county (T35N, R14E). There is much discussion on windfall plus maps showing windfall from the GLO notes, and its effects on forest dynamics. A general discussion of fire is included, as well. The results of the research conclude that the trend is away from an evenly mixed sugar maple, hemlock, yellow birch forest to a higher proportion of sugar maple. But, because of constant disturbances such as windthrow, fire, drought, etc., the forest will never be a pure stand of sugar maple. The stand probably originated after a fire in the 16th century.

Keywords: WI/ vt, hemlock-hardwood forest/ vt, maple forest/ succession/ windthrow, occurrence of/ fire history/ GLO/ presettlement vegetation/ maple, sugar/ hemlock/ birch, yellow/ basswood/ pine, white.

462. **---. 1950. The composition of a remnant of white pine forest in the Lake States. Ecology. 31(2):290-292.**

Note: Forest composition of an approximately 400 yr old white pine stand located by Plum Lake on Notre Dame property is described. Stand disturbance at certain time intervals is mentioned but, the type of disturbance was unknown. The measurements were taken in 1946 and, a large windstorm that might have damaged the stand occurred in the area in 1949.

Keywords: WI/ MI/ vt, pine forest/ vt, hemlock forest/ vt, hemlock-hardwood

forest/ windthrow, occurrence of/ disturbance ecology/ old-growth/ pine, white/ birch, paper/ hemlock/ maple, sugar/ balsam fir/ northern white cedar.

463. ---. 1990. **Forest history and management in the northern midwest.** *In*, Sweeney, J. M. **Management of dynamic ecosystems. The Wildlife Society, North Central Section, West Lafayette, IN. p. 107-122.**

Abstract: The static forest exists only to a degree, and that in part as a result of attempts by management to achieve certain goals. The forests of Holocene time consisted of species adapted to the prevailing climate that became established, when seed was available and where substrate conditions were favorable. With amelioration of local climate, and with arrival of other species, forest composition and structure changed. Climatic events and associated disturbances played major roles in determining forest composition and structure, and in creating the massive stands that were exploited during the past 2 centuries. As the older forests have been replaced by younger stands, the nature and frequency of disturbance has changed—from infrequent but catastrophic events to more frequent but less severe ones. Clearly forest management has had a major impact on wildlife species and their habitats. Goals and technologies of management are well established but they are subject to modification in ways that could shift some forest ecosystems into a more dynamic, diverse, and even more productive condition. Changes in size and shape of clearcut blocks, recognition of natural stand rotation periods, and modification of timber stand improvement practices would all be beneficial. Fire has long been recognized as an important tool in producing change, and prescribed fire should be used more frequently in the future. Different mechanical and silvicultural approaches to drastically alter forest floor conditions may also be appropriate. The forest changes continuously and future major changes are to be anticipated as a result of extrinsic factors not presently subject to control, such as acid rain, depletion of the ozone layer, and climatic warming.

Keywords: WI/ MI/ MN/ review/ management/ fire, prescribed/ logging, clearcut/ silviculture/ climate change/ flooding/ windthrow, effects on vegetation/ disturbance ecology.

464. ---. 1992. **Ecological characteristics of the White Pine.** *In*, Stine, Robert A. and Baughman, Melvin J. **The White Pine Symposium Proceedings, Sept 16-18, 1992, Duluth, MN. Minnesota Extension Service v. NR-BU-6044-S. p. 10-18.**

Note: No new research but a good description of white pine characteristics.

Abstract: White pine, a relatively long-lived, versatile, and genetically variable species, is well adapted to many sites in the Lake States and Ontario. Adequate seed production and ability to become established in the open as well as under a variety of canopy conditions permit it to recover from disturbance forming pure or mixed stands. A degree of shade tolerance and rapid growth after the first 8 or 10 years encourage the success of white pine. Resistance of older stems to fire and wind augment its long term survival. Once far more abundant and the "kingpin" of the early timber industry, white pine can and should play a major role in future Lake States forests.

Keywords: MN/ WI/ MI/ vt, pine forest/ review/ fire regime/ windthrow, effects on vegetation/ pine, white.

465. **Stewart, O. C. 1951. Burning and natural vegetation in the United States. The Geographical Review. 41:317-320.**
Keywords: fire, Native American use of.
466. **Stocks, Brian J. 1975. The 1974 wildfire situation in northwestern Ontario . Canadian Forestry Service, Department of the Environment. O-X-232.**
Note: The pre-fire forest type in both areas is mature jack pine overstory in the upland and mature black spruce in the lowland sites. Red Lake No.31 was a relatively undisturbed forest stand and Dreyden No. 18 was composed of mostly blown down trees due to a large windstorm the year before. The Red Lake fire had a much higher rate of spread and intensity than did the Dreyden fire mainly because of the differences in fuel arrangement (wood on the ground vs. wood, needles, etc. of standing forest).
Abstract: During the 1974 fire season in Ontario 1,625 wildfires destroyed a total of 524,005.7 hectares (1,294,800.2 acres), the greatest area burned over in this province since 1923. This report summarizes and analyzes the fire weather and wildfire situation in northwestern Ontario before and during the critical burning period of 1974, and gives special attention to the analysis of the two most significant wildfires of this year: Red Lake No. 31 and Dryden No. 18.
Keywords: Ontario/ Canada/ vt, conifer-feathermoss forest/ wildfire/ fire behavior/ windthrow, occurrence of/ pine, jack/ spruce, black/ feathermoss.
467. ---. **1985. Forest fire behavior in spruce budworm-killed balsam fir. In, Sanders, C. J.; Stark, R. W.; Mullins, E. J., and Murphy, J. Recent Advances in Spruce Budworms Research, Proceedings of the CANUSA Spruce Budworms Research Symposium, Sep 16-20, 1984, Bangor, Maine. Canadian Forestry Service.**
Abstract: An intensive experimental burning program was carried out in Ontario between 1978 and 1982, in order to quantitatively document fire behavior in balsam fir mortality resulting from an eastern spruce budworm infestation. Forest fire potential in budworm-killed balsam fir was shown to be significantly increased for a number of years following stand mortality. Crown breakage and wind throw, with resultant fuel complex rearrangement and increased surface fuel loadings, peaks 5-8 years after mortality. Fire potential is greatest during this period, decreasing gradually as balsam fir surface fuel begins to decompose and understory vegetation proliferates. Spring fires, occurring prior to flushing, behave explosively with continuous crowning, high spread rates, and severe downwind spot fire problems. Summer fires in this fuel type do not spread at all in the early years following mortality; however, sufficient surface fuel accumulation 4-5 years after mortality will permit summer fire surface spread. Western studies were limited; no significant short- or long-term effects on fire potential or intensity were noted, primarily because there is little mortality of host species as a result of defoliation.
Keywords: Ontario/ Canada/ vt, balsam fir forest/ wildfire/ fire, prescribed/ fire behavior/ insects/ budworm, spruce/ balsam fir.
468. **Stoekeler, Joseph H. 1948. The growth of quaking aspen as affected by soil**

properties and fire. Journal of Forestry. 46(10):727-737.

Note: Repeated fires in aspen reduces the site index of the stand.

This paper brings out some important relationships between growth of aspen and soil texture, pH, intensity and frequency of burns, water tables, former forest cover, and ground cover.

Keywords: WI/ MN/ vt, aspen forest/ fire effects/ soil morphology/ aspen, trembling.

469. **Stoekeler, Joseph H. and Arbogast, Carl, Jr. 1955. Forest management lessons from a 1949 windstorm in northern Wisconsin and Upper Michigan. Lake States Experiment Station, Station Paper 34. 11 pp.**

Note: The publication summarizes the damage incurred by a severe windstorm that occurred in Wisconsin and Michigan on October 10, 1949. Of the 15 million acres of forest land affected, 2,302,866 acres was salvaged from the Nicolet, Chequamegon, and Ottawa N.F.'s.. Damage was greater in hemlock-hardwood stands than it was in second growth hardwood stands, especially if they had recently had an improvement cut. Highest damage occurred on exposed slopes, swamp edges, ridges, lake and stream banks. Types of damage to trees varied by species. Fore instance, hemlock damage was normally associated with uprooting or shallow-roots. Tall white spruce on the edge of swamps were uprooted and broken. Breakage of balsam fir and white cedar was normally due to heart rot. Damage to other species was usually associated with heart rot as well. In descending order susceptibility of species to damage is as follows; balsam fir, white cedar, white spruce, white pine, and northern hardwoods (sugar maple, yellow birch, basswood, white ash, and American elm) are low. Economics and board-feet salvaged timber is given.

Keywords: WI/ MI/ National Forest, Chequamegon-Nicolet/ National Forest, Ottawa/ vt, hemlock-hardwood forest/ vt, aspen-birch forest/ vt, balsam fir forest/ vt, spruce-fir forest/ vt, swamp conifer forest/ vt, pine forest/ windthrow, tree damage/ management/ hemlock/ balsam fir/ northern white cedar/ spruce, white/ pine, white/ maple, sugar/ birch, yellow/ basswood/ ash, white/ elm.

470. **Stokes, M. A. 1980. The dendrochronology of fire history. In, Stokes, M. A. and Dieterich, John H. Proceedings of the Fire History Workshop. US Forest Service, Rocky Mountain Forest and Range Experiment Station.**

Keywords: fire history/ dendrochronology.

471. **Stone, Earl L. 1975. Windthrow influences on spatial heterogeneity in a forest soil. Eidg. Anst. Forstl. Versuchswes. Mitt. 51:77-87.**

Keywords: windthrow, effects on soil/ soil formation.

472. **Strommen, N. D.; Van Den Brink, C., and Kidder, E. H. 1969. Meteorological Drought in Michigan. Michigan State University, Agricultural Experiment Station. Research Report 78. 28 pp.**

Note: A drought index was developed for Michigan. The state was subdivided into 10 divisions and, then data from 1931 to 1966 was analyzed in terms of drought severity class. Western Upper Peninsula and the lower southeast division

of lower Michigan proved to be the driest of the 10 areas.

Keywords: MI/ weather .

