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A STUDY OF A *TSUGA CANADENSIS* STAND IN HEMLOCK RAVINE, HALIFAX CO., NOVA SCOTIA

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Species composition and hemlock (*Tsuga canadensis* (L.) Carr.) age class structure and growth rate were compared for 3 sites (bottom, middle and top) in a hemlock stand on the north-facing side of Hemlock Ravine, located in the City of Halifax, Nova Scotia. This information was used both to assess hemlock habitat quality of each site and as a basis for reconstructing past conditions in the ravine. Overall, the hemlock stand appears healthy with respect to recent reproduction, potential for regeneration, and age class distribution. On the basis of 6 measures drawn from growth rate and age class structure data, there seems to be a gradient of hemlock habitat, from the best and moistest area at the bottom of the ravine slope to the poorest and driest area at the top. The distinct pattern in growth rate observed for all sites over the last century was best correlated with mean March to May temperature. Although it has been emphasized with conifers that water supply is dominant in determining relative annual ring widths, the correlation between precipitation and hemlock growth rate in this study was insignificant. The contribution of canopy opening to the observed peaks in growth rate was also explored. The present healthy existence of this valuable hemlock stand would be adversely affected by increased visitor pressure or a decrease in the flow of the small stream at the bottom of the ravine. Erosion potential would be increased and regeneration decreased (especially on the steep slopes) and the moisture regime would be altered. This study provides baseline data to which future work can be compared and changes detected.

Introduction

Tsuga canadensis (L.) Carr., largely confined to the Hemlock-White Pine-Northern Hardwood Forest delineated by Nichols (1935), reaches its northern limit on Cape Breton Island, N.S. To date, all research on hemlock has been concentrated in the southwestern part of the province (Miles & Smith 1960) where it occurs both in extensive pure stands and with red spruce (*Picea rubens* Sarg.).

This paper reports the study of a hemlock stand (44° 41'N, 63° 39'W) which is isolated on the steep, north-facing slope of a ravine through which a small stream flows. The location of the stand (roughly 0.12 km^2) is shown in Figure 1. The stand is in Hemlock Ravine which was recently (1978) purchased as a Nature Reserve by the City of Halifax in conjunction with the Nature Conservancy of Canada.

Species composition and hemlock age class structure and growth rate are compared for 3 sites (bottom, middle and top) on the ravine-side gradient. This information is used both to assess hemlock habitat quality and as a basis for reconstructing past conditions in the ravine. Field work was done in the autumn of 1976.

Methods

Three plots (10 m by 40 m) were positioned parallel to the top edge of the north-facing slope, one near the bottom, middle, and top. These plots were separated from one another by about 10 m. The lower one was not extended to the stream because of a well-worn foot path adjacent to its edge.

Diameters of all trees with diameter breast height (DBH)$\geq$1 cm were measured to

