Evaluation of growth changes, related to a lake level increase, on near-lake hardwood trees at the Goodyear Swamp Sanctuary

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ABSTRACT

In 1955, Otsego Lake, Otsego County, New York, was artificially raised by 18 inches (45.7 cm). In order to ascertain any effects on growth of near-shore trees, incremental cores were taken from upland and lowland black cherry (*Prunus serotina*), white ash (*Fraxinus americana*), American basswood (*Tilia americana*) and sugar maple (*Acer saccharum*) trees in the Goodyear Swamp Sanctuary. Data showed no significant difference between either the upland sampled trees (which would not have been affected by lake level) and lowland sampled trees (which may have been affected by lake level change), or between any years within the growth of a given species, regardless of proximity to the time of dam construction. The data are inconclusive in its representation of growth because of the small sample size for each species and because of some dendrological factors that were either intentionally or unintentionally omitted from the study.

INTRODUCTION

Tree growth is affected by many different environmental factors including rainfall, soil conditions, age of the tree, and organism crowding (Grissino-Mayer, 2002). Changes in water level are an additional factor that may affect the annual growth of trees that are in close proximity to a standing body of water. In 1955, the Village of Cooperstown, on the shores of Otsego Lake, added eighteen-inch flashboards to the top of the dam at the south end of the lake where it feeds into the Susquehanna River (USACE, 1981). The purpose of this construction was to increase the head pressure, facilitating water withdraw by the village. The Goodyear Swamp Sanctuary, at the northern end of the lake on the western shore, was affected by the raised water levels. Because of the raised level, some hardwood trees that were surrounding the marsh area had their root systems inundated with water. Other trees that were at a higher elevation were simply exposed to a higher groundwater level without having complete root inundation. When tree root systems are saturated with water, growth of many upland species is inhibited. The excessive amount of water, instead of facilitating growth, interferes with the absorption of oxygen and other nutrients from the soil (Tiaz, 1998). This type of distress would be, theoretically, illustrated in the growth rings of the lowland trees. Also, the annual rings should show a significant decrease in growth in the years immediately after the date of the raised water level. By taking incremental bores of lowland trees and comparing the growth from one year to the next, and comparing that growth pattern with those of upland trees of the same species, one could potentially observe the changes in growth due to the raised water level.

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METHODS

Trees were sampled from the north side of the Boundary Trail and the Main Walkway, beyond the Glimmerglass Overlook (Figure 1). To provide an initial survey of lowland tree species, collection was first performed in a species-blind manner. Trees whose girth indicated that they may have been growing through the time of dam construction (about 50 years old or more) and were at a lowland position were marked with surveyor's tape for increment boring, and ordered with no regard to their species (as illustrated in Figure 2). After all of the trees were marked, each one was keyed out to species and recorded along with the diameter at breast height (DBH) and the elevation above the water level. Each tree was then sampled using a 5 mm increment borer. Three upland trees were then selected from each species, with attention paid to girth and elevation (they had to be on or above a distinct upslope on the site to be considered upland). These trees were marked with surveyor's tape, and their DBH and elevation were recorded. Cores were sampled from these upland trees as well.

All cores were then stained with an oil based wood stain to increase the visual contrast between the growth rings then allowed to dry for two to three days. Using a dissecting microscope, the individual rings were marked with an indentation using an insect mounting pin. Every fifth pin mark was highlighted using a blue China Marker, and every tenth pin mark was highlighted using a red China Marker for ease in ring counting and growth measurement. A calibrated ocular micrometer was used to measure the distances between the marked rings. Measurements were taken to a twentieth of a millimeter.

A repeated analysis of variance (rmANOVA), with an alpha value of 0.05, was used to determine whether or not there was a statistically significant difference between the growth patterns of the lowland and upland trees of the same species. A year-by-year analysis of variance (ANOVA), also with an alpha value of 0.05, was used to determine whether or not there were statistically significant differences in growth years related to the date of dam construction.

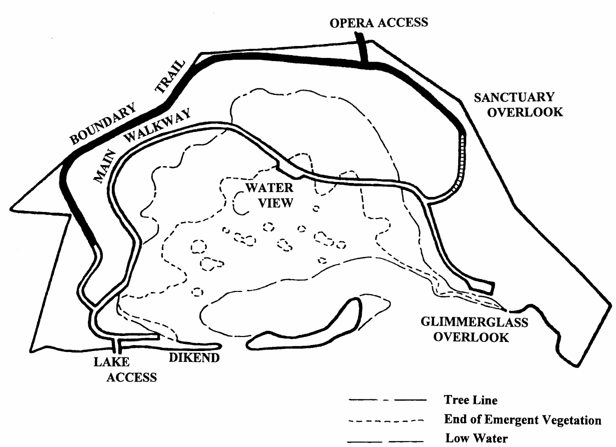

Figure 1. Goodyear Swamp Sanctuary, Otsego County, NY.