473. **Strong, Moses. 1877. The geology of the Upper St. Croix District; soils and vegetation. Geology of Wisconsin. 3:375-381.**

Note: Cited by Curtis (1959) on fire frequency. Droughty soils are necessary in the maintenance of prairie (pine barrens) in northern Wisconsin.

Keywords: WI/ vt, pine barrens/ fire and soils/ GLO/ presettlement vegetation/ soil morphology/ geology.

474. **Swain, Albert Marvin. 1973. A history of fire and vegetation in northeastern Minnesota as recorded in lake sediments. Quaternary Research. 3:383-396.**

Note: Jack pine, associated with black spruce, balsam fir, paper birch, white spruce and trembling aspen, is currently the most common conifer species living around Lake of the Clouds. Stands of red pine and of white pine are scattered throughout the area. White pine has been gradually decreasing in the area for the past 3000 years (Fig. from Craig 1972). Fire frequency is probably a little high for red pine and white pine stands to be common. This study compliments Heinselman (1973) which is a fire scar study for BCWA. Note similar study at Hug Lake and a comparison of fire regime and vegetation (Swain 1980).

Abstract: The record of charcoal in lake sediments indicates that fire has always been an important ecological factor in the forest history of northeastern Minnesota. The annually laminated sediments of Lake of the Clouds permit precise dating of the charcoal peaks and record the changes in the influx of various pollen types. A detailed record of the past 1000 yr shows that the average frequency of fire is approximately 60-70 yr, with a range of about 20-100 yr. The amount of charcoal in sediments dating between 1000-500 y.a. is consistently higher than that for the last 500 yr. although the fire frequency for the two periods was not appreciably different. Pollen analysis shows no change or only short-term changes in percentages of major pollen types following charcoal peaks.

Keywords: MN/ BWCAW/ National Forest, Superior/ vt, boreal forest/ vt, conifer-feathermoss forest/ vt, pine forest/ vt, aspen-birch forest/ fire interval/ fire effects/ paleoecology/ pollen analysis/ charcoal analysis/ pine, jack/ pine, red/ pine, white/ birch, paper/ balsam fir/ spruce, white/ spruce, black/ aspen, trembling/ northern white cedar/ alder/ shrubs/ herbs.

475. ---. 1974. **A history of fire and vegetation in northeastern Minnesota as recorded in lake sediments. University of Minnesota, St. Paul. Ph.D. dissertation. 89 pp.**

Abstract: The record of charcoal in lake sediments indicates that fire has always been an important ecological factor in the forest history of the Boundary Waters Canoe Area (BWCA) of northeastern Minnesota. This study is based on the results of charcoal and pollen analyses from two lakes--Lake of the Clouds and Hug Lake--located in the non-logged portion of the BWCA. The surface sediments of these lakes were sampled with a freezing device that consists of a tube filled with dry ice and butanol on which sediment is frozen while it is in place at the bottom of the lake.

The annually laminated (varved) sediments of Lake of the Clouds permit precise dating of the charcoal peaks and record changes in the percentages and influx of the various pollen types. Pollen and charcoal diagrams were made for the past 80 years with two years per sample, and for the past 1000 years with 10 years per sample, and for the past 10,000 years. The detailed record of the past 1000 years shows that the average frequency of recorded fires was approximately 60-70 years, with a range of about 20-100 years. The amount of charcoal in sediments dating between 1000-500 years ago is consistently higher than that for the past 500 years, although the fire frequency for the two periods was not appreciably different. Pollen analysis of the past 1000 years shows no change or only short-term changes in the percentages of the major pollen types following charcoal peaks. The record of charcoal analysis of the past 10,000 year period is consistent with the climatic interpretation based on pollen analysis. There are no obvious changes in the percentages or influx of pollen at Lake of the Clouds as a result of logging in the region, which never penetrated closer than six kilometers. The abrupt rise in *Ambrosia* pollen begins in the late 1890's according to the varve chronology.

The pollen and charcoal diagrams from Hug Lake show only the history of vegetation and fire for approximately the past 400 years. The time scale for the Hug Lake diagrams was calculated by estimating the number of years of sediment in each sample by dividing the pollen concentration by a constant influx value. Pollen analysis shows that the conspicuous absence of conifers in the vegetation surrounding Hug Lake has existed for at least 400 years and is not the result of the large fires that occurred during the 1800's. The results from charcoal analysis indicated a frequency of fire comparable to that at Lake of the Clouds. A sharp decline in the pollen of white pine (*Pinus strobus*) at about 1900 at Hug Lake coincides with the beginning of commercial logging several kilometers to the south.

Keywords: MN/ BWCAW/ National Forest, Superior/ vt, boreal forest/ vt, conifer-feathermoss forest/ vt, pine forest/ vt, aspen-birch forest/ fire interval/ fire effects/ logging/ paleoecology/ charcoal analysis/ pollen analysis/ pine, jack/ pine, red/ pine, white/ birch, paper/ balsam fir/ spruce, white/ spruce, black/ aspen, trembling/ northern white cedar/ alder/ shrubs/ herbs.

476. ---. 1978. Environmental changes during the past 2000 years in north-central Wisconsin. *Quaternary Research*. 10:55-68.

Note: Around the lake, at least 2 fires have occurred in the past 85 years. Charred stumps and fire scarred trees are probably from logging fires and possibly lightning fires.

Abstract: A 2000-year accumulation of varved sediments from Hell's Kitchen in north-central Wisconsin was analyzed for pollen, charcoal, and seeds. The varves provided an accurate time scale for the study. The pollen record indicates changes on two different time scales. Short-term changes lasting several decades appear to be superimposed on long-term changes lasting several centuries. The short-term changes are related to individual fires, and the long-term changes result from increases or decreases in the frequency of these perturbations. From 2000 to

1150 years ago the interval between fires was about 100 years, and from 1150 to 120 years ago the interval increased to about 140 years. Evidence from pollen, seeds, and charcoal at Hell's Kitchen Lake suggests that at least two "moist" intervals occurred during the past 2000 years, one between 2000 and 1700 years ago and the other between 600 and 100 years ago. A third but minor "moist" period occurred about 1150 to 850 years ago. A pollen and seed diagram shows that these intervals are characterized by increased percentages of white pine pollen, hemlock pollen, and yellow birch seeds, and by decreased levels of charcoal. The "dry" interval of 1700 to 1150 years ago is characterized by increased percentages of paper birch seeds, oak pollen, and aspen pollen, along with high levels of charcoal. The times of climatic change indicated at Hell's Kitchen Lake are nearly synchronous with those based on studies of tree rings, soils, glacial activity, and other pollen studies from various regions of North America, but the direction of these inferred changes is not always the same. This result suggests that the long-wave pattern of the general circulation has been variable during the past 2000 years.

Keywords: WI/ vt, aspen-birch forest/ vt, maple forest/ vt, pine forest/ vt, hemlock forest/ fire interval/ fire effects/ paleoecology/ pollen analysis/ charcoal analysis/ macrofossils/ climate change/ pine, white/ hemlock/ birch, yellow/ birch, paper/ oak/ aspen, trembling.

477. ---. **1980. Landscape patterns and forest history in the Boundary Waters Canoe Area, Minnesota: A pollen study from Hug Lake. Ecology. 61(4):747-754.**

Abstract: Paleoecological studies of the past 400 yr indicate that the mosaic patterns in the Boundary Waters Canoe Area in northeastern Minnesota USA appears to be related to topography and presence of large lakes, and to the ways in which these features influence periodic forest fires. Pollen and charcoal analyses from a site (Hug Lake) located in primarily deciduous forest were compared to those from Lake of the Clouds which is located in a region dominated by coniferous forest. The results showed that the average interval between fires at both sites was similar (70 yr), but the absence of conifers in the area surrounding Hug Lake probably was related to the lack of effective firebreaks such as steep topography and large lakes that are essential for the survival of conifers when regional fire frequency is high. The deciduous character of the forest around Hug Lake has existed for at least 400 yr and was not the result of several large fires that occurred in the area around the 1800's.

Keywords: MN/ BWCAW/ National Forest, Superior/ fire interval/ fire effects/ fire barriers/ landform/ paleoecology/ pollen analysis/ charcoal analysis/ birch, paper/ aspen, trembling/ shrubs.

478. --. **1981. Final Report to National Park Service on forest and disturbance history of the Apostle Islands.**

Note: The report examines the recent and past fire history on Stockton Island and the vegetation composition and the changes occurring in the unmanaged forests of Stockton Island, Bear Island, and the Bayfield peninsula by using dendrochronological and paleoecological techniques.

Abstract: Through tree-ring analysis it was found that at least 9 fires occurred on

the tombolo of Stockton Island in 250 years (1 every 28 yrs). Most of these were small surface fires. Overstory composition is a mix of red and white pine. North of the tombolo, a fire frequency of 0 to 3 fires over 250 years was found. No fire scars were found in stands of hemlock, yellow birch and northern white cedar. Fire frequency was higher on the sandy beach soils as opposed to glacial till of the uplands. A decline in white pine pollen occurred when hemlock and yellow birch became important. Results from this study indicate that fire regimes on the Apostle Islands for like vegetation types were similar to mainland fire regimes.
Keywords: WI/ island/ vt, pine forest/ vt, hemlock-hardwood forest/ fire scar/ fire interval/ growth ring analysis/ soil morphology/ pollen analysis/ paleoecology/ pine, white/ pine, red/ hemlock/ birch, yellow/ northern white cedar.