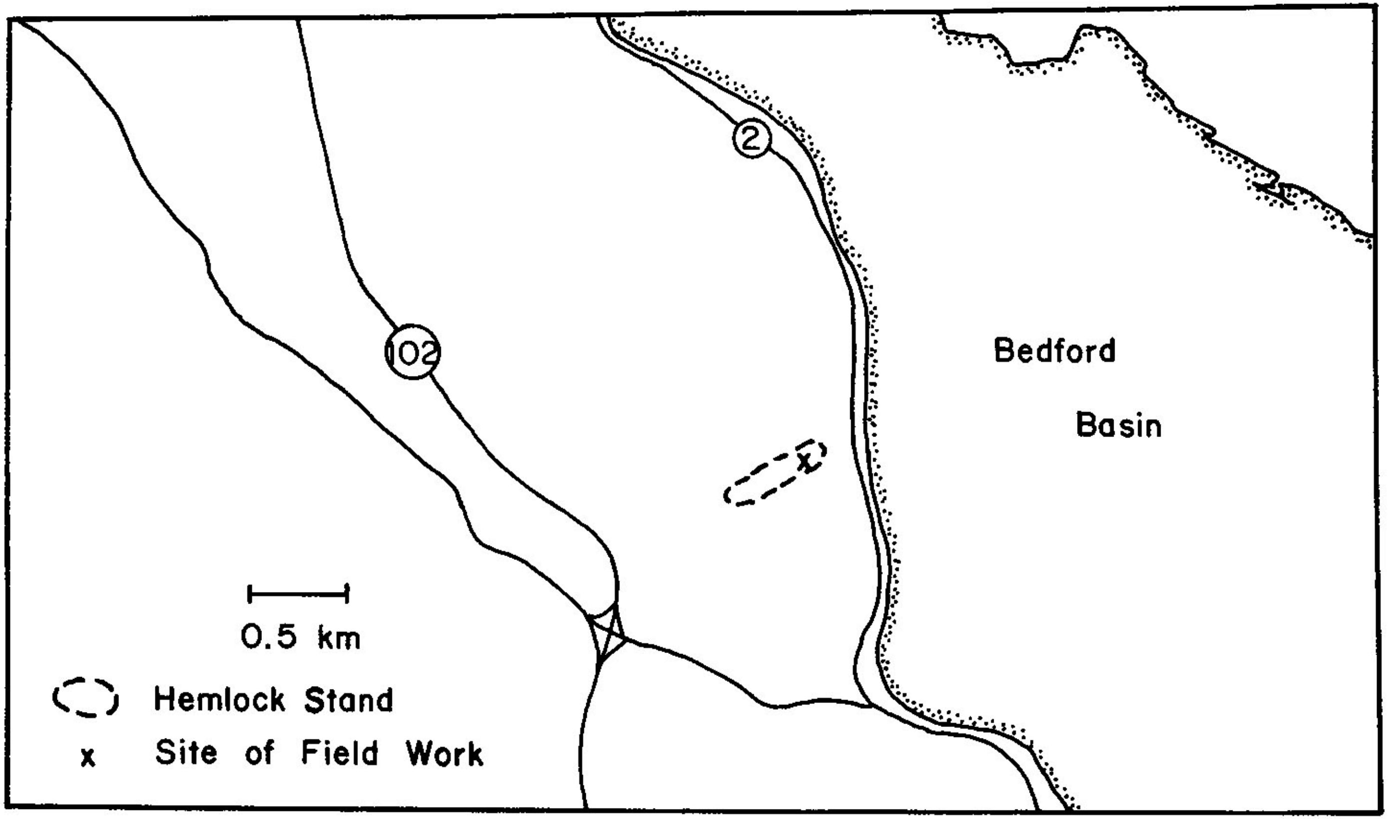

Fig 1. *A portion of topographic map 11D/12 (Halifax, 1: 50,000), (Ed. 4, 1973) showing the location of the hemlock stand studied, between highways 102 and 2.*

the nearest cm and smaller seedlings and saplings were counted in each plot. The ages of a number of randomly chosen hemlocks in each site were determined using an increment borer.

Slope and soil depth were measured to better characterize the three sites. A soil auger was used to measure 20 soil depths over the length of each plot. Slope was measured by a slope meter for 5 locations in each site.

Results and Discussion

Species Composition

Plot compositions are shown in Figure 2 for 3 arboreal species. In the middle and lower sites, hemlock is clearly dominant, followed in abundance by red spruce and balsam fir (*Abies balsamea* (L.) Mill.) However, this is not as obvious in the upper plot. If only large trees (those individuals with DBH $\geq$10 cm = circumference $\geq$ 31 cm) are considered, hemlock is most abundant in the upper plot. The distribution of hemlock will later be examined on the basis of age class structure.

Red spruce appears to be reproducing best near the top of the slope. The ratios of red spruce to hemlock seedlings ($<$ 1 cm DBH) for the 3 sites (bottom, 1:5; middle, 1:1; top, 4:1) increase towards the top. The difference in ratios among sites is significant as a Chi Square Test using seedling numbers from Figure 2 indicates (X^2 = 99.1, $p \ll .001$). In the top site, the high potential for red spruce regeneration was clearly shown where a dense cluster of saplings of red spruce and not hemlock had grown up under a hole in the canopy. It is interesting to note that just beyond the top site where the terrain levels off, forest composition changes and red spruce becomes dominant over hemlock.

No balsam fir survived beyond 5 cm DBH. The short life span of balsam fir under hemlock, resulting from intolerance of shading, was noted by Martin (1959) who also found no larger balsam fir.

Betula lutea Michx.f., *Acer rubrum* L., and *A. pensylvanicum* L. are reproducing in the middle plot. In the upper plot, *A. rubrum* seedlings were present, but in the lower plot *A. rubrum* was represented only by a few older trees. Other species present in the plots were: 1) *Fagus grandifolia* Ehrh., *Quercus rubra* L. in the lower plot; 2) *Betula papyrifera* Marsh. in the middle plot; 3) *Betula papyrifera, Fagus grandifolia,* and *Pinus strobus* L. in the upper plot.

Soil depths ranged from 2 to 65 cm and there were no significant differences between depths for any two sites (Mann-Whitney U Test, $= >$ .05). The slope of the lower plot (9°) was significantly smaller than the slopes of the middle plot (26°) and the upper plot (28°) (Mann-Whitney U Test, U=0, p=.004). Such steep slopes (stand maximum 36°) have a high potential for erosion which could pose a problem with an increase in visitors to the ravine.

Hemlock Age Class Structure

Age determination A regression line and correlation coefficient for DBH versus age were determined for each plot on the basis of a random sample of trees thick enough (diam. $\geq$ 6 cm) to core. The two largest trees sampled had diameters of 82 cm and 98 cm and were about 286 and 309 years old respectively. These individuals were not used in the regression analyses because they were rotten in the center and their ages could not be determined accurately.