RESULTS

Table 1 lists the field label (sample number) for each tree sampled, the species, the diameter at breast height (DBH) and the elevation above lake level.

Position	Sample #	Species	DBH(cm)	Elevation above water(cm)
Lowland	1	Cherry	32.9	50
Lowland	2	American basswood	31.9	60
Lowland	3	Sugar maple	21.7	80
Lowland	4	Sugar maple	38.4	121
Lowland	5	White ash	23.3	101
Lowland	6	White ash	24.3	80
Lowland	7	White ash	21.0	78
Lowland	9	White ash	26.5	40
Lowland	10	American basswood	26.4	76
Lowland	11	White ash	29.3	76
Lowland	12	American basswood	21.8	116
Lowland	13	Sugar maple	40.1	127
Lowland	14	Cherry	20.5	109
Lowland	15	Sugar maple	40.7	119
Lowland	16	Cherry	20.9	207
Upland	U1	Cherry	32.3	213
Upland	U2	Cherry	21.7	210
Upland	U3	Cherry	17.8	811
Upland	U4	White ash	30.2	601
Upland	U5	White ash	30.5	360
Upland	U6	White ash	25.6	523
Upland	U7	American basswood	22.7	1009
Upland	U8	American basswood	50.5	288
Upland	U9	American basswood	27.2	380
Upland	U10	Sugar maple	43.1	380
Upland	U11	Sugar maple	40.4	453
Upland	U12	Sugar maple	21.6	484

Table 1. Collection data for sampled trees, including position, marking number, species, diameter at breast height (DBH) in centimeters, and elevation above water in centimeters

The annual ring growth from year to year ranged from tenths of a millimeter to almost five millimeters. The variation of growth from one year to the next was sometimes extensive, and there were often large ranges of growth between a single year's growth of trees of the same species. Because there were multiple years being studied within a single sampled tree, a repeated measure analysis of variance was the most appropriate statistical mechanism for evaluating whether or not there existed a significant difference between the mean growths of the upland and lowland trees of the same species. Significant difference is illustrated by a p-value, which ranges between 0 and 1. The p-value is a discussion of the probability that the two mean values being compared are equal, and the difference evidenced between them is simply a factor of the sample size involved. The closer the p-value is to 1, the greater the certainty that the means are the same. The closer the p-value is to 0, the greater the certainty that the means are different. The threshold at which one can state significant difference is called the alpha value. The most commonly used alpha value for the determination for significant difference is 0.05 (meaning that there is a 5% chance that the means are the same, in spite of the calculations), and if the p-value is greater than 0.05 one cannot conclude significant difference. With these parameters, significant difference was only shown between the upland and lowland samples of white ash (Table 2).

Species	Alpha value	rmANOVA p-value
Cherry	0.05	0.982
White ash	0.05	<0.001
American basswood	0.05	0.066
Sugar maple	0.05	1.000

Table 2. Repeated measure analysis of variance values for difference between upland and lowland trees of the same species

Similarly, with an alpha value of 0.05 as a measure of significance for the ANOVA from year to year in each species for both upland and lowland trees, with the exception of white ash, no significant difference was shown between any years of growth measured regardless of species or position (Table 3).

Species	Position	Alpha value	ANOVA P-value
Cherry	Lowland	0.05	0.5319
Cherry	Upland	0.05	0.8631
White ash	Lowland	0.05	0.4858
White ash	Upland	0.05	0.0019
American basswood	Lowland	0.05	0.7168
American basswood	Upland	0.05	0.8121
Sugar maple	Lowland	0.05	0.5671
Sugar maple	Upland	0.05	0.1064

Table 3. Analysis of variance values for significant difference between the years of growth within the species at one position

Figures 2-9 illustrate the mean growth from year to year of each species at each position, with error bars indicating standard deviation from the mean. Although not definitive, the extent of the standard deviations from the mean data points indicates the disparate nature of the data for that particular year, even within a single species. It is this wide variation that causes difficulties in drawing conclusions about year-by-year difference.