479. **Swain, Albert Marvin and Winkler, Margorie G. 1983. Forest and disturbance history at Apostle Islands National Lakeshore. *Park Science*. 3(4):3-5.**
Note: Pollen and charcoal analysis was used to compare the vegetation record with the fire record of two sites, Stockton Bog and Brander Bog, on Stockton Island of the Apostle Islands. Vegetation and fire history were different at the two sites. The vegetation surrounding Stockton Bog was dominated by red pine, white pine, and paper birch for most of the 6000 yr pollen record with some removal of white pine during the logging period. The vegetation surrounding Brander Bog was dominated by hemlock, yellow birch and other hardwoods (and white pine) for thousands of years until logging removed large amounts of white pine and hemlock. Charcoal peaks were much more common at Stockton Bog than at Brander Bog. Tree ring analysis indicates at least 9 fires within the past 250 years around Stockton Bog as compared to 1 to 3 fires during the same time period at Brander Bog. The soils surrounding Brander Bog are glacial till that overlie bedrock and, the soils surrounding Stockton Bog are described as (sandy) beach ridges.
Keywords: WI/ vt, pine forest/ vt, hemlock-hardwood forest/ fire scar/ fire interval/ fire effects/ logging/ soil morphology/ paleoecology/ pollen analysis/ charcoal analysis/ pine, red/ pine, white/ birch, paper/ birch, yellow/ hemlock.
480. **Sweet, E. T. 1880. Geology of the western Lake Superior district; climate, soils, and timber. *Geol. Wis.* 3:397-407.**
Keywords: WI/ geology/ weather/ soil morphology.
481. **Tanner, Helen Hornbeck, editor. 1986. *Atlas of Great Lakes Indian History*. University of Oklahoma Press, Norman, OK.**
Note: Indian history from 1641 (Iroquois warfare) to the 1870's, and the change in dominance from Indian to white people is described. Documents such as diaries, agency documents, publications, archeological records, oral histories, etc. is used to depict accurately the occurrences of the time. Many maps were included showing village locations, boundaries, treaty lines, etc. A few pages were devoted to associating vegetation of the time with Indian subsistence patterns prior to major changes caused by European invasion.
Keywords: MI/ MN/ WI/ fire, Native American use of/ review.

482. **Taylor, J. Wolfred. 1978. Downburst: July 4, 1977. Wisconsin Natural Resources. 2(4):23-25.**
Note: A downburst that occurred in Wisconsin on July 4, 1977 is described, and the research of Dr. Theodore Fugita is discussed. A map of the downburst path is included.
Keywords: WI/ windthrow, tree damage/ downburst/ weather.
483. **Terasmae, J and Weeks, N. C. 1979. Natural fires as an index of paleoclimate. Canadian Field Naturalist. 93:116-125.**
Note: Referenced in Dansereau and Bergeron, 1993.
Keywords: Canada/ Quebec/ paleoecology/ pollen analysis/ charcoal analysis/ fire history/ climate change.
484. **Tester, John R. 1989. Effects of fire frequency on oak savanna in east-central Minnesota. Bulletin of the Torrey Botanical Club. 116(2):134-144.**
Abstract: From 1964 to 1984, prescribed burning experiments were performed on oak (*Quercus* spp.) forest and oak savanna in east-central Minnesota, USA. Eighty-nine burns were carried out on 9 compartments ranging from 2.6 to 27.5 ha. Intervals between fires varied from 1 to 12 years. Soil pH increased significantly with frequency of burning. Total nitrogen was positively correlated ($P < 0.01$) with percent organic matter. Species richness was highest in areas which were burned approximately every 2 years. Different plant functional groups responded differently to frequency of burning. Cover of true prairie grasses increased from less than 5 to about 15 per cent. True prairie forbs showed a significant increase in cover from less than 2 to about 8 per cent with increasing frequency of burning. Density of true prairie shrubs showed a tendency to increase whereas density of non-prairie shrubs and of trees showed tendencies to decrease with increased frequency of fire. Thus, the frequency of prescribed burning strongly influenced vegetative composition and physiognomy as well as soil characteristics.
Keywords: MN/ Cedar Creek Natural History Area/ vt, oak forest/ vt, oak savanna/ vt, prairie/ fire, prescribed/ fire effects/ succession/ soils, nutrient analysis/ shrubs/ herbs/ life history attributes.
485. ---. **1996. Effects of fire frequency on plant species in oak savanna in east-central Minnesota. Bulletin of the Torrey Botanical Club. 123(4):304-308.**
Abstract: From 1964 through 1984, nine forest sites, ranging in size from 2.6 to 27.5 ha, were each burned from two to 19 times. Percent cover of 13 of 14 true-prairie grasses was positively correlated with burn frequency. Of these, eight have C4 and six have C3 photosynthetic pathways. Cover of 34 of 39 true-prairie forbs, and of *Amorpha canescens*, increased with frequency of burning. All except *Aster oolentangiensis* are C3 species. Cover of six of seven native, not prairie, species, all C3, decreased with increasing burn frequency. These data suggest that the adaptation of true-prairie species to repeated burning outweighs the effects of their photosynthetic pathways.
Keywords: MN/ Cedar Creek Natural History Area / vt, prairie/ vt, oak savanna/ fire, prescribed/ fire effects/ physiology.

486. **Tester, John R.; Starfield, A. M., and Frelich, Lee E. 1997. Modeling for ecosystem management in Minnesota pine forests. *Biological Conservation*. 80:313-324.**
Abstract: Ecosystem management implies a concern over time periods of tens to hundreds of years for sites on a scale of tens to hundreds of hectares. Decision makers need to be able to model the likely consequences of alternative management strategies at these temporal and spatial scales. They therefore require models that can be constructed quickly and cheaply, that capture the key components of the ecosystem, that respond plausibly to management actions, and are easy to explain, modify and understand. This paper presents the frame-based modeling paradigm as a response to these needs. Frame-based modeling paradigm is used to examine the effects of soil, weather, fire and deer population density on management of the white pine ecosystem in northern Minnesota.

The management objective is to maintain white pine forest. The paper described how current understanding of seedling establishment, tree growth, competition, herbivory and the effects of fire and high winds, can be captured at a consistent level of resolution in a model that can be presented, completely, in a few pages of text. The paper goes on to describe how the model was tested at three sites in northern Minnesota, and was then used to explore alternative management strategies.

Our results confirm that it is comparatively easy to maintain a forest in early successional stages by burning or clear-cutting, and in late stages by suppression of fires and control of cutting. Establishment and maintenance of mid-successional stages, such as red and white pine, is much more difficult and requires a finely-tuned balance between natural disturbance and management action. For example, the pine forest was only maintained on average for 117 years out of 1000 years (average among 1000 simulated stands) on poor soil with high fire frequency and high deer density. When the deer population was low, when all wild fires were suppressed, and when prescribed ground fires were used to promote pine establishment, years in pine was 804 out of 1000 years. The model provides guidance for management decisions to maintain the desired conditions.

The paper draws some conclusions from this particular modeling exercise that are likely to be generally applicable.....to what management can hope to achieve, the importance of maintaining strategies over long periods, and the difficulties of predicting and measuring success when the time horizon is hundreds of years.

Keywords: MN/ management/ modeling/ fire modeling/ logging/ mammals/ deer browsing/ pine, white.

487. **Thompson, J. N. 1980. Treefalls and colonization patterns of temperate forest herbs. *American Midland Naturalist*. 104:176-184.**
Keywords: herbs/ windthrow, effects on vegetation/ microsite/ pit and mound.
488. **Turner, Monica G.; Dale, Virginia H., and Everham III, Edwin H. 1997. Fires, hurricanes, and volcanoes: comparing large disturbances. *BioScience*.**

47(11):758-768.

Note: The publication compares and contrasts characteristics and effects of disturbances on plant communities and vegetation recovery. Three events, Mt. St. Helens volcanic eruption, the 1998 Yellowstone fires and Hurricane Hugo, are described in detail. The mechanisms described are important to remember when considering large scale disturbances.

Keywords: WY/ WA/ Puerto Rico/ wildfire/ hurricane/ volcano/ disturbance ecology/ landscape ecology.

489. **Turner, Monica G.; Gardner, Robert H.; Dale, Virginia H., and O'Neill, Robert V. 1989. Predicting the spread of disturbance across heterogeneous landscapes. *Oikos*. 55:121-129.**

Abstract: The expected pattern of disturbance propagation across a landscape was studied by using simple landscape models derived from percolation theory. The spread of disturbance was simulated as a function of the proportion of the landscape occupied by the disturbance-prone habitat and the frequency (probability of initiation) and intensity (probability of spread) of the habitat-specific disturbance. Disturbance effects were estimated from the proportion of habitat affected by the disturbance and changes in landscape structure (i.e., spatial patterns). Landscape structure was measured by the number of habitat clusters, the size and shape of the largest cluster, and the amount of edge in the landscape. Susceptible habitats that occupied less than 50% of the landscape were sensitive to disturbance frequency but showed little response to changes in disturbance intensity. Susceptible habitat that occupied more than 60% of the landscape were sensitive to disturbance intensity and less sensitive to disturbance frequency. These dominant habitats were also very easily fragmented by disturbances of moderate intensity and low frequency. Implications of these results for the management of disturbance-prone landscapes are discussed. The propagation of disturbance in heterogeneous landscapes depends on the structure of the landscape as well as the disturbance intensity and frequency.

Keywords: modeling/ fire modeling/ disturbance ecology/ landscape ecology.

490. **Turner, Monica G. and Romme, W. H. 1994. Landscape dynamics in crown fire ecosystems. *Landscape Ecology*. 9(1):59-77.**

Abstract: Crown fires create broad-scale patterns in vegetation by producing a patch mosaic of stand age classes, but spread and behavior of crown fires also may be constrained by spatial patterns in terrain and fuels across the landscape. In this review, implications of landscape heterogeneity for crown fire behavior and the ecological effects of crown fires over large areas are discussed. Fine-scale mechanisms of fire spread can be extrapolated to make broad-scale predictions of landscape pattern by coupling knowledge obtained from mechanistic and empirical fire behavior models with spatially-explicit probabilistic models of fire spread. Climatic conditions exert a dominant control over crown fire behavior and spread, but topographic and physiographic features in the landscape and spatial arrangement and types of fuels have a strong influence on fire spread, especially when burning conditions (e.g. fuel moisture and wind) are not extreme. General trends in crown fire regimes and stand age class distributions can be observed

across continental, latitudinal, and altitudinal gradients. Crown fires are more frequent in regions having more frequent and/or severe droughts, and younger stands tend to dominate these landscapes. Landscapes dominated by crown fires appear to be nonequilibrium systems. This nonequilibrium condition presents a significant challenge to land managers, particularly when implications of potential changes in global climate are considered. Potential changes in global climate may alter not only frequency of crown fires but also severity. Crown fires rarely consume the entire forest, and spatial heterogeneity of burn severity patterns creates a wide range of local effects and is likely to influence plant reestablishment as well as many other ecological processes. Increased knowledge of ecological processes at regional scales and effects of landscape pattern on fire dynamics should provide insight into understanding behavior and consequences of crown fires.