Discs taken from 5 saplings were used to determine DBH and age breast height for a sample of trees too small to core. With data taken from these discs, an age correction factor for the underestimation of age as measured at breast height (1.3 m from ground level) was estimated.

In determining the curve used to obtain age from diameter for trees not cored, a regression line was plotted through the points (age vs diam) for cored trees. The points for the 5 saplings were then added to the graph and a smooth age from

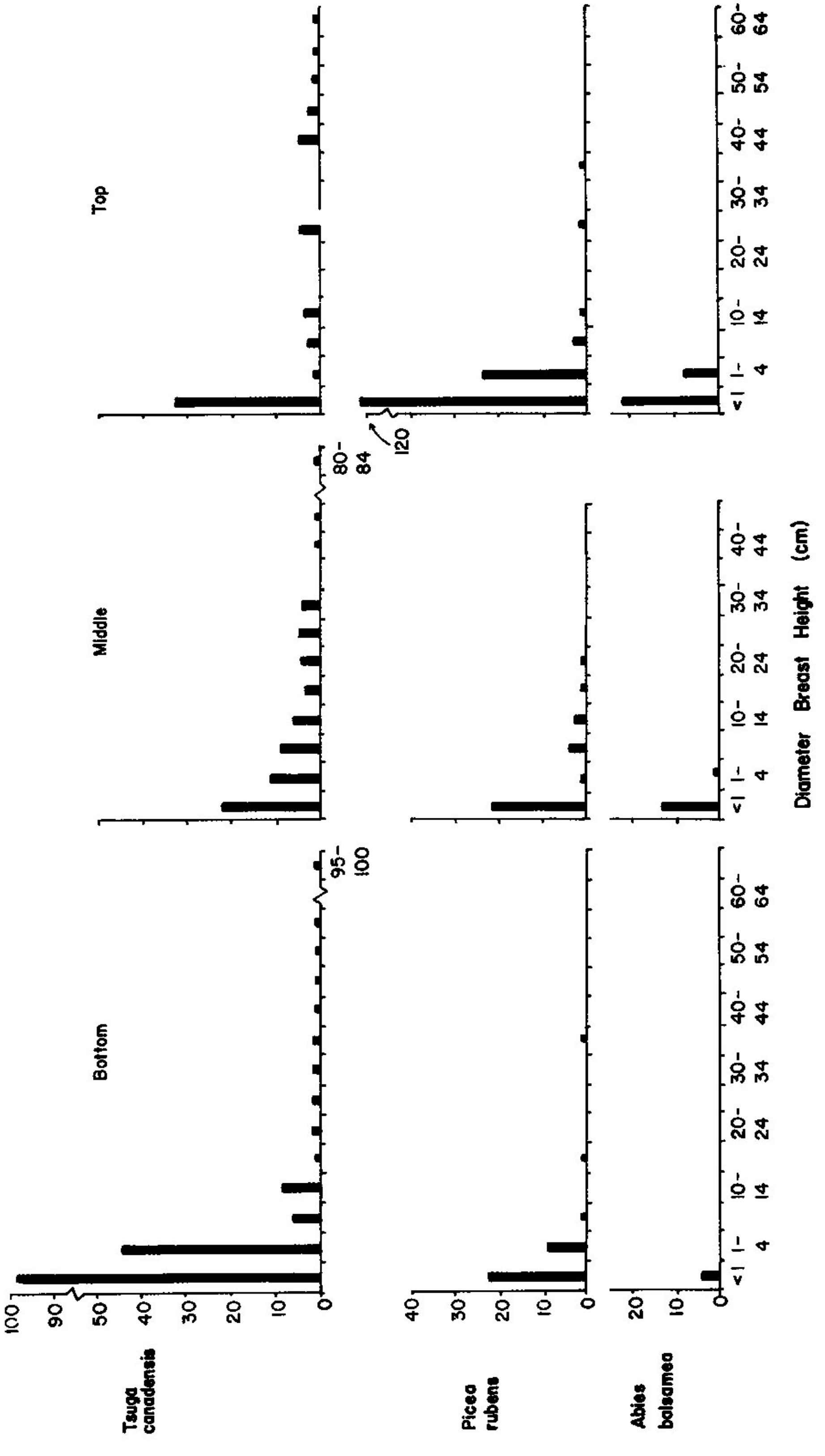

Fig 2. *Diameter class distributions for 3 arboreal species for each of the 3 plots.*

