Recognizing All-aged Hemlock Forests

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Abstract

Eastern hemlock (*Tsuga canadensis* (L.) Carr.) occurs in old-growth stands sometimes over 400 years old, throughout its principal range from Nova Scotia to Wisconsin. Studies based on aging as well as diameter distributions indicate a stand structure often dominated by an initial multi-decade post-disturbance pulse of seedling establishment, followed after a century or more by one or more subsequent pulses of seedlings and saplings. Over 400 years these new stems tend to produce a truly all-aged forest. The seedling and sapling layers are eliminated when white-tailed deer populations exceed 3 to 4 per km^2 (12-15/sq. mile), and entire stands are lost periodically to wind storms and accidental fires. Management for this old growth type requires two major components: control of deer populations, and maintenance of a mosaic of developmental age classes so that, if the oldest stand is lost, mid-aged younger stands in the area are poised to replace it.

Introduction

Local conclusions vary widely as to whether differences in the structure of eastern hemlock (*Tsuga canadensis* (L.) Carr.) stands should be attributed to this species interactions with regional patterns of climate and soil. The alternative view is that differences in hemlock old-growth are attributable largely to non-climatic influences such as fire, wind-storms and deer browse. The goal of this paper is to summarize evidence from Nova Scotia, central Ontario and Wisconsin indicating that, across this range at 45° north latitude, great similarities exist in eastern hemlock stands when they are free of the external forcings that affect juvenile age-classes. The results indicate an all-aged structure develops regardless of climatic conditions.

Throughout its range, large stands of hemlock have been established within a few decades after new habitat is created by fire or wind events, as long as a seed source remains. Following such disturbances, seed trees often are local, commonly along a steep slope or water course. On the other hand, our results indicate that juvenile age-class establishment may be eliminated over long periods if white-tailed deer populations exceed 3 to 4 individuals per sq. Km.(12 - 15/sq. mi.). Investigations of hemlock in regions from Nova Scotia to Wisconsin have had to use reference all-aged stands as well as younger, relatively even-aged post disturbance stands to distinguish the various agents that have structured hemlock forests, one way or another in the past. In locations where wildlife browsing influences have not been present, all three regions have developed a fully all-aged stand structure with some trees over 400 years old.

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Approach

Comparative information has been obtained on eastern hemlock stand structure by investigators working near its moisture deficient western limit (in Wisconsin), in Central Ontario, and in a per-humid environment in Nova Scotia, all at or close to 45° north latitude. Some of the data have been drawn from a long series of studies by the senior author and his graduate students and colleagues (Anderson and Loucks 1979, Loucks 1962, Goff 1967, and Hett and Loucks 1976), and by a colleague working in Nova Scotia (Drinkwater 1952).

Results

Data from the Flambeau Forest in Central Wisconsin (Anderson and Loucks 1979) show the effects of deer browsing on hemlock stand structure (Figure 1, a). A reference site in Menominee County (b) shows that when year-round hunting by native Americans kept white-tailed deer populations low, the seedling and sapling populations of eastern hemlock (solid circles) are high. Triangles are the numbers of all species in these size classes. In the Flambeau Forest, with abundant deer, no saplings and only a very few seedlings were present. In the 12-year-old Flambeau Forest deer exclosures (c), hemlock seedling numbers were restored fully to the level expected in an all-aged forest, while two of four plots in a large four-year old fenced area (d-g), show preliminary recovery of seedlings and a few saplings. The latter are stems released from almost complete needle browse.

When hemlock seedlings are found in the Flambeau, they show direct effects of intensive deer browsing, sometimes combined with leaf litter and snow depression of young stems. Seedling success is improved on logs or stumps (in the absence of deer browsing), because the potentially smothering leaves are blown off these microhabitats.

Another study (Hett and Loucks 1976) undertook tree-ring counts for all hemlock stems found on plots established in two Wisconsin and two central Ontario old-growth stands, Figure 2. When examined in detail, the distribution of hemlock stem numbers, by age-class, is not different between the Wisconsin sites (Gardner Dam, a, and West Branch, b), and the Central Ontario sites (Northwest Lake, c, and Pot Lake, d), just south of Algonquin Park (From Hett and Loucks 1976). The negative exponential model (log number of stems over age) was applied to the data, aggregated in ten-year age classes, but a modest sine wave was added. The filled circles are the observed averages and the open circles are the points estimated by the negative exponential sine wave equation.