Keywords: fire effects/ fire behavior/ landscape ecology/ modeling/ climate change/ fire, review.

491. **Ubrock, W.J. 1998. Oak savannas and woodlands. Transactions of the Wisconsin Academy of Sciences, Arts and Letters. 86:1-234.**
Note: Presentations from the 1997 Midwest Oak Savanna and Woodland Conference, University of Wisconsin, Madison.
Keywords: WI/ vt, oak savanna/ regeneration, vegetative/ fire effects.
492. **Vale, Thomas (editor). 2002. Fire, Native Peoples and landscape. Island Press.**
Keywords: fire, Native American use of.
493. **Van Wagner, C. E. 1963. Prescribed burning experiments red and white pine. Canadian Department of Forestry, Forest Research Branch. Publication 1020. 27 pp.**
Keywords: Canada/ vt, pine forest/ fire, prescribed/ pine, red/ pine, white.
494. **---. 1965. Describing forest fires-old ways and new. Forestry Chronicle. 41:301-305.**
Keywords: fire, review.
495. **Van Wagner, C. E. 1968. Fire behavior in a red pine plantation: field and laboratory evidence. Department of Forest and Rural Development, Canada. Publication 1229.**
Keywords: Canada/ vt, pine forest/ fire, prescribed/ fire behavior/ pine, red.
496. **---. 1968. The line intersect method in forest fuel sampling. Forest Science. 14:20-26.**
Keywords: fuels/ methodology.
497. **---. 1970. Fire and red pine. Proceedings of the Annual Tall Timbers Fire Ecology Conference. Tall Timbers Research Station, Tallahassee FL. p. 211-219.**
Note: Silvical knowledge of red pine with some preliminary results from prescribed fires experiments at the Petawawa Forest Experiment Station are used to answer the following questions."1) What specific properties of red pine make fire necessary for regeneration? 2) How liable are red pine stands to fire? 3) How

are red pine trees affected by fire? 4) Exactly what kind of fire is best for perpetuating red pine in the natural forest? 5) What kind of prescribed fire would be most useful in managing red pine?"

Keywords: Ontario/ Canada/ vt, pine forest/ fire, prescribed/ fire effects/ pine, red/ silviculture/ regeneration, seed/ fire, review.

498. ---. 1972. **Duff consumption by fire in eastern pine stands. Canadian Journal of Forest Research. 2:34-39.**
Keywords: Canada/ fire, prescribed/ fire effects/ litter and duff/ pine, red/ pine, white.
499. ---. 1977. **Conditions for start and spread of crown fires. Canadian Journal of Forest Research. 7:23-34.**
Keywords: fire behavior.
500. ---. 1978. **Age-class distribution and forest fire cycle. Canadian Journal of Forest Research. 8:220-227.**
Note: Data collected and published by Heinselman (1973) for Boundary Waters Canoe Area was used to compare fire rotation using age-class structure (50 yrs) and using dendrochronological methods (100 yrs). Using dendrochronological techniques, the fire record becomes more difficult to determine the further back in time one goes. Age-class structure, on the other hand, takes the reduced number of old trees into account and is probably a more accurate estimate of fire cycle. Using age-class structure, "63.2% of all stands are younger than the mean age C."
Abstract: The expected age-class structure of a forest dependent on random periodic fire disturbance and renewal is derived and presented. It is simply the negative exponential distribution, well known in probability mathematics. An important feature of this concept is that the present age-class structure of such a forest is the key to its past fire history. Its limitations are discussed, and the computer simulation of variations, including the interaction of fire and logging, is described. Three examples of its use in interpreting fire history are given.
Keywords: MN/ BWCAW/ National Forest, Superior/ vt, boreal forest/ vt, pine forest/ vt, conifer-feathermoss forest/ vt, aspen-birch forest/ fire frequency/ fire modeling/ age-class structure/ pine, red/ pine, jack/ pine, white/ aspen, trembling/ birch, paper.
501. ---. 1988. **The historical pattern of annual burned area in Canada. Forestry Chronicle. 64:182-185.**
Keywords: Canada/ wildfire.
502. **Vogl, Richard J. 1964. The effects of fire on a muskeg in northern Wisconsin. Journal of Wildlife Management. 28(2):317-329.**
Note: Author mentions that, historically, fires were fairly frequent at location.
Abstract: The effects of prescribed burning on vegetation of Powell-Flambeau Marsh were studied during summers of the years 1959 through 1962. This area, located in north-central Wisconsin, is a hybrid community of open sphagnum bog

or treeless muskeg and sedge meadows. The marsh is being managed to increase its productivity for wildlife, particularly for geese, ducks, sharp-tailed grouse (*Pedioecetes phasianellus*), and white-tailed deer (*Odocoileus virginianus*). The burning was analyzed quantitatively using 14 paired stands, one member of each pair being an unburned control adjacent to the burned area. The vegetation within each stand was sampled using quadrant frequency studies. To evaluate the effects of fire, all plant species were divided into groups called increasers, decreasers, and neutrals, invaders, or retreaters, depending upon their responses to fire as reflected in average percent frequency changes. Results indicated that prescribed burning produces a conversion or retrogression from conifer swamp dominated by trees to open sphagnum bog or muskeg dominated by sedges and ericaceous shrubs. The muskeg may be changed further to northern sedge meadows, dominated by sedges and supporting a minimum of woody vegetation. This sedge meadows successional stage is considered more desirable than the other types because it allows the greatest movement, feeding, and nesting of game birds. Fire also improves game habitat by reducing the "rough" of woody and nonwoody plants, stimulating new and palatable growth, and increasing fruit and seed production.

Keywords: WI/ vt, wetland/ vt, sedge meadow/ fire, prescribed/ fire effects/ birds/ mammals/ shrubs/ herbs.

503. ---. 1964. **The effects of fire on the vegetational composition of bracken-fern-grasslands. Transactions of the Wisconsin Academy of Sciences, Arts and Letters. 53:67-82.**

Note: In northeastern Wisconsin, vegetation change on 15 burned bracken fern-grassland openings were compared to 12 unburned openings of the same type. Most of the openings in the study originated after logging and post-harvest intense fires. Dominant species include bracken fern, sweet fern, sweet blueberry, and *Carex* sp. Findings include: 1) species composition changed very little with fire. 2) Where tree species were encroaching into openings, fire reduced canopy cover from 22.4% to 4.3%. 3) Fire stimulated resprouting and early spring growth. 4) Where there was a hardpan, the fires removed the existing vegetation thereby increasing surface water in the wet season and becoming very dry when the rains stop. Other theories in the maintenance of bracken fern grasslands are as follows. 1) The most important agent slowing the encroachment of trees into openings is the grassland sod and shade produced by the bracken fern. 2) Where there are depressions, frost may also be a factor in reducing tree invasion.

Keywords: WI/ vt, grassland/ fire, prescribed/ fire effects/ logging/ fern, bracken /fern, sweet/ blueberry, sweet/ sedge/ shrubs/ herbs.

504. ---. 1964. **Vegetational history of Crex Meadows, a prairie savanna in northwestern Wisconsin. The American Midland Naturalist. 72(1):157-175.**

Note: Open grown jack pine (68%), and red pine (13%), with small stands of aspen (7%), paper birch (6%), white pine (3%), scrub oak (2%) and bur oak (1%), growing on gently rolling sand plains, make up the presettlement forest stand structure. Tree density averaged 8 trees per acre. Presettlement fire regime is only discussed in a general way.

Crex Meadows, located in the sand barrens of northwestern Wisconsin, has a history of vegetational composition of wetlands mixed with jack pine-scrub oak savanna.

The vegetational history of this prairie-forest ecotone starts with the examination of the written records and journals of early explorers, and continues through the effects of pre-European settlement, major European settlement, and present-day changes. The pre-settlement vegetation on Crex is examined and compared quantitatively to present-day vegetation using the original surveyors' records. Past vegetation of natural prairie was maintained by fire and the current prescribed burning performed by the Wisconsin Conservation Department has restored the area to a state similar to that of pre-settlement times, brush prairie savanna.

Keywords: WI/ vt, prairie-forest ecotone/ vt, pine forest/ vt, pine-oak forest/ vt, prairie-oak scrub/ sand plains/ fire history/ fire, prescribed/ GLO/ presettlement vegetation/ pine, jack/ pine, red/ birch, paper/ pine, white/ oak, scrub/ oak, bur.

505. ---. 1971. **Fire and the northern Wisconsin pine barrens. Tall Timbers Fire Ecology Conference, 1970. Tall Timbers Research Station, Tallahassee, FL. p.175-209.**

Note: The effects of prescribed burning on Namekagon, St. Croix-Brule, Peshtigo River-Athelstane barrens and Manitowish pine barrens in northern Wisconsin are described. The 4 areas can be classified as prairie-like (Namekagon and Peshtigo) and nonprairie-like (St. Croix and Manitowish). Species diversity and magnitude of change due to prescribed burning was greater in the prairie-like stands than in the nonprairie-like stands. Prairie-like stands are similar to prairies south of the Curtis tension zone. The prairie-like areas seem to be larger and homogenous as opposed to the nonprairie-like pine barrens which seem to be intermixed with soils other than fine sand and natural fire barriers (lakes). This would suggest different fire regimes for the two types. Tree species composition of the pine barrens includes red pine, jack pine, aspen, etc. Prior to logging, the pine barrens had a higher component of red pine than Curtis (1959) suggested. I estimate the fire rotation between 1871 and 1943 of the St. Croix stands to be 31 yrs.

Keywords: WI/ vt, prairie/ vt, pine barrens/ fire, prescribed/ fire interval/ fire barriers/ pine, red/ pine, jack .

506. **Vora, Robin S. 1993. Moquah Barrens: pine barrens restoration experiment initiated in Chequamegon National Forest. Restoration & Management Notes. 11(1):39-44.**

Note: A description of a restoration project carried out on the Moquah Barrens, began in 1991, after the occurrence of an ice storm earlier that year. Six different prescriptions, involving cutting and burning, on 184 hectares are described. It was too early to report results.