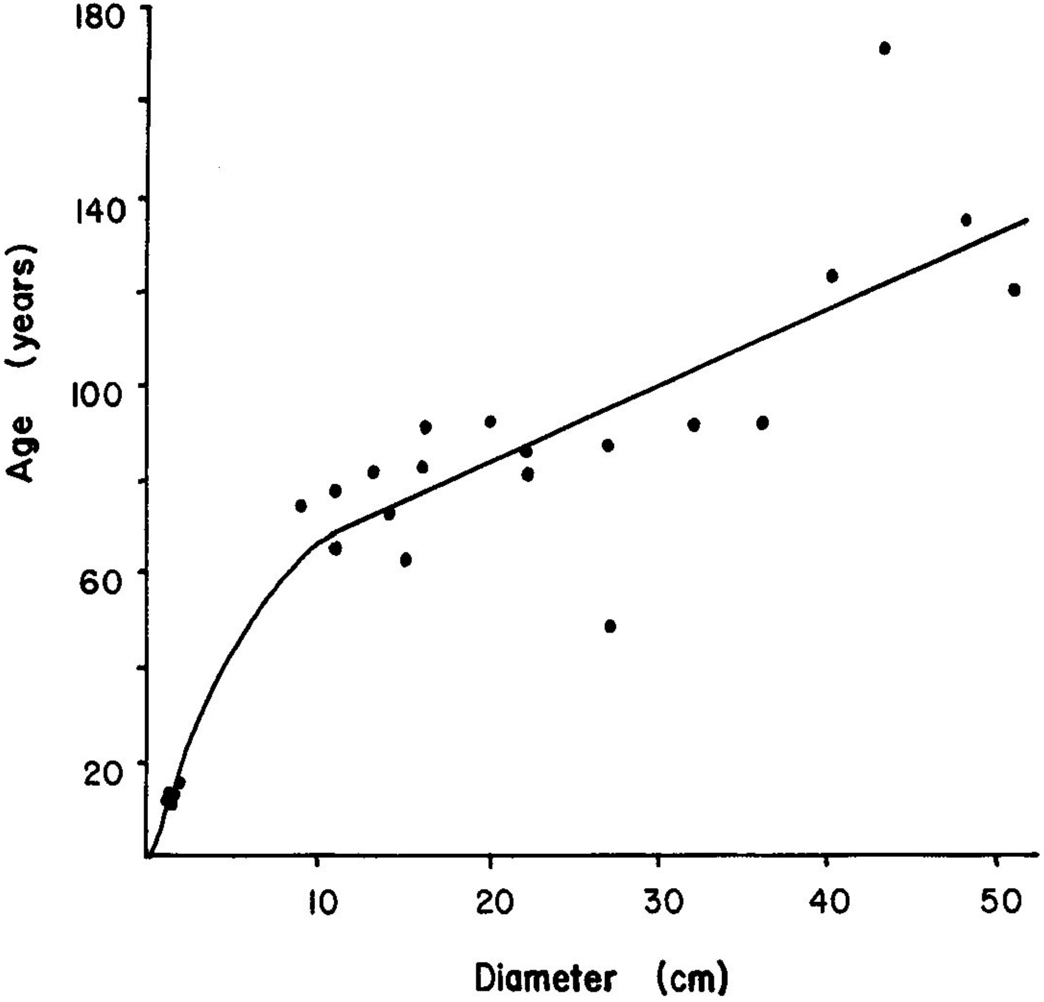

Fig 3. *Age vs diameter curve used to determine age from diameter for trees not cored in the bottom site (regression line: age (yr) = 1.63 (diam. (cm)) + 50.73, correlation coefficient = 0.76).*

diameter for the lower plot is shown in Figure 3. The regression equations and correlation coefficients for the other 2 sites were very similar to those of the bottom site. In each plot less than 5 uncored trees had to be aged using the regression equations.

The 5 saplings varied in age from 17 to 23 years. Errors in age determined at breast height (age at ground level minus age at breast height) for them ranged from 6 to 10 years. Although the age correction factor probably varies with age and possibly site, the mean value of 8 years was added to the ages obtained from cores and to those determined from the age-diameter curves for trees ≥ 1 cm DBH.

Age structure The corrected ages calculated as above were used in the age class distributions shown in Figure 4. The bottom site has the most 'healthy' structure, one where the greatest number of age classes are represented and where frequency gradually decreases with age. Figure 4 indicates that recent reproduction (individuals < 10 years, corresponding to those < 1 cm DBH), presently highest in the bottom site, is relatively good for all sites. Unfortunately regeneration here cannot be compared to stands in southwestern Nova Scotia because there only the percentage of seedlings which was hemlock and not the number of seedlings were recorded (Miles & Smith 1960). This Nova Scotian stand appears comparable to those in New England which also have good natural regeneration (Forbes 1955).

Growth Rate

Comparisons of mean growth rates among sites were made using an analysis of variance (Table I a, b). The trees were not cored parallel to the slope contours, and, because of the steepness of the slope, the annual rings may have grown eccentrically. For these reasons, mean growth rates used in the ANOVA were determined as follows:

$$\text{mean annual radial increment} = \frac{\text{diameter - (2X bark thickness)}}{\text{2X breast height}}$$

The complete ANOVA (Table Ib) shows that there is a significant difference in growth rate among age classes and among sites. Significant interaction indicates a difference in age structure among the 3 sites (Fig 4).