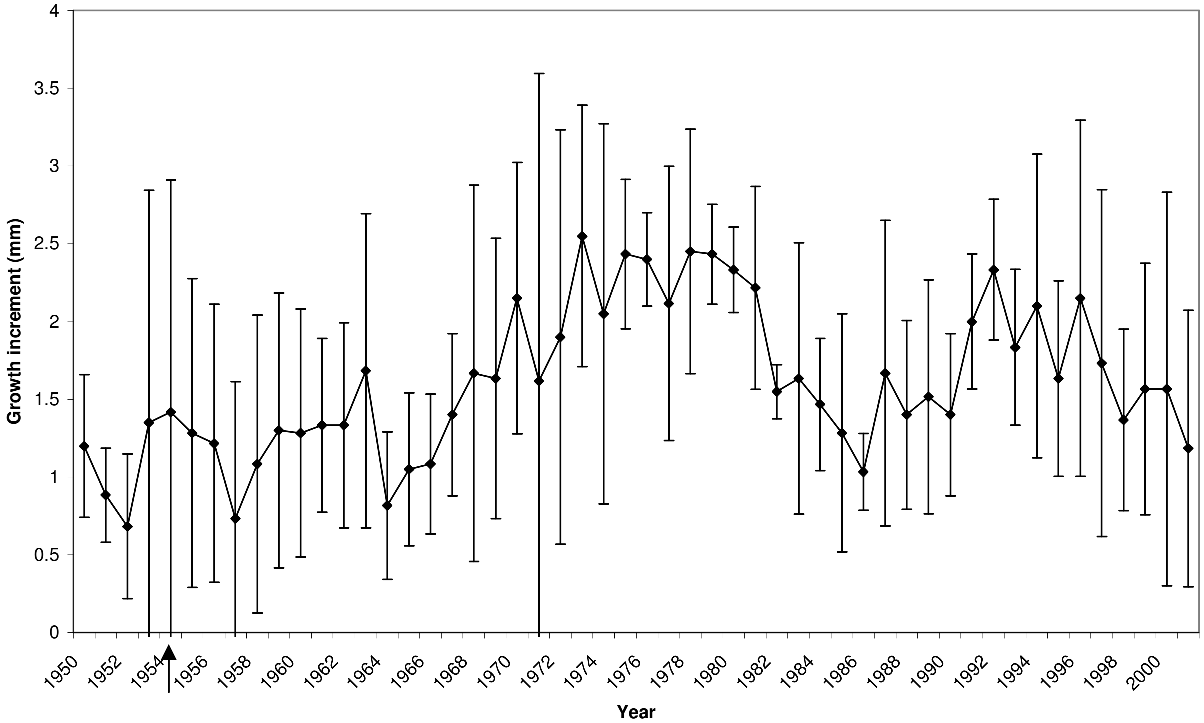

Figure 2. Mean annual lowland cherry growth with standard deviation error bars. Arrow indicates year of lake level increase.