Keywords: WI/ National Forest, Chequamegon-Nicolet/ vt, pine barrens/ weather, effects on vegetation/ fire, prescribed/ logging/ restoration ecology/ pine, jack/ pine, red/ pine, white.

507. **Waddington, Jean C. B. 1969. A stratigraphic record of the pollen influx to a lake in the Big Woods of Minnesota. In, Schumm, S. A. and Bradley, W. C. United States contributions to Quaternary Research. Geological Society of America, Inc. Special Paper 123.**

Abstract: Determination of pollen concentration (absolute pollen frequency), combined with eight radiocarbon dates from a 16-m core, provides an estimate of pollen influx to a small lake in the present Big Woods area of south-central Minnesota. The observed variation in pollen influx is difficult to relate to the vegetational history inferred from the relative pollen stratigraphy. An alternative hypothesis relates the changes in pollen influx to variation in the water level and movement of sediment in the lake basin.

The pollen stratigraphy is consistent with other sites in Minnesota and South Dakota; it indicates that the Rutz Lake area was covered by boreal forest at the time the lake was formed and by a parkland of deciduous trees shortly after. Prairie dominated the area from about 8000 to 3200 years ago, when an increase in moisture favored an oak parkland again. The remaining openings were invaded by the mixed deciduous forest known as the Big Woods about 400 years ago.

An index of the charcoal content of the sediment is maximum during the time of greatest prairie expansion and confirms the importance of fire in the prairie environment.

Keywords: MN/ vt, Big Woods/ vt, prairie/ vt, oak savanna/ pollen analysis/ charcoal analysis/ paleoecology/ climate change.

508. ---. **1978. Vegetational changes associated with settlement and land-clearance in Minnesota over the last 125 years: a comparison of historical and sedimentary records. University of Minnesota, St. Paul. Ph.D. dissertation. 180 pp.**

Note: Lakes were selected from the Big Woods to BWCA in a transect across vegetation zones. Local increases in ragweed pollen and decreases in pine pollen in laminated lake sediments indicate settlement and land-clearance. Charcoal abundance was calculated to determine if changes in charcoal could estimate fire dates. It was found that charcoal abundance is accurate if lamina are analyzed in 2 yr segments. Presettlement vegetation is discussed.

Keywords: MN/ BWCAW/ National Forest, Superior/ vt, Big Woods/ vt, pine forest/ vt, jack pine forest/ vt, aspen forest/ vt, aspen-birch forest/ vt, maple forest/ fire interval/ GLO/ presettlement vegetation/ pollen analysis/ charcoal analysis/ land-use.

509. **Walker, J. D. and Stocks, Brian J. 1975. The fuel complex of mature and immature jack pine stands in Ontario. Canadian Forestry Service, Great Lakes Forest Research Centre, Sault Ste. Marie, Ontario. Information Report 0-X-229. 19 pp.**

Keywords: Ontario/ Canada/ vt, boreal forest/ vt, jack pine forest/ fuels/ pine, jack.

510. **Warners, David P. 1987. Effects of burning on sedge meadow studied (Wisconsin). Restoration and Management Notes. 5(2):90-91.**
Note: The complete report is under "Abstract".
Abstract: The effects of controlled burning on shrub-invaded and uninvaded sedge meadows at Summerton Bog in central Wisconsin were studied. Shrub invasion threatens this endangered ecosystem, which is home to a variety of orchids and other endemic species. Burns were conducted by Wisconsin Chapter of the Nature Conservancy in the springs of 1984 and 1985. Sampling in 1986 compared the effects of fire in invaded and uninvaded sites to adjacent unburned sites. Methods employed were quadrant sampling, species lists, measurements of tussock sedge (*Carex stricta*), shrub sampling, and continuous water table recording. Preliminary analysis has shown tussock sedge the key species in sedge meadows, and bluejoint grass (*Calamagrostis canadensis*) to be found at significantly higher numbers on the burned areas. Herbaceous species associated with the shrub carr, such as three-leaved Solomon's seal (*Smilacina trifolia*), marsh fern (*Thelypteris palustris*), and asters are found at markedly lower frequencies on burned sites. Fire did not significantly reduce shrub cover, but composition appears to have shifted in favor of red-osier dogwood (*Cornus stolonifera*), while bog birch (*Betula sandbergii*) and poison sumac (*Rhus vernix*) are considerably less numerous in the burned area. Hydrographs revealed that invaded areas were consistently wetter than uninvaded sedge meadows, contradicting present theory. A subsequent burn was conducted in April 1987 and sampling will be repeated in the summer of 1987.
Keywords: WI/ vt, wetland/ fire, prescribed/ fire effects/ hydrology/ shrubs/ herbs.
511. **Waterman, W. G. 1922. Development of plant communities of a sand ridge region in Michigan. Botanical Gazette. 74(1):1-31.**
Note: Succession of the plant communities and the soils of a sand dune area in Benzie county, Michigan, the Platte River and Otter Creek floodplains are described. The soils range from shifting sand dunes to clay-gravel. The general soil moisture from ridge to swale is xeric to standing water. The formations, plant communities on specific landforms, and successional stages of the plant communities described in this paper are: moving dune, sand ridge, sand ridge depressions, river and lake border. Wind and fire are acknowledged as influencing factors in the vegetation and soils development.
Keywords: MI/ vt, dune-swale complex/ fire and soils/ windthrow, occurrence of/ succession/ soil morphology/ landform/ shrubs/ herbs.
512. **Webb, Sara L. 1988. Windstorm damage and microsite colonization in two Minnesota forests. Canadian Journal of Forest Research. 18:1186-1195.**
Abstract: Scattered trees were uprooted, snapped, or bent during a 1983 windstorm in two northwestern Minnesota pine forests. I tested potential correlates (tree species, tree size, cause of damage) of damage type, and compared consequences of the uprooting, snapping, and bending of trees by assessing post damage survival and by surveying formation and colonization of microsites (mounds, pits, stumps, and dead boles). Larger trees damaged directly by wind

were usually snapped and killed in both study areas, regardless of tree species. Smaller trees damaged by falling neighbors were either (i) bent without sustaining mortality or forming microsities, a damage type prevalent among strong-wooded *Acer saccharum* and *Ostrya virginiana* in a *Pinus-Acer* study area, or (ii) uprooted, forming small mounds and pits, a damage type prevalent among weak wooded *Abies balsamea* and *Picea* spp. in a *Pinus-Abies* study area. Bent trees usually survived, at least for several years. However, uprooted and snapped trees were equally unlikely to survive their damage. Thus, uprooting and snapping were equally likely to result in dead bole formation. Windstorm-related microsities covered small proportions (6 and 18%) of the floor of the two forest, most as dead boles rather than as stumps, mounds, or pits. Microsites from uprooting, microsities from snapping, and background substrates did not differ in colonizing tree flora but did differ in density of colonists. The role of microsities varied with the autecology of tree species present. In the *Pinus-Abies* area, rotting wood of stumps and boles was the major establishment substrate for all regenerating tree species. In the *Pinus-Acer* area, *Acer saccharum* and *A. rubrum* were numerically dominant over other species on all substrates, with seedling densities highest away from microsities. Observed patterns of survival and tree regeneration indicate that uprooting and snapping of trees do not differ strongly in their consequences for either forest.

Keywords: MN/ Itasca Park/ vt, maple forest/ vt, pine forest/ vt, spruce-fir forest/ windthrow, effects on soil/ windthrow, tree damage/ windthrow, effects on vegetation/ regeneration, seed/ microsite/ pine, white/ pine, red/ balsam fir/ maple, sugar/ maple, red/ spruce, white/ spruce, black/ hop hornbeam.

513. ---. 1989. **Contrasting windstorm consequences in two forests, Itasca State Park, Minnesota. Ecology. 70(4):1167-1180.**

Abstract: Thunderstorm winds (~25-35 m/s) often damage scattered trees in northern Minnesota forests. Following one moderate windstorm on 3 July 1983, I surveyed damaged trees within two Itasca Park study areas (1) to identify mortality patterns and their correlates, (2) to evaluate windstorm consequences for shade-intolerant species, and (3) to investigate formation of light-gaps.

Risk of direct wind damage was predicted best by tree size (in both stands) and either tree species (in a *Pinus/Acer* stand) or species wood strength (in a *Pinus/Abies* stand). However, the overall risk of mortality, combining direct wind damage and damage from falling trees, was more complex. Tree mortality in the *Pinus/Acer* study area was related to tree size, species, species wood strength, and incidence of species-specific fungal pathogens. Mortality in the *Pinus/Abies* study area, where many understory trees were killed, was not predictable on the basis of tree size, but mortality risk was affected by tree species and species wood strength (data on fungal pathogens were unavailable for this stand). Within most populations, the size distribution of wind struck trees differed from the population size distribution. However, mortality risk, including that from falling trees, increased with tree size only for *Populus tremuloides*. In one study area, smaller trees were most vulnerable within the *Picea* and *Pinus strobus* populations. The difficulty of generalizing about windstorm consequences is illustrated by large

intraspecific variation in amount of damage between different populations of *Betula papyrifera*, *Pinus resinosa*, and *Pinus strobus*.

For shade-intolerant species expected to benefit from disturbance, windstorm consequences differed in the two stands, despite shared postfire origins and several tree species in common. In the *Pinus/Acer* forest, heavy mortality to shade-intolerant *Populus tremuloides*, *Pinus resinosa*, and *Pinus strobus* combined with a well-developed, windfirm understory and infrequent light-gap formation to benefit existing shade-intolerant, windfirm *Acer saccharum* and tall shrubs. In the nearby *Pinus/Abies* forest, the windstorm produced more regeneration opportunities for shade-intolerant species (*Betula papyrifera*, *Populus tremuloides*, *Fraxinus pennsylvanica*), because the shade-tolerant understory species of this stand (*Abies balsamea*, *Picea glauca*) were more heavily damaged, and because more light-gaps were formed, although such light-gaps were small relative to published gap size thresholds for tree establishment. Differences between the two communities in their responses to the same storm event appear to result from differences in forest structure and differences in the windfirmness of shade-tolerant understory taxa.