Habitat Assessment

Intuitively one might suggest from Figure 4 that there was a gradient in hemlock habitat from good (bottom) to fair (middle) to poor (top). Several quantitative measures can be considered in assessing habitat quality, including:

1) the number of age classes represented (Fig 4); although this is a function of classification interval, all sites were classified the same way.
2) the number of seedlings surviving to establish over the past 10 years (Fig 4)
3) the number of mature individuals (those $\geq$ 10 cm DBH, corresponding to those ≥ 60 years) established in the last 100 years.
4) the number of age classes where mean growth rate is highest (see Table I a).
5) mean maximum radial increment over 1 decade (using trees of similar ages)
6) mean of mean radial increment per decade (using trees of similar ages).

With regard to 5 and 6, the increase in radial increment for each decade, 1967 - 1976, 1957 - 1966 . . . to 1866 was recorded. Trees greater than 90 years old

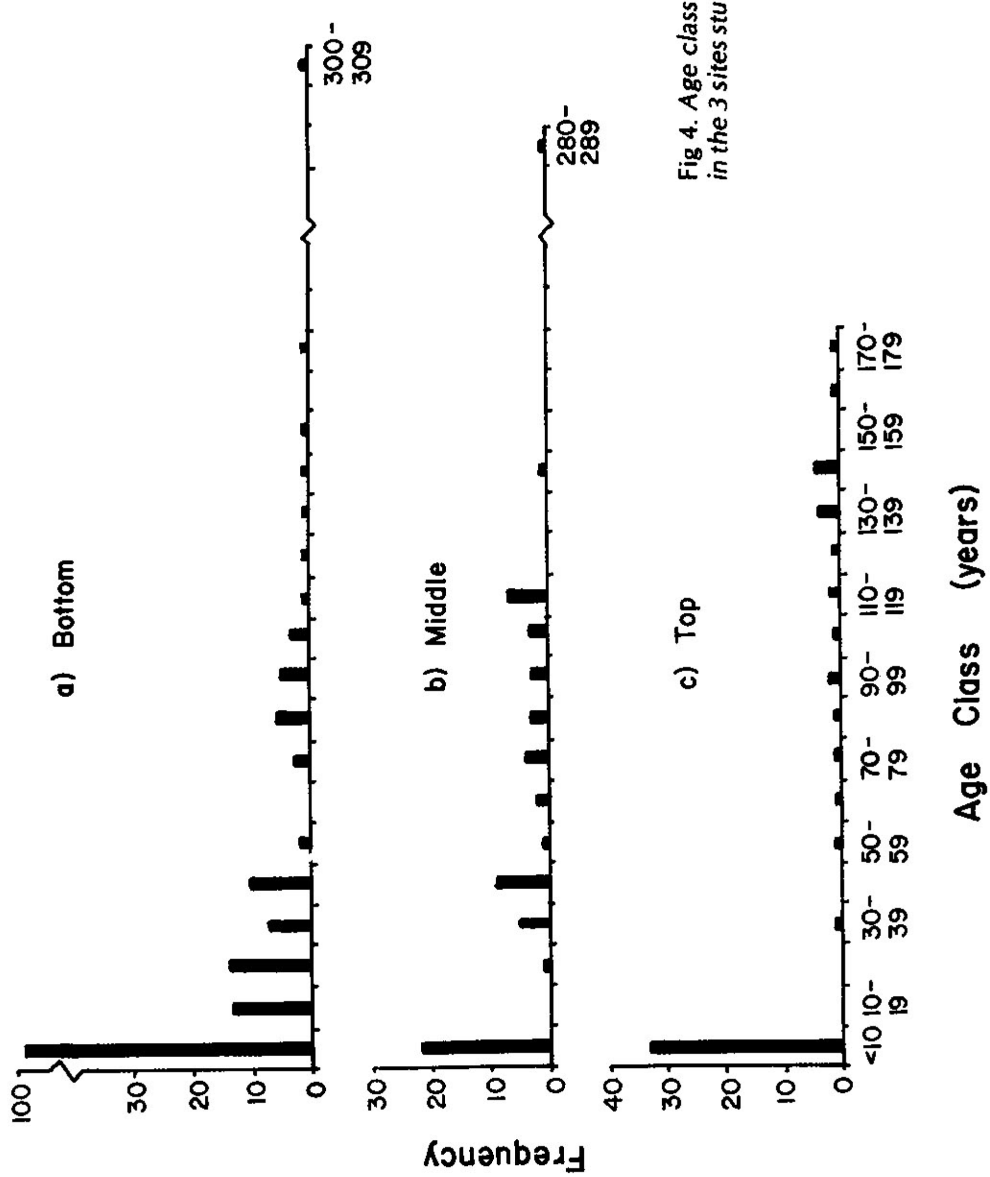

Fig 4. Age class distribution for hemlock in the 3 sites studied.

Table I Analysis of variance for growth rate vs site and age.

(a) means of mean annual radial increment in mm.