The West Branch stand in Wisconsin (see b in Figures 1 and 2) has trees up to 350 years of age (Hett and Loucks 1976). A single large white pine stump with a discarded log was

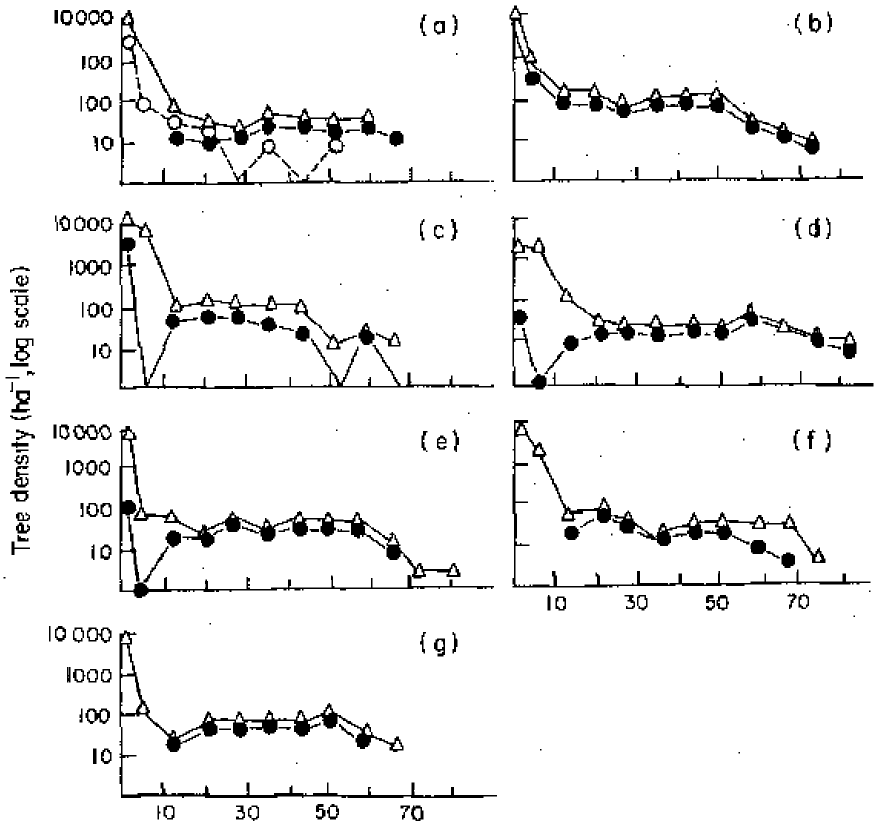

Figure 1.—The relationship between $\log_{10}$ number of stems (ha^{-1}) and stem diameter (cm) for hemlock (closed circle), sugar maple (open circle) and all trees (triangle) for a series of study sites in Wisconsin. Most of the Flambeau Forest (a) has lost the seedling layer, in contrast to a control area in Menominee County (b), areas exclosed in 1961 (c), and exclosed in 1969 (d-g). For clarity, sugar maple is shown for only stand (a), though this relationship is similar to that in other stands in the Flambeau area.

present, and a ring count indicated the stand was of fire origin 475 years prior to the 1967 study. Other younger stands in the area were also of fire origin (Goff 1967), comprised of white pine 300 years old with an understory of hemlock 200 to 280 years old. At the Ontario sites, subsequent studies by the Lamont Doherty Geophysical Laboratory found many individual hemlocks over 400 years old.

The results of an analysis using the residuals (departures as log number of stems) from a power function model for the four hemlock stands show the same sinusoidal patterns (Hett and Loucks 1976). The results in Figures 1 and 2 show that eastern hemlock abundance-age distributions generally conform to the “Type II” distribution expected for plants, that is, a negative exponential decline in numbers, or a gradual straight-line decline in the log of number of stems by age class (Schmelz and Lindsey 1965). Some long-term variation, or pulses, in initial seedling success obviously are present. The sinusoidal variation in input (Figures 2 and 3) has been interpreted by Hett and Loucks (1976) as an auto-induced effect from the intense shading under the early hemlock sapling and pole-sized age classes, followed by opening of the understory as the canopy matures, increasing seedling numbers and sapling success.

For Nova Scotia, data on hemlock stand structure are available from the work of M. H. Drinkwater (1952). He established 30 plots in an old-growth stand on an island in Jordan Lake, Queens County, Nova Scotia. The results showed hemlock to be the dominant species in every size-class from seedlings to the large over-story trees (Table 1). The only significant competitor species is red spruce (*Picea rubens* Sarg.), which Drinkwater concluded could become more important as a future stand develops.