Keywords: MN/ Itasca Park/ vt, pine forest/ vt, maple forest/ vt, spruce-fir forest/ windthrow, tree damage/ windthrow, effects on vegetation/ regeneration, seed/ pine, red/ pine, white/ maple, sugar/ balsam fir/ aspen, trembling/ birch, paper/ spruce, white/ ash, green.

514. ---. 1999. **Disturbance by wind in temperate-zone forests.** Walker, Lawrence R. *Ecosystems of the World, Ecosystems of disturbed ground.* Elsevier, New York. p. 187-222.

Note: This is a good general reference describing windstorms and their influence of temperate-forest ecosystems. Significant research of vegetation response by forest type, study type (gap vs. blowdown, hurricane vs. tornado, etc.) and location is cited. The theoretical framework, spatial scales, disturbance type, magnitude, intensity, severity, return interval, patch dynamics, etc. is outlined. Detailed descriptions of disturbance regimes, tree mortality and damage, and vegetation response is given.

Keywords: windthrow, effects on vegetation/ disturbance ecology/ windthrow, review/ theory.

515. Webb, Sara L. and Scanga, Sara E. 2001. **Windstorm disturbance without patch dynamics: twelve years of change in a Minnesota forest.** *Ecology.* 82(3):893-897.

Abstract: In an old-growth *Pinus-Populus-Acer* forest, treefall areas did not diverge from undisturbed control areas over a 12-year period following windstorm disturbance. Woody plant populations sampled in 1984, 1992, and 1996 changed significantly over time, but treefall areas did not change differently than control areas in plant species richness, composition, or vegetation structure. Preexisting tall shrubs and windfirm saplings cast heavy shade even where canopy trees blew down, preventing formation of deep lightgaps and limiting resource heterogeneity on the forest floor. Thus, in this forest, disturbance by

moderate windstorm did not initiate the sort of patch dynamics that enriches diversity by admitting light-demanding species into the understory. The unresponsiveness of the understory, juxtaposed on heavy mortality to shade-intolerant species, suggests that moderate windstorms will neither initiate patch dynamics nor set back succession but will hasten successional takeover by shade-tolerant trees in such forests.

Keywords: MN/ Itasca Park/ vt, pine forest/ vt, maple forest/ windthrow, effects on vegetation/ patch dynamics/ succession/ maple, sugar/ pine, red/ pine, white/ maple, red/ aspen, trembling/ aspen, big tooth/ oak, red.

516. **Weber, M. G. and Flannigan, M. D. 1997. Canadian boreal forest ecosystem structure and function in a changing climate- impact on fire regimes. Canadian Forest Service. 5:3-4, 145-166.**

Abstract: Boreal forest fire regime, which encompasses fire intensity, frequency, seasonality, size, type (crown versus surface), and severity (depth of burn), is an organizing factor of boreal forest landscapes and highly dependant on climate. This review combines what is known about boreal forest dynamics from paleoecological studies, with the information derived from state-of-the-art climate and vegetation modelling, to present possible scenarios of the impact of anticipated climate change on boreal forest ecosystem structure and function, particularly in relation to fire regimes. Anticipated climatic/atmospheric impact on plant physiological, communal, ecosystem, and finally landscape-level interactions with fire are reviewed. All indications from the modelling sector point towards unprecedented increased regional or seasonal temperatures, with projected changes most pronounced at high latitudes and there greatest in winter. Anticipated climate change scenarios are expected to alter dramatically the boreal forest ecosystems and fire regimes with which they currently in equilibrium. Changed fire regimes could be represented by increased annual area burned because of an extended fire season, increased fire frequency, and severity. Simulation studies show the potential for greatly reduced boreal forest area and increased fragmentation due to climate change. Fire regime as an ecosystem process is highly sensitive to climate change because fire behavior responds immediately to fuel moisture, which is affected by precipitation, relative humidity, air temperature, and wind speed. This interaction between climate change and fire regime has the potential to overshadow the importance of the direct effects of global warming on species distribution, migration, substitution, and extinction. Such a scenario suggests that rate and magnitude of fire-regime-induced changes to the boreal forest landscape could greatly exceed anything expected due to atmospheric warming alone. Socioeconomic implications of alter fire regimes in a changing climate are discussed in terms of adaptive fire management strategies, age class distribution, and such global stewardship issues as biodiversity, carbon cycling, and sequestration.

Keywords: Canada/ vt, boreal forest/ fire regime/ fire behavior/ fire modeling/ climate change.

517. **Weyenberg, Scott. 2000. White pine regeneration in stands recently disturbed by fire and logging in northeastern Minnesota. Minnesota DNR.**

Keywords: MN/ vt, pine forest/ fire/ logging/ pine, white.

518. **White, Alan S. 1981. The effects of prescribed burning, soil, land-use history, and topography on plant-species composition at Cedar Creek Natural History Area. University of Minnesota, St. Paul.**
Keywords: MN/ Cedar Creek Natural History Area/ vt, oak savanna/ fire effects/ fire, prescribed/ soil morphology/ landform/ land-use.
519. ---. **1983. The effects of thirteen years of annual prescribed burning in a *Quercus ellipsoidalis* community in Minnesota. Ecology. 64:1081-1085.**
Abstract: A *Quercus ellipsoidalis* community in central Minnesota has been prescribed burned annually since 1965 in an attempt to restore the area to its presettlement oak savanna structure and composition. By 1979 density and basal area of the overstory were significantly lower in the burned area than in the adjacent unburned area but were still higher than estimated savanna values because of the persistence of stems ≥ 25 cm diameter at breast height (dbh). A tall-shrub/small-tree layer was totally lacking in the burned area but averaged 19% cover in the unburned area. Understory richness was significantly higher in the burned area than in the unburned area. Most of the species that showed a significant difference between the two areas peaked in the burned area; this was especially true for grasses and forbs. These results indicate that annual prescribed burning is gradually restoring the area to savanna but that the restoration is not yet complete. Complete restoration may not be possible with annual burning because such burning seems to have little effect on large-tree (≥ 25 cm dbh) mortality.
Keywords: MN/ Cedar Creek Natural History Area/ vt, oak savanna/ fire effects/ fire, prescribed/ oak, pin .
520. --. **1986. Prescribed burning for oak savanna restoration in central Minnesota. US Forest Service, Research Paper NC-266.**
Keywords: MN/ Cedar Creek Natural History Area/ vt, oak savanna/ fire, prescribed/ fire effects/ restoration ecology/ oak, pin.
521. **Whitney, Gordon G. 1986. Relation of Michigan's presettlement pine forests to substrate and disturbance history. Ecology. 67(6):1548-1559.**
Abstract: Little is known of the factors that engendered the classic pine forests of Michigan in the period before settlement by Europeans. Some of the forests were relatively open savannas of jack pine and red pine. Other stands were composed of large red and white pines, occasionally with an admixture of hemlock and hardwoods. The early Government Land Office Survey records of Roscommon and Crawford Counties were used to determine the composition and the disturbance history of the pine forests of northern lower Michigan. The abundance of pine (mainly *Pinus banksiana*, *P. resinosa*, and *P. strobus*) in this area that was between lobes of the Wisconsin Laurentide ice sheet was correlated with the presence of coarse-textured soils derived from outwash and ice-contact deposits. These soils promoted a vegetation type which was extremely susceptible to fire. Records suggest the average return time for severe crown fires ranged from 80 yr in the case of the jack pine forest type to 120-240 yr for the

mixed pine type to 1200 yr for the hemlock-white pine-northern hardwoods type. Blowdowns had a much longer return time and reached their greatest frequency in the swamp conifer and hemlock-white pine-northern hardwoods types. A three-dimensional diagram summarizes the role of fire, windthrow, substrate, and topography in the formation of Michigan's pine forests.

Keywords: MI/ vt, pine forest/ fire interval/ fire effects/ GLO/ presettlement vegetation/ windthrow, frequency/ soil morphology/ landform/ pine, jack/ pine, red/ pine, white.

522. ---. 1987. **An ecological history of the Great Lakes forest of Michigan.** *Journal of Ecology*. 75:667-684.

Note: Study location: Roscommon and Crawford counties.

Summary

(1) The historical development, i.e. changing species composition and the areal extent, of the vegetation of the High Plains region of Michigan is traced with the use of printed and manuscript materials and contemporary forest survey records.

(2) The classic pre-settlement Great Lakes pine forest occupied the rolling upland areas and was conditioned to fires at 130-260 year intervals. Fires were much more frequent on the drier outwash sands of the jack pine plains and openings and almost non-existent on the moist hemlock-white pine-northern hardwoods forests of the uplands and the swamp conifer forests of the lowlands.

(3) Selective logging of the white pine and later the hemlock and the better hardwoods converted the hemlock-white pine-northern hardwoods type to sugar maple. Waves of fires, following the logging in rapid succession, upset the natural equilibrium of the Great Lakes forest. The ignition of the remaining debris or the slash destroyed the remaining seed trees and the seedling pine in the mixed pine type. The result was a poorly stocked forest of oak sprouts and aspen suckers. Oak and aspen had formerly played a relatively subordinate role in the pre-settlement forest.

(4) The cessation of fires in 1920-40 allowed the maturation of the oak, the aspen, and the jack pine and set the stage for the new pulp-oriented industrial forest of the 1950's.

Keywords: MI/ vt, pine forest/ vt, pine-hemlock-hardwood forest/ vt, maple forest/ vt, oak forest/ vt, aspen forest/ fire interval/ GLO/ presettlement vegetation/ land-use/ logging/ pine, jack/ pine, red/ pine, white/ hemlock/ maple, sugar/ oak/ aspen, trembling.

523. ---. 1994. ***From Coastal Wilderness to Fruited Plain.*** Cambridge University Press, Cambridge, UK.

Note: "A history of environmental change in temperate North America from 1500 to the present." The how's and why's of environmental change of the last 500 years are examined. Data from fire frequency publications for the midwest to the northeast by vegetation type are summarized. There is also a chapter devoted to Indian practices on the land, delving heavily into the use of fire.