Site	Age Classes (years)					
	30-49	50-69	70-89	90-109	110-129	130
Bottom	2.67	0.97	0.96	1.34	1.80	1.45
Middle	0.87	0.77	0.86	1.65	0.81	0.87
Top	0.96	0.63	0.85	1.52	1.92	1.42

(b) complete ANOVA

Source	SS	df	MS	F	
Age	3.65044	5	0.73008	4.94	(p .01)
Site	2.13534	2	1.06767	7.22	(p .01)
Interaction	4.96489	10	0.49649	3.36	(p .01)
Error	7.54290	52	0.14790		

Table II Values of hemlock habitat measures for 3 study sites.

Habitat Quality Measure		Site	
	bottom	middle	top
no. age classes represented	17	13	14
No. seedlings established in last 10 years	98	22	33
no. mature trees established in last 100 years	14	12	5
no. age classes having highest mean growth rate	4	1	1
mean maximum radial growth over 1 decade (mm)*	24.2	23.3	23.2
mean of mean radial increment per decade (mm)*	13	14	13

*no. of trees in sample: bottom-12, middle-14, top-13 were used because this gave a number of decades with which to work and this group was probably under the least suppression (because of shading). The values of these measures were determined for the 3 sites and are shown in Table II. The first 3 measures of habitat suitability are related to regularity and abundance on regeneration; they suggest that the best hemlock habitat is at the bottom of the slope, next to the stream. This is also supported by the first measure based on growth rate. However, the last two measures indicate that for trees greater than 90 years old, all sites are equally good habitat.

Based on both measures from age class structure and growth rate, there indeed appears to be a gradient in hemlock habitat, with the best at the bottom. This is supported by Oosting and Hess (1956) who worked with hemlock on a north-facing ravine slope in North Carolina. In their study, hemlock was found near the stream in the bottom of the ravine and it diminished in abundance towards the top of the slope, with oak (*Quercus sp*) eventually replacing it at the top. Several authors have noted that hemlock seedlings tend to do best on the moister areas (Black & Mack 1976; Hough 1939; Stearns 1951). This suggests that the apparent gradient in habitat may result in part from a corresponding moisture gradient.

Tree Ring History

In the 17th century, the annual character of tree rings was fully recognised (Studhalter 1955). Since that time they have been used to date glacier advances and retreats, landslides, erosion cycles and as an index of past climatic conditions (Glock 1955).

When mean radial increment per decade for hemlock was plotted against time, the same pattern was found for all three sites regardless of their differences in age class structure and growth rates (Fig 5). How is this growth ring history to be interpreted? As Schulman (1941) noted, the observed growth rates depend on a variety of factors. Here a few climatic factors and the possible influence of man will be discussed.

One might expect rainfall to be most critical from May to August when the temperature is most suitable for rapid growth, and that ring width would be a good index of precipitation during this period. Comparisons of mean May to August and mean annual precipitation to growth per decade showed that this was not the case. Correlation coefficients were not significant.

There are several possible reasons for this unexpected relationship. The effect of precipitation may be offset by other factors. Secondly, precipitation received may not be a measure of water availability, to which the trees respond. Thirdly, the observed increase in radial increment per decade is to some extent inaccurate because it was determined from only 1 core per tree and eccentric growth is to be expected on such steep slopes. An additional factor which may be obscuring the relationship is the use of means over a decade rather than yearly growth and precipitation. The possibility that there is no relationship also exists.

Temperatures from June to August are generally suitable for growth and those from September to February are cool with growth being minimal. Therefore, temperatures from March to May were selected to be compared to growth because they determine spring water supply (from ice and snow) and the starting date for the season of rapid growth. Both the growth rate curves (Fig 5) and the temperature curve (Fig 6) have corresponding peaks and hollows. The correlation coefficient for these two variables is 0.51. Of the 2 factors, precipitation and temperature, the tree ring widths are better correlated with temperature (when working with decades).

In other work concerning the relationship between tree growth and temperature and precipitation, some authors have obtained good correlations for hemlock (Lyon 1943). Glock (1955) says of Lyon's work with hemlock, " . . . the correlations between relative growth rates and the precipitation records of certain periods of the year