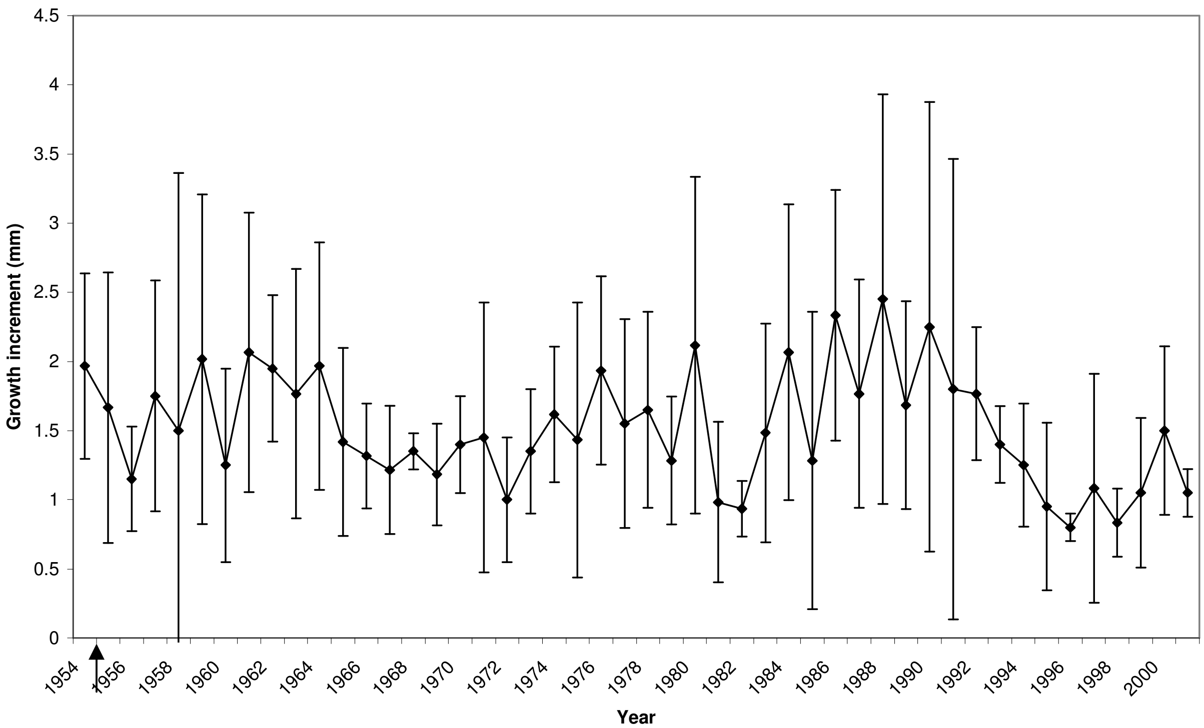

Figure 3. Mean annual upland cherry growth with standard deviation error bars. Arrow indicates year of lake level increase.

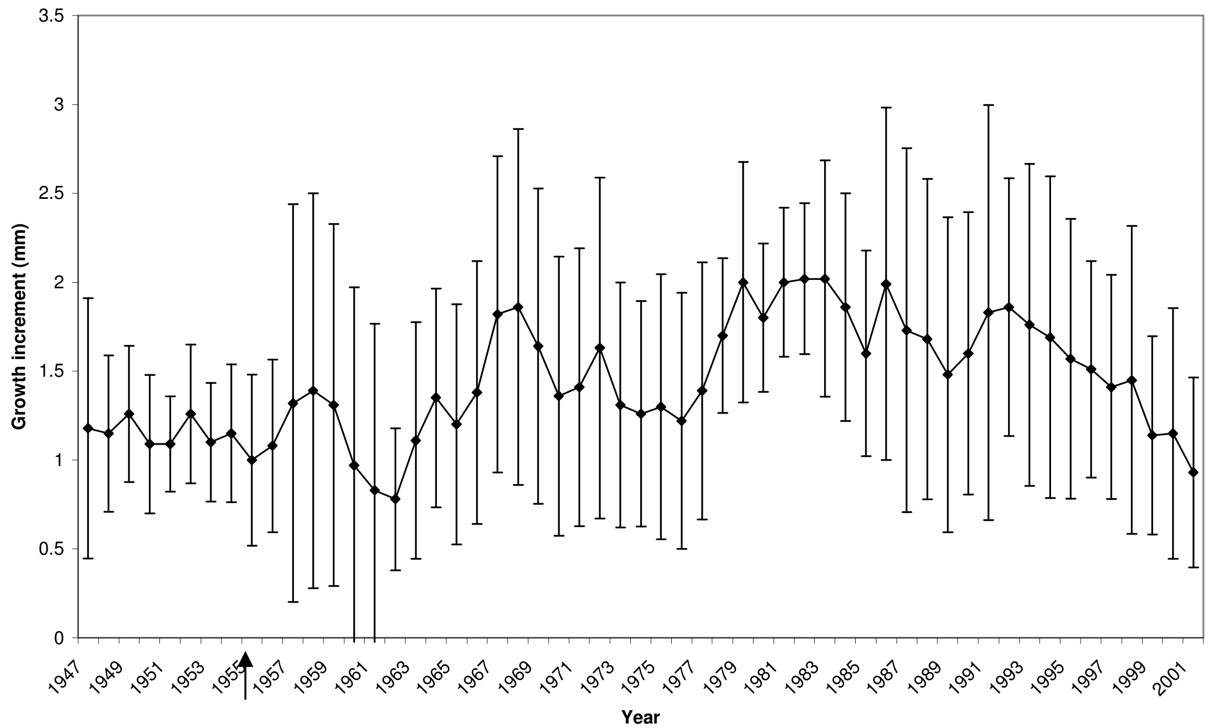

Figure 4. Mean annual lowland white ash growth with standard deviation error bars. Arrow indicates year of lake level increase.