The age of this stand (200 to 300 years) was estimated from tree-ring counts of freshly cut stumps in a nearby clearcut. A majority of the harvested trees were between 200 and 250 years old, indicating that the stand originated after a disturbance (possibly a hurricane) between 250 and 300 years prior to the study. Although few trees were lost in 90 mph winds in 1950, many other hemlock stands were severely decimated in west-central Nova Scotia by hurricane “Edna” in September 1954. Nevertheless, the distribution of stems shown in Table 1 indicates a transition from a relatively long-term pulsed origin of the stand, through a period of limited new stem establishment, into the recent period of a more fully all-aged distribution, similar to the stands in Ontario and Wisconsin.

Discussion

Although many present-day old-growth hemlock stands appear to have originated under pine, birch and aspen following fire (see Loucks 1962 and Goff 1967), devastating windstorms can also have led to the initial several-decade pulse of hemlock seedling establishment. These origins are inferred partly because of the history of devastating storms recorded throughout the range of hemlock (hurricanes in the

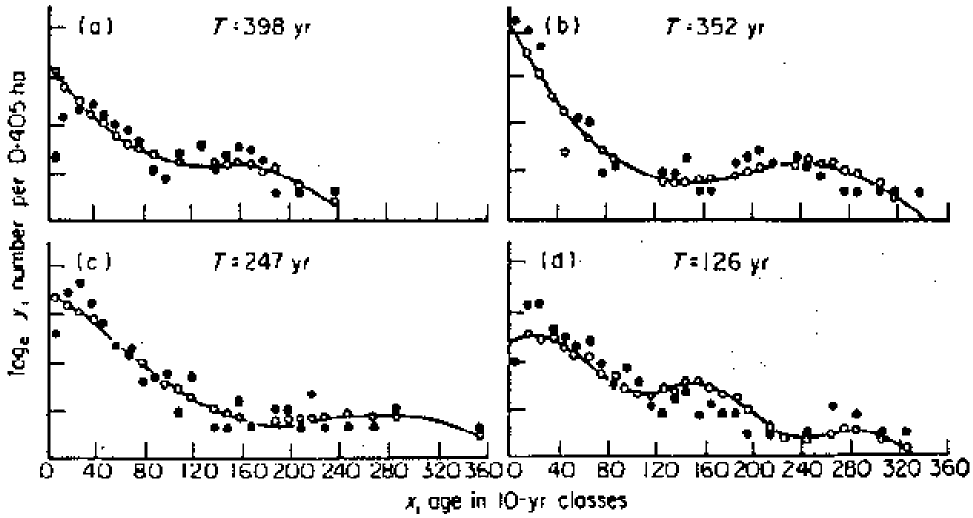

Figure 2.—Application of a negative exponential sine wave analysis using ten-year age classes for four hemlock stands: (a) Gardner Dam stand, (b) Wet Branch stand, (c) Pot Lake stand and (d) Northwest Lake stand. *T* = length of sine wave. The filled circles are the observed averages and the open circles are those points estimated by the sine wave equation.

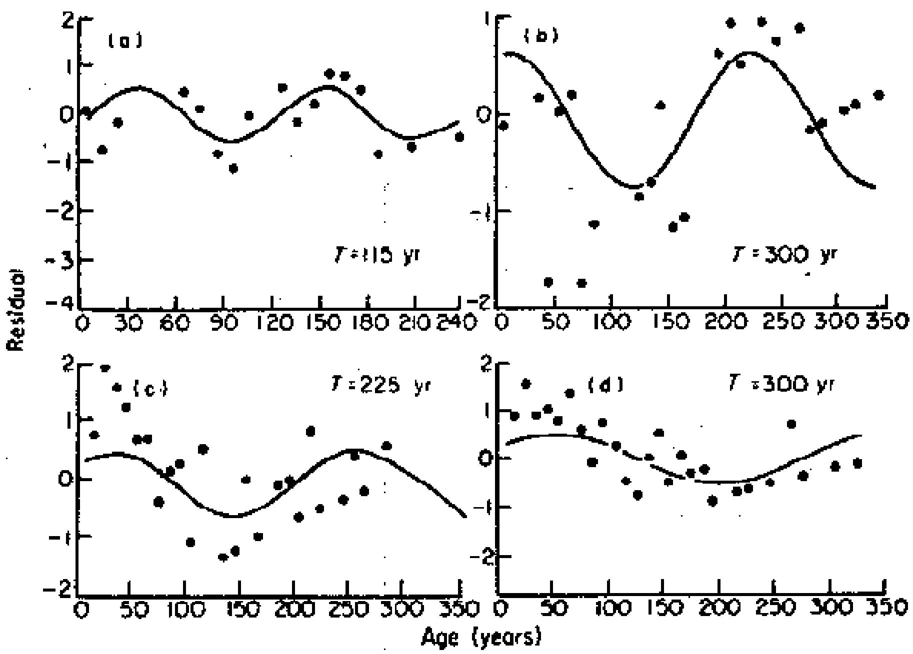

Figure 3.—The results of a sine wave analysis using the residuals from the power function model for the four hemlock stands with a linear age axis: (a) Gardner Dam stand, (b) West Branch stand, (c) Pot Lake stand and (d) Northwest Lake stand. *T* = length of sine wave.