Keywords: MI/ MN/ vt, Big Woods/ vt, grassland/ vt, oak savanna/ vt, prairie/ vt, maple forest/ vt, spruce-fir forest/ vt, pine forest/ fire, review/ review/ paleoecology/ presettlement vegetation/ GLO/ fire, Native American use of/ fire frequency/ disturbance ecology/ spruce/ aspen/ balsam fir/ basswood/ birch/ maple/ oak.

524. **Wickman, Allen. 1976. Smoke! The Huntersville-Badoura Fire. Minnesota Volunteer. 39(229):44-51.**
Note: A description of the fire behavior and route of the Huntersville-Badoura fire that began in September, 1976.
Keywords: MN/ wildfire/ wildfire, historic/ fire behavior.
525. **Wilkinson, William. 1889. The great Hinckley Fire of 1894. Natural History. 89/1:54-55.**
Note: An excerpt from *Memorials of the Minnesota Forest Fires in the year 1894*. An account by William Wilkinson of what he saw and happened to him and others during the Hinkley Wildfire.
Keywords: MN/ wildfire/ wildfire, historic.
526. **Willis, Gary L. and Coffman, Michael S. 1975. Composition, structure, and dynamics of climax stands of eastern hemlock and sugar maple in the Huron Mountains, Michigan. Ford Forestry Center, Houghton, MI. Technical Bulletin 13. 43 pp.**
Note: In order to explain the perpetuation of hemlock and sugar maple stands, 26 stands were randomly selected and characteristics sampled that would determine differences in structure and composition of forest stands in the Huron Mountains. Soil characteristics differed between the eastern hemlock and sugar maple stands but, all stand types were perpetuated by windfall. Forest origin may have been about 1550 when a large catastrophic fire occurred in the Upper Peninsula (many of the oldest yellow birches are prefire relics) as cited by Graham (1941).
Keywords: MI/ Huron Mountains/ vt, hemlock-hardwood forest/ windthrow, occurrence of/ fire history/ soil morphology/ birch, yellow/ maple, sugar/ hemlock.
527. **Wright, C. E. 1880. The Huronian Series west of Penokee Gap. In, Geology of Wisconsin by T.C. Chamberlain. 3:241-301.**
Note: References a large windthrow up by the Marengo Indian Trail, WI. Cited in Stearns (1949).
Keywords: WI/ windthrow, occurrence of.
528. **Wright, H. E. Jr. 1974. Landscape development, forest fires, and wilderness management. Science. 186:487-495.**
Note: Long and short term vegetation, and disturbance data for the Appalachian Mountains and the BWCA is described in order to explain the function of disturbance regimes of the forested areas. It is concluded that disturbance regimes need to be maintained in wilderness areas to preserve the present forested ecosystems.

Keywords: MN/ BWCAW/ National Forest, Superior/ NC/ fire effects/ disturbance ecology/ windthrow, occurrence of/ climate change/ management/ fire, review/ windthrow, review.

529. --. 1980. **The role of fire in land/water interactions. University of Minnesota, Limnological Research Center. Contribution No. 208. 421-444.**
Note: A review of the literature. Also in Fire regimes and Ecosystem Properties
Abstract: Forest fires cause a temporary increase in runoff to streams and lakes, in part of decreased evapotranspiration, according to studies in Washington (Entiat Fire), Minnesota (Little Sioux Fire), and Ontario (Experimental Lakes Area). Mass transport of nutrients and cations also increases, but no algal blooms were detected. Extent of fires is commonly limited by natural fuelbreaks provided by lakes and streams. The charcoal and pollen stratigraphy of annually laminated lake sediments provides a record of past fire frequency. Lake-sediment studies also document forest history over thousands of years, showing the shift from fire-adapted forests to fire resistant forests, or the reverse.
Keywords: MN/ WA/ Ontario/ Canada/ Little Sioux fire/ National Forest, Superior/ fire effects/ wildfire, historic/ paleoecology/ pollen analysis/ charcoal analysis/ hydrology/ soil drainage/ water chemistry/ fire, review.
530. --. 1981. **The role of fire in land/water interactions, In, Mooney, H. A; Bonnicksen, T. M.; Christensen, N. L.; Lotan, J. E., and Reiners, W. A. Fire regimes and ecosystem properties. US Forest Service, General Technical Report WO-26. p. 421-444.**
Note: This pub. can also be found at the Univ. of Minnesota, Limnological Center, Contribution no. 208.
A good summary of fire/water interactions research up to the date of publication.
Abstract: See citation above.
Keywords: MI/ Little Sioux fire/ National Forest, Superior/ WA/ Ontario/ Canada/ fire effects/ fire interval/ wildfire, historic/ paleoecology/ pollen analysis/ charcoal analysis/ hydrology/ water chemistry/ soil drainage/ fire, review.
531. **Wright, H. E. Jr. and Heinselman, Miron L. 1973. The ecological role of fire in conifer forests of western and northern North America. Quaternary Research. 3:319-328.**
Note: This publication is an introduction to the symposium on the ecological role of fire published in this journal (i.e. Frissel, 1973). The following suggestions made by C.F. Cooper for further study are given; 1) Fire as an influence on the physical-chemical environment; 2) Fire as a regulator of dry-matter accumulation; 3) Fire as a controller of plant species and communities; 4) Fire as the determinant of wildlife habitat patterns, populations; 5) Fire as a controller of forest insects, parasites, fungi, etc.; and 6) Fire as the controller of major ecosystem processes and characteristics.
Keywords: fire effects/ fire, review.
532. **Wright, Richard F. 1974. Forest fire: Impact on the hydrology, chemistry, and sediments of small lakes in northeastern Minnesota. University of Minnesota,**

St. Paul. Interim Report 10. 120 pp.

Abstract: The Little Sioux fire of May 1971 burned most of the virgin forested watersheds of Meander and Lamb Lakes, two small lakes located in the Boundary Waters Canoe Area (BWCA) of northeastern Minnesota. During 1972, the second year after the fire, hydrologic and chemical (Ca, Mg, K, Na, and P) budgets were determined for the terrestrial watersheds of Meander and Lamb Lakes and for the lakes themselves. Budgets were also measured for Dogfish Lake, a lake physically and chemically similar to Meander Lake but whose watershed was not burned in the Little Sioux fire.

The cation budgets for the unburned watershed of Dogfish Lake revealed a very low rate of weathering by solution, similar to rates measured on other Canadian Shield watersheds. Much of the cation and phosphorus supply came from atmospheric precipitation. The export of cations and phosphorus from the Dogfish Lake watershed was comparable to that reported from similar watersheds elsewhere.

The lakes received a large fraction of their cation and phosphorus supplies directly from precipitation. Additional supplies came from the watershed runoff and from diagenesis of the lake sediments. Most of the annual supply of cations was exported from the lakes in effluent. However, over 70% of the phosphorus was retained in the lakes, probably in sediments.

The impact of the Little Sioux fire on these processes was evaluated by comparing the budgets measured at Dogfish Lake with those measured at Meander Lake. This comparison showed that as a result of the burning of the Meander Lake watershed, runoff increased by 60% and the potassium and phosphorus exports increased by 265% and 135% respectively. The exports of calcium, magnesium, and sodium did not change significantly. The increase in runoff, probably due to the reduction in vegetative transpiration, is comparable to that measured after the 1970 Entiat fire in western Washington and to that resulting from clear-felling experiments at Hubbard Brook, New Hampshire and Coweeta, North Carolina. The increased nutrient losses after fire are less than those observed at Hubbard Brook and Coweeta. There was no indication of a drastic increase in nitrate export such as occurred after the Entiat fire and at Hubbard Brook.

The increase in phosphorus loading of Meander Lake was 40%, a value that probably falls within the natural year-to-year variation in supply, and did not represent a major impact on Meander Lake.

Although the phosphorus loading of Meander Lake was about 25 mg/m²/yr, the sedimentation rate of phosphorus is 250 mg/m²/yr in the sediment beneath the center of the lake. The discrepancy between these values indicates that the phosphorus is probably being concentrated in deep-water sediments. Since a shift in the rate or locale of the concentration mechanism will alter the sedimentation

rate of phosphorus at any one spot, phosphorus concentration profile in the lake sediments do not offer a reliable record of phosphorus loading.

The little Sioux fire, a spring fire, may not be typical of fires that burn during the late summer and fall. Fall fires might cause larger nutrient losses because more of the forest-floor material is likely to be consumed and revegetation does not begin until the following spring.

Fire is a natural part of the BWCA forest ecosystems. The results of this study indicate that nutrient losses after the Little Sioux fire were minimal. Other fires in the BWCA or fires in other types of forests, however, might cause large nutrient losses.

Keywords: MN/ Little Sioux fire/ National Forest, Superior/ BWCAW/ fire effects/ wildfire, historic/ wildfire/ lake/ hydrology/ water chemistry/ soil drainage.

533. ---. 1976. **The impact of forest fire on the nutrient fluxes to small lakes in northeastern Minnesota. Ecology. 57:649-663.**

Abstract: The Little Sioux fire of May 1971 burned most of the mixed coniferous- deciduous forest on the watersheds of Meander and Lamb lakes, two small, low conductivity lakes located in the Boundary Waters Canoe Area (BWCA) of northeastern Minnesota, USA. During 1972, hydrologic and chemical (Ca, Mg, K, Na, and P) budgets were determined for the terrestrial watersheds of Meander and Lamb lakes and for the lakes themselves. Budgets were also measured for Dogfish Lake, a lake physically and chemically similar to Meander Lake but whose watershed was not burned in the Little Sioux fire.

These budgets show that the atmosphere supplies a significant fraction of the cations and phosphorus (Ca, 90%; Mg, 35%; K, 95%; Na, 55%; P, 95%) to the BWCA watersheds, with the remainder coming from chemical weathering. The budgets are similar to those reported for other Canadian Shield lakes and watersheds.