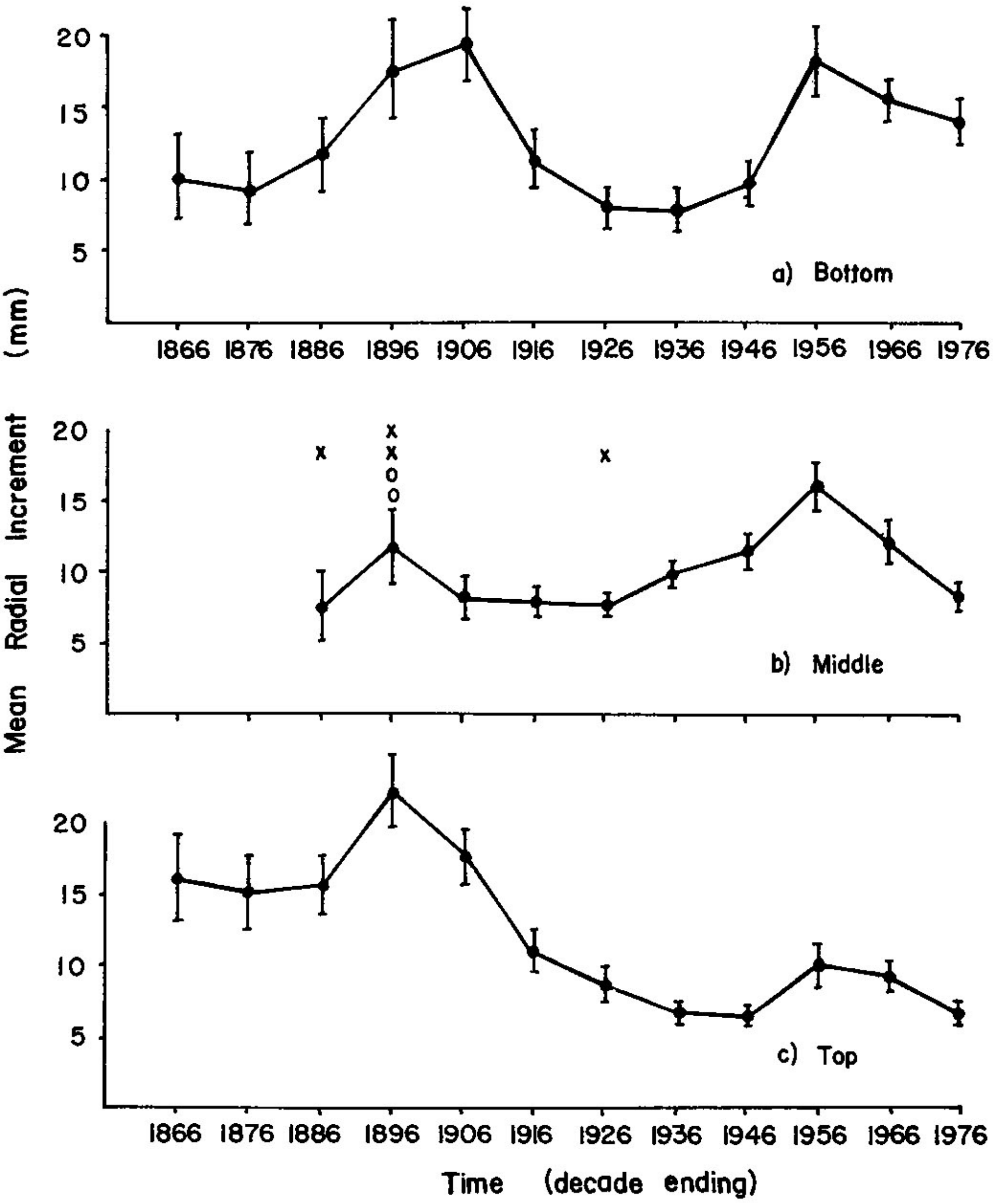

Fig 5. *Mean growth per decade for all trees cored in each plot; bars indicate 95% confidence intervals for means; x = decade of establishment of white birch cored, o = decade of establishment of red maple cored.*