east and thunderstorm downbursts or tornadoes in the central and west), and partly because of the early surveyor records (especially in Wisconsin) showing many miles of blown down forests, some of which now have regenerated to hemlock under intolerant hardwoods. Given the frequency of these naturally occurring events, management for hemlock old growth must ensure that younger stands are maintained in age classes designed to replace the present old growth, should a disaster strike.

For example, the consequences of a downburst storm for old-growth hemlock in Wisconsin is described by Canham and Loucks (1984). This report concerns a storm that struck the 360-acre Flambeau Forest studied by Anderson and Loucks (1979) on July 4, 1977 with winds of over 250 m.p.h., bringing down 100% of the stand in just a few minutes. Remeasurement of the former plots proved impossible because the tangle of trees on top one another was impenetrable and former woods roads and deer fences

Table 1.—Size-class distribution in a 200 to 300-year stand of Eastern Hemlock and Red Spruce, Pitman Point (Jordan Lake) Nova Scotia, 1950 (After Drinkwater 1952).

Size Class	Hemlock	Red Spruce	Other Conifers	Hardwoods
Seedling to 0.5”*	1,533	350	151*	550*
1-3”	21	104		
4-6”	15	16		
7-9”	12	9		
10-12”	17	2		
13-15”	25	2		
16-18”	28			
19-21”	22			
22-24”	9			
25-27”	5			
28” +	2			

* Data available only for the “seedling to 0.5-inch” size class.

could not be relocated even to provide a local landmark. Using the data on extent of blowdown observed by early surveyors, largely from 1840 to 1860, Canham and Loucks were able to calculate the return time for catastrophic windthrow in this region to be 1,210 years, just three times the life span of the trees. As noted above, fires also occur in this region, and for the zonal soils commonly dominated by hemlock, the return time for fire also is believed to be about 1000 years.. The presence of both types of disturbances shortens even further the average natural interval during which truly all-aged hemlock stands could have developed.

The processes described in the previous sections also are influenced by wind-induced single-tree patch openings within mature canopies, allowing some seedling and sapling establishment throughout the 30 to 40 decades of stand development. The data presented by Drinkwater (1952), and by Hett and Loucks (1976) suggest that development of the initial, relatively even-aged young hemlock stand leads to a long period of low reproductive success, followed by quite high success. Both of these responses in stand structure can be seen as part of the shadow cast by the initiating stand onto stand structure up to 3 or 4 centuries later. Although the pulse pattern being seen at the present time is interesting, it may be temporary, i.e., in later years, in the absence of a relatively even-aged overstory, there may no longer be any long-term period of low seeding or sapling establishment. The more important finding, however, is that hemlock stands are all-aged across a broad geographic area, in the absence of wildlife impacts.

These results also indicate that the most important steps in “managing” old-growth hemlock stands are of two kinds: (1) removal of the risks to regeneration that can be controlled, particularly the high levels of deer browsing that are found in some regions; and (2) provision of an area-wide pattern of age-class states so that mid-aged hemlock stands under pine or intolerant hardwoods can develop into old growth if catastrophic events destroy present day stands.

Conclusions

Given the differences in climate east to west along a gradient at 45° N. latitude from Nova Scotia through Central Ontario to Wisconsin, mature eastern hemlock stands have surprisingly similar stand structure in the absence of intensive deer browsing. Successional dynamics following fire or wind storms also is similar across this range (see Loucks 1962, Zedler and Goff 1973, and Canham and Loucks 1984).

The principal differences along the gradient are in the composition of the competing tree species. These include red spruce, balsam fir and occasionally beech in Nova Scotia, mainly sugar maple, yellow birch and some beech in central Ontario; and sugar maple with yellow birch and no beech in central Wisconsin. Young hemlock stands often establish under pine or intolerant hardwoods following fire, but hemlock is not a fire-tolerant species (Loucks 1962). The autecological and competitive adaptations of hemlock appear to be similar across its east to west range, consistent with its relatively homogeneous genetic makeup. Therefore, management for old-growth hemlock should be framed at a landscape level in which multiple, mid-aged stands are allowed to develop toward the old growth structure, recognizing that catastrophe loss of old growth can happen.

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