The impact of the Little Sioux fire on nutrient fluxes was evaluated by comparing the budgets measured at Dogfish Lake with those measured at Meander Lake. This comparison showed that as a result of the burning of Meander Lake watershed, runoff increased 60% and the K and P exports increased 265% and 93%, respectively. The exports of Ca, Mg, and Na did not change significantly. The increase in runoff, probably due to the reduction in vegetative transpiration, is comparable to that measured after the 1970 Entiat fire (western Washington) and to that resulting from clear-felling experiments at Hubbard Brook (New Hampshire) and Coweeta (North Carolina). The increased nutrient losses after fire are less than those observed at Hubbard Brook and Coweeta. There was no indication of a drastic increase in nitrate export such as occurred after the Entiat fire and at Hubbard Brook.

The increase in phosphorous loading of Meander Lake due to the fire was 38% (to

25 mg/m²yr), a value that probably falls within the natural year-to-year variation in supply, and it did not represent a major impact on Meander Lake.

Fire is a natural part of the BWCA forest ecosystems. The results of this study indicate that nutrient losses after the Little Sioux fire were minimal, perhaps because it was a spring fire. Fall fires may cause larger nutrient losses because more of the forest-floor material is likely to be consumed and revegetation does not begin until the following spring.

Keywords: MN/ Little Sioux fire/ National Forest, Superior/ BWCAW/ fire effects/ wildfire/ wildfire, historic/ hydrology/ soil drainage/ water chemistry/ lake.

534. **Yarnell, Richard Asa. 1964. Aboriginal relationships between culture and plant life in the upper Great Lakes region. University of Michigan, Ann Arbor. Anthropological Papers 23.**

Note: The known uses of plants by Native Americans living in the upper Great Lakes region prior to European settlement is summarized. The use of prescribed fire for agricultural and game habitat improvement purposes is described.

Keywords: MN/ WI/ MI/ fire, Native American use of / review/ shrubs/ herbs.

535. **Yarranton, M. and Yarranton, G. A. 1975. Demography of a jack pine stand. Canadian Journal of Botany. 53:310-314.**

Note: The survivorship curve of a jack pine in stand established after a 1915 wildfire is plotted. The stand experienced high mortality from 1940 to 1950 and even higher mortality between 1950 to 1963. The mortality corresponds to drought years.

The buildup of dead wood is predisposing stand to another catastrophic fire. The estimated fire return interval is 30 to 40 years (Maclean & Bedell, 1955).

Stand is located 30 mi. east of Cochrane in Freele township (49°5'N 80°25'W). Black spruce have been invading site since 1934.

Keywords: vt, conifer-feathermoss forest/ pine, jack/ fire effects/ succession.

536. **Zhang, QuanFa. 1998. The impacts of natural disturbance and human activities on a forested landscape in the eastern Upper Peninsula of Michigan. Michigan Technological University, Houghton. Ph.D. dissertation.**

Keywords: MI/ landscape ecology/ disturbance ecology.

537. **Zhang, QuanFa; Pregitzer, Kurt S., and Reed, D. D. 1999. Catastrophic disturbance in the presettlement forests of the Upper Peninsula of Michigan. Canadian Journal of Forest Research. 29(1):106-114.**

Note: Results include fire and windthrow rotation periods by forest type.

Abstract: The General Land Office (GLO) survey notes (1840-56) were used to examine the interaction among natural disturbance, vegetation type, and topography in the presettlement forests of the Luce District, an ecological unit of approximately 902 000 ha in the Upper Peninsula of Michigan, USA. The

surveyors recorded 104 fire and 126 windthrow incidences covering 3.1 and 2.8% of the total length of the surveyed lines, respectively. The rotation periods over the entire landscape were 480 years for fire and 541 years for windthrow, but these varied with vegetation type and topographic position. Fire occurred more frequently on southerly aspects and at elevations where pinelands were concentrated. The density of windthrow events increased with elevation and slope, with the highest occurrence on westerly aspects. Based on the estimated rotation periods, it was calculated that 7.5, 24.4, and 68.1% of the presettlement forest were in the stand initiation, stem exclusion, and old forest (including both understory reinitiation and old growth) stages, respectively. Pinelands and mixed conifers were the major components in both the stand initiation (34.5 and 31.1%) and the stem exclusion stage (20.9 and 39.8%), while mixed conifers (39.3%) and northern hardwoods (34.7%) were the major old-forest cover types. The diverse mosaic of various successional stages generated by natural disturbance suggests a 'shifting-mosaic' landscape in this region.

Keywords: MI/ vt, pine forest/ vt, aspen-birch forest/ vt, swamp forest/ vt, spruce forest/ vt, maple forest/ vt, hemlock forest/ vt, hemlock-hardwood forest/ windthrow, frequency/ fire interval/ wildfire/ landscape ecology/ GLO/ presettlement vegetation/ pine, jack/ pine, red/ pine, white/ tamarack/ northern white cedar/ spruce, black/ spruce, white/ maple, sugar/ hemlock/ aspen/ birch.

538. ---. 2000. **Historical changes in the forests of the Luce District of the Upper Peninsula of Michigan. American Midland Naturalist. 143(1):94-110.**

Abstract: General Land Office (GLO) survey notes (1840-56), current land cover generated from Landsat TM Imagery (1991) and the Forest Inventory and Analysis plots (1991-92, US Forest Service) were used to examine changes in forests of the Luce District in Upper Michigan over the past 150 yr. Historical changes in two subdistricts, Grand Marais and Seney, were also analyzed. Interpretation of GLO notes showed that the presettlement landscape was a mixed conifer matrix (39% of total area), interspersed primarily with northern hardwoods (29%), wetlands (14%) and fire-susceptible pinelands (13%). Estimates of pre-European settlement stand density ranged from 81 trees/ha in open lands to 408 trees/ha in northern white cedar stands (*Thuja occidentalis*), and estimates of basal area ranged from 3.5 m²/ha in wetlands to 27.7 m²/ha in mixed hardwood/conifer forests. Notable changes in species composition over the last 150 y are the increase of red maple (*Acer rubrum*; +14%) and the decline of tamarack (*Larix laricina*; -11%), hemlock (*Tsuga canadensis*; -7%), white pine (*Pinus strobus*; -6%), beech (*Fagus grandifolia*; -5%) and yellow birch (*Betula alleghaniensis*; -5%). Contrasts between the two subdistricts, Grand Marais and Seney, reflect the influence of the integration of climate, physiography and disturbance regime. Overall presettlement vs. present-day tree diameter distributions differed between the two time periods. Differences in the diameter distributions among individual tree species are related to their growth rates and life expectancies. The diameter distributions of short-lived species are similar between the two time periods. Most species have diameter distributions with more small trees today than in presettlement forests, especially long-lived taxa such as hemlock and white pine.

Keywords: MI/ vt, wetland/ vt, maple forest/ vt, hemlock forest/ vt, hemlock-hardwood forest/ vt, pine forest/ vt, swamp forest/ vt, white cedar forest/ fire, general reference to stand structure/ GLO/ presettlement vegetation/ remote sensing/ FIA/ weather/ landform/ disturbance ecology/ land-use/ beech/ birch, yellow/ pine, white/ northern white cedar/ maple, red/ tamarack/ hemlock.

539. **Zimmerman, Dale A. 1956. The jack pine association in the Lower Peninsula of Michigan: its structure and composition. University of Michigan, Ann Arbor. 278 pp.**

Abstract: The purpose of this study is to describe both structurally and floristically the jack pine plains of the Lower Peninsula of Michigan, to record the exact location of these "plains," and to point out here-to-fore unrecognized differences within that plant association in this region.

Field mapping and compilation of data from published maps shows that except for one more or less continuous large block of pine land in Oscoda, Crawford, and parts of adjacent counties, examples of this vegetation type, are widely distributed in northern Lower Michigan. These pine plains occupy only 475,000 acres (exclusive of plantings).

The largest and purest stands of jack pine are in the interior. Stands near the periphery of the association's range in Michigan (i.e., nearer to the Great Lakes) differ from interior stands structurally and floristically.

Data on stratification, coverage, constancy, and abundance were obtained through field studies in 150 quadrats in different forests, savannas, and "burns"--the three primary structural divisions of the jack pine association.

Four seasons of field work (resulting in the collection of 1,095 specimens), evaluation of published records, and examination of herbarium specimens have shown the pine plains flora to contain 176 species of vascular plants, 12 of which are introduced. Several species, previously reported in the literature, are not admitted to the list.

Examination of Michigan botanical history suggests that certain changes have taken place in the flora and vegetation of the area since lumbering era in the 1890's.

Two to four strata occur in jack pine forests and savannas: usually only the arboreal and ground layers contribute appreciable coverage. The "intermediate" (low shrub) layer and tall shrub layer are more often present, are better developed, and therefore provide more coverage in peripheral than in interior stands. Deciduous species are more frequent in the arboreal layer in peripheral stands. The number of species in the ground layer steadily decreases as coverage of the arboreal layer increases (in both peripheral and interior areas).

Some species are largely or completely restricted to peripheral stands. Others to

interior stands. Peripheral pine areas generally include deciduous forest species that are lacking in the interior pine plains.

Several general conclusions can be drawn from the study: (1) The flora of the interior jack pine plains is sparse because of severe environmental conditions which few plants can withstand: a dry, sandy, strongly acid substratum containing little organic matter, and deficient in lime and plant nutrients, frequent severe burning, a short growing season, with killing frosts in early June and in early September. (2) Floristic differences between interior and peripheral jack pine stands probably are, in large part, the result of regional differences in length of growing season. The relatively long frost-free period in peripheral areas allows more species to thrive there than in the interior. (3) Apparent floristic and vegetational changes in the pine plains in recent decades probably resulted from deterioration of the soil (primarily to destruction of humus) through burning. (4) In Lower Michigan the jack pine plains represent a relict plant association which probably reached its peak of abundance in early post-Wisconsin time. It was replaced to a great extent by other pine communities until their removal through lumbering late in the nineteenth century, which resulted in a second period of abundance for jack pine in this region. More efficient fire control and prevention, modern silvicultural practices, and urban development will further limit expansion of the pine plains, but continued lumbering, small fires, and local abandonment of settled land will undoubtedly open up new areas for occupancy by the jack pine association in the future.

Keywords: MI/ vt, pine barrens/ fire, general reference to stand structure/ classification/ pine, jack.

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