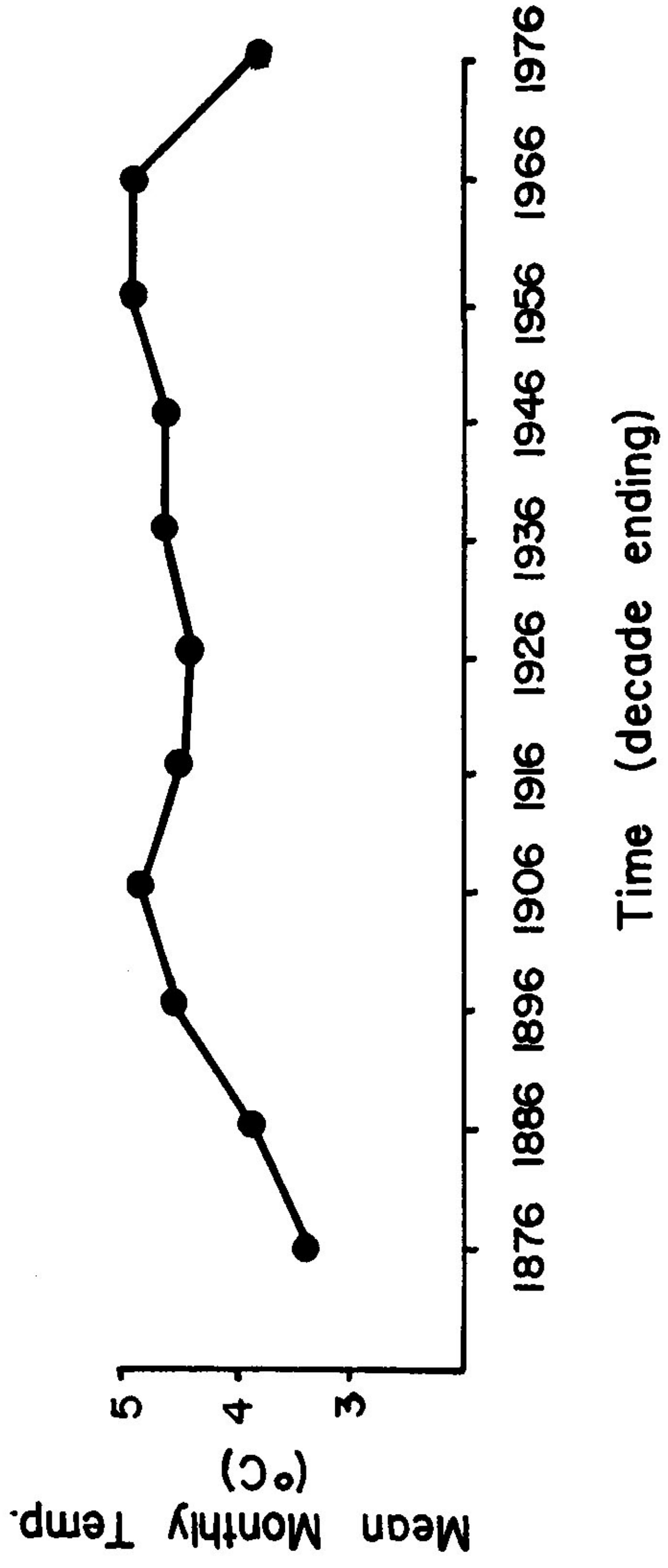

Fig 6. Temperature data for March to May for decades indicated; data from the Halifax station.

(May to July, May to August) are so high that the occurrence of a notably narrow or wide ring of wood is presumptive evidence for a drought or generous supply of water". On the other hand, various authors (Avery *et al.* 1940; Meyer 1941) found an insignificant correlation between hemlock ring width and precipitation. Clearly, the use of tree ring records as a reliable measure of climatic factors can be made only when one eliminates variation in ring width resulting from other factors (e.g. trend with age). When this was done for hemlock, Shumacher and Day (1937) found that it was a good indicator of moisture conditions.

Growth rate can also be affected by the degree of canopy opening. This could be brought about naturally by storms and hurricanes or artificially by the selective removal of valuable timber trees. Creating gaps in the canopy would also enhance the establishment of other less shade tolerant species. With this in mind, ages were determined from cores for 4 white birch (*Betula papyrifera*) and 2 of the red maples (*Acer rubrum*) found within the plots. Figure 5b shows that of the 6 trees, 4 probably started to grow during the decade ending in 1896, one of the earliest peaks in growth. None was close to the 1956 peak. These results suggest that canopy opening may have played a part in the early peak.

Over the years there has been a number of intense North Atlantic hurricanes (1935, 1938, 1944, 1966) which affected Nova Scotia. The first 3 may have contributed to the 1956 peak through increasing canopy opening, but this was not reflected by the establishment of shade intolerant species. No major storms were recorded around the time of the early peaks.

Artificial canopy opening through man's activities is the second possiblility. There is no field evidence to support this as a factor contributing to the 1956 peak. With regard to the early peaks and artificial canopy opening, I spoke to a number of people including H. Haverstock, owner of the nearest sawmill (established 1850), the Nova Scotia Museum's authority on ship building in the area, and Lou Collins, an official of Heritage Trust. Documents from the Nova Scotia Public Archives (Harris, Mullane, Smith, Storey) were also consulted. None of these sources indicated that wood had been taken from the ravine for any purpose at the turn of the century or at any other time. Perhaps the relationship between the establishment of the white birch and red maples and the growth peak is not evidence for general canopy as hypothesized earlier, and it is by chance that the two occurred at the same time.

It should be recognised that Hemlock Ravine is of great value to the Halifax-Dartmouth area. The hemlock stand in this ravine is several centuries old and relatively untouched by man. Yet, this unique natural feature is within reach of a large urban population. Here exists ample opportunity for education in natural history and biological processes.

This study has shown that the hemlock stand in Hemlock Ravine is healthy, having good recent reproduction, potential for regeneration, and age class distribution. There are 2 main factors critical to the maintenance of the health of this valuable stand which should be kept in mind with any management consideration and in the development plans for the surrounding area. Increased visitor pressure, especially on the steep slopes, will increase the potential for erosion and decrease hemlock regeneration. Secondly, special attention should be paid to the small stream in the bottom of the ravine. This stream influences the moisture regime which is critical in the establishment of hemlock seedlings. Hopefully this study will serve to provide baseline data to which future work can be compared and changes detected.

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