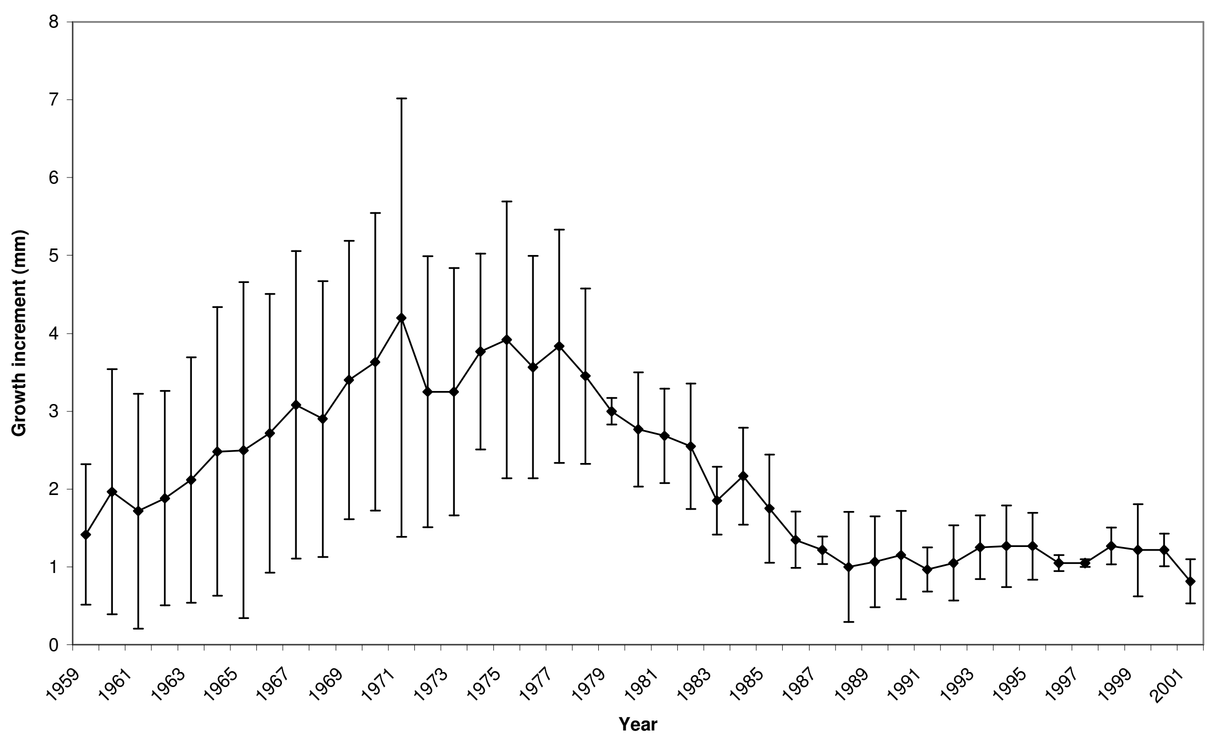

Figure 5. Mean annual upland white ash growth with standard deviation error bars

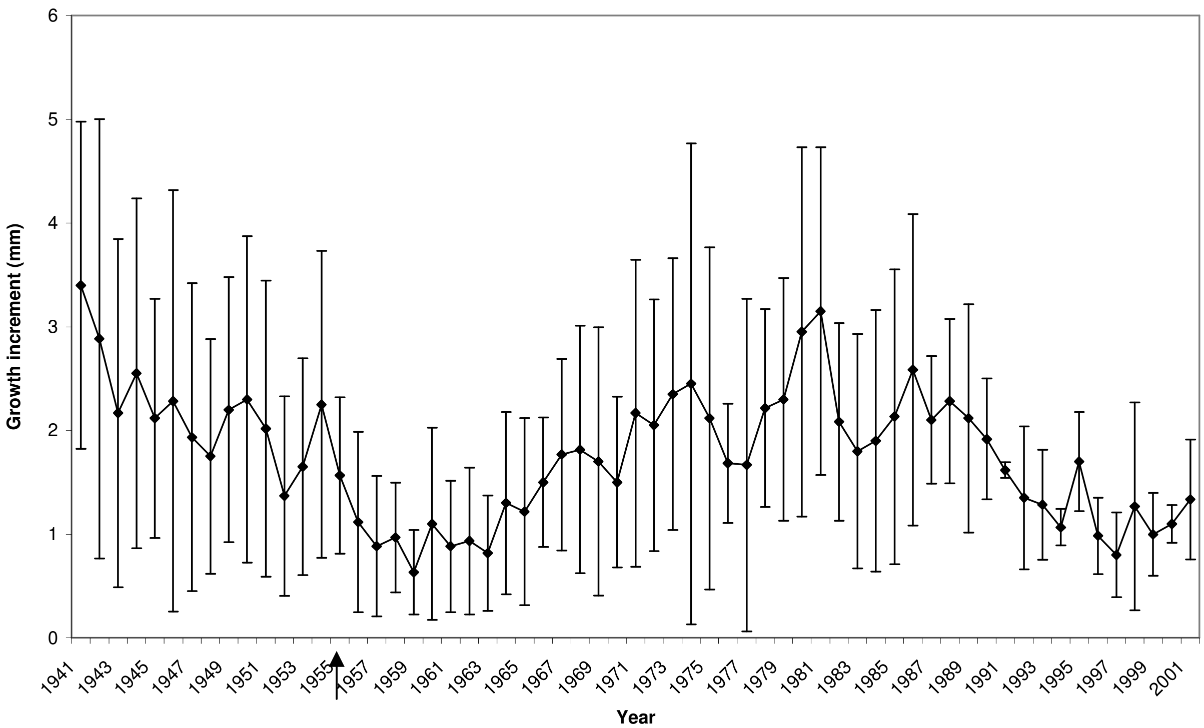

Figure 6. Mean annual lowland american basswood growth with standard deviation error bars. Arrow indicates year of lake level increase

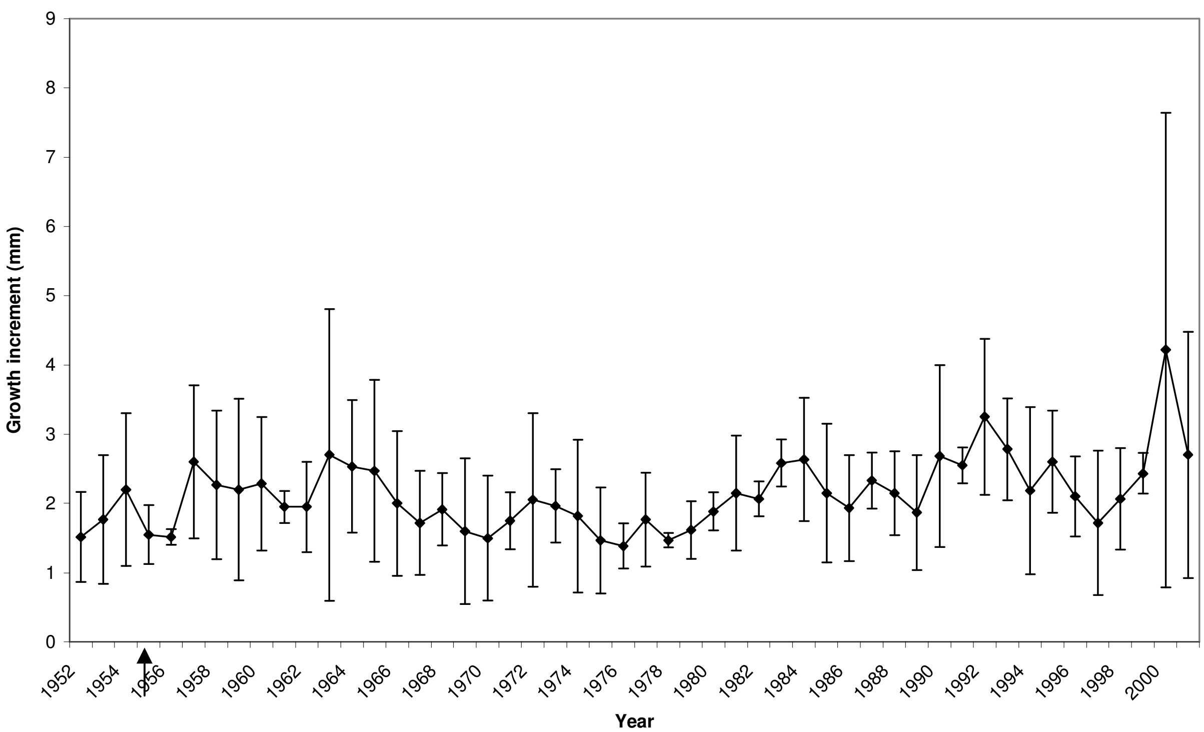

Figure 7. Mean annual upland American basswood growth with standard deviation error bars. Arrow indicates year of lake level increase.

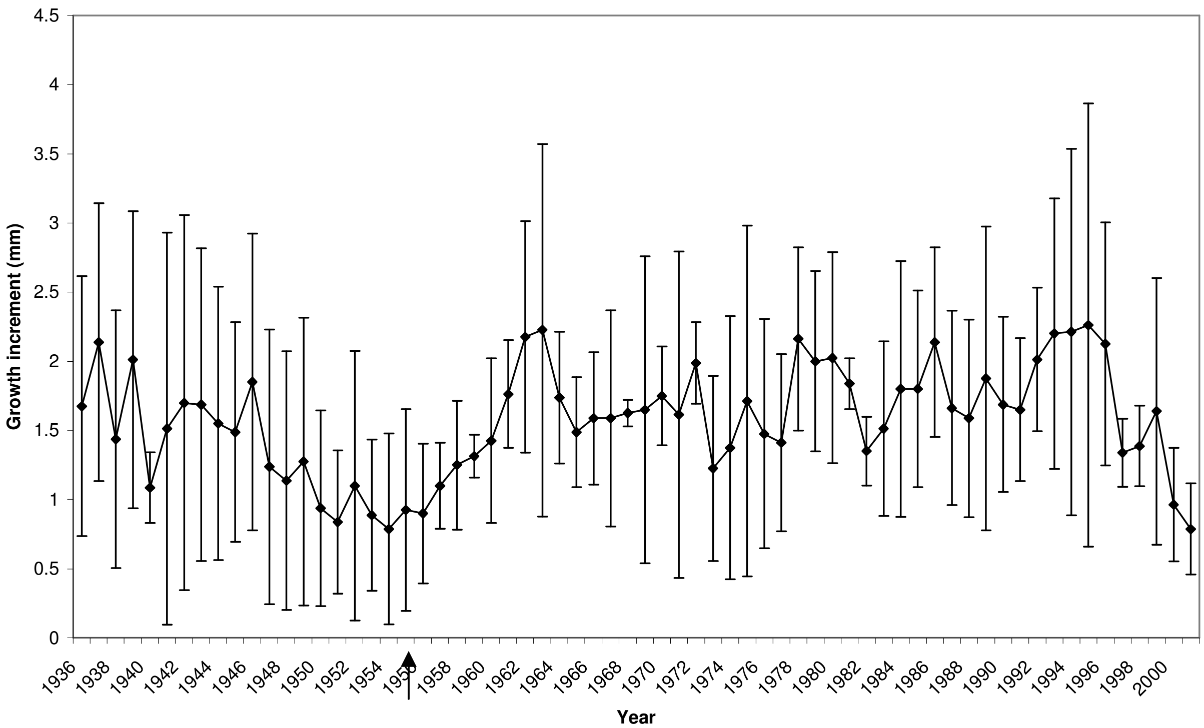

Figure 8. Mean annual lowland sugar maple growth with standard deviation error bars. Arrow indicates year of lake level increase.

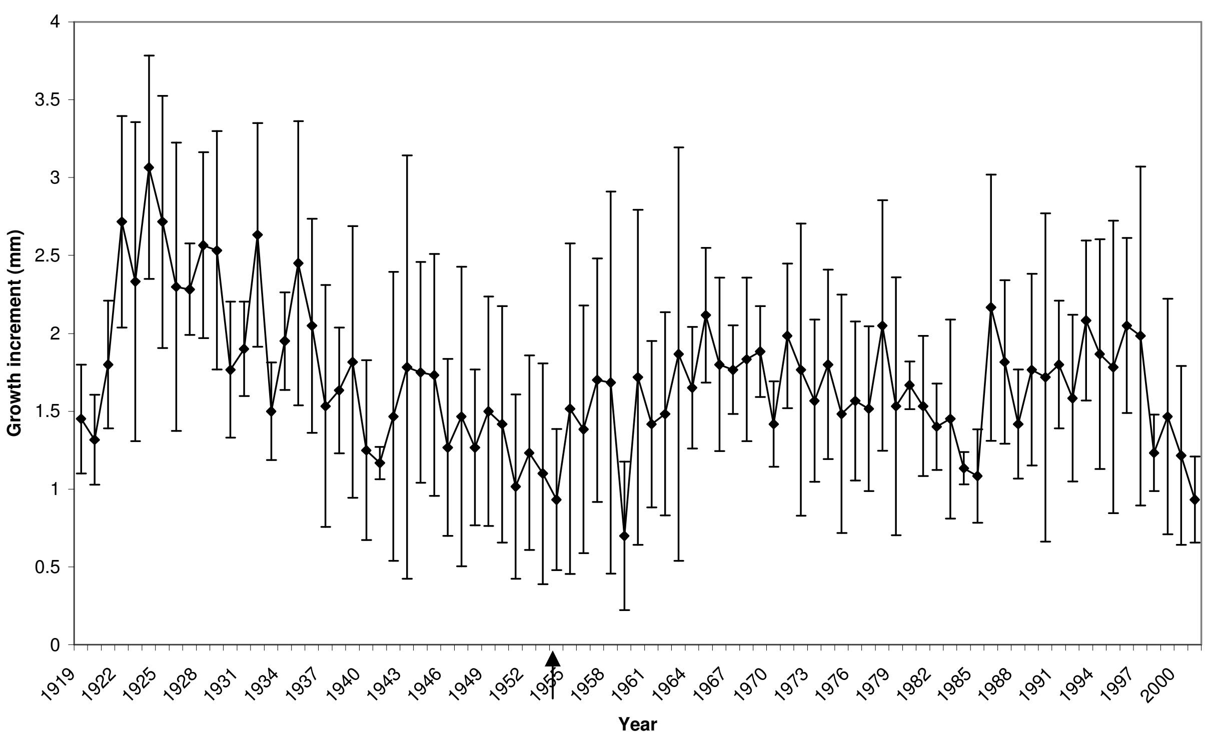

Figure 9. Mean annual upland sugar maple growth with standard deviation error bars. Arrow indicates year of lake level increase.

DISCUSSION

The lack of conclusive significant differences within this study is initially surprising, but examination of the procedure and the sampling situation makes it a bit more predictable. The lowland regions had a vast quantity of white ash, and comparatively few examples of other species. This made equal sampling of each species difficult. Similarly, the upland hardwood stand was dominated by sugar maple with few other species. Red maple, for example, was completely unrepresented in the upland sampling area, even though there were sufficient sampling opportunities for it within the lowland region. It was, therefore, excluded from comparative calculation altogether.

There were also factors that are essential principles of dendrology that were not included in calculation because of either negligence or the nature of the sampling. One key factor that was not taken into account was age-related growth patterns. Trees grow at different rates at different times in their lifespan, and this effect would mask the impact of an event such as the dam construction in this case. Because it is very rare for an increment bore to perfectly intersect the pith of a given sampled tree, it is almost impossible to determine the specific age of a particular tree for any growth year. Without the age of the tree for the year of growth in question, one would be hard pressed to implement age-related growth patterns. Another key factor that was not taken into account was the density of tree growth around any specific sampled tree. Because tree growth density can affect competition for resources and, thereby, resultant growth potential for a given tree, it is important when comparing growth rates. Unfortunately, this factor was considered too late for it to be integrated into this study.

Annual lake levels before and shortly after the time of the dam's construction were unavailable, which made it difficult to take the effects of varying lake level into account. In the course of examining an incomplete record of the lake levels (Hollis, 1999), it was shown that lake levels varied as much as 24 inches within the course of a given year, and it is possible that a permanent 18 inch change would not be great enough to affect trees that were already well adapted to moist soils.

Simply because the sampled trees did not illustrate a significant difference related to the construction of the dam at the end of the lake, or even between the trees in the lowland area near the lakeshore and in the upland area farther from the lake's effects, does not mean that there are no indications of impact. The stumps of dead trees observed throughout the Goodyear Swamp Sanctuary illustrate some sort of impact, as well as the presence of multiple stems exhibited by the red maples present near the lakeshore. Red maples respond to water-distressed circumstances by generating multiple root crown growth (Bennett-O'Dea, 2002). Some cores were taken of the red maples, and many of the basal sprouts were a little less than 50 years old. It is possible that these sprouts were a result of the permanently increased lake level.

Although there was not consistent evidence of this, there were several individual lowland trees that illustrated the exact pattern hypothesized. There was a sharp decrease in the distance between the annual growth rings shortly after 1955, and it remained low for about ten years afterward. After that ten year period of decreased growth, the distance between the growth rings began to increase again. This resurgence of growth was probably the tree adapting to its new situation, and possibly expending more energy in the growth of upland or surface roots. This sort of adaptation would have been necessary for the plants sampled to survive as they did. Unfortunately the mean annual growth of all the samples does not illustrate this effectively.

Future study may be desirable by examining the annual rings of trees growing in other areas around the lake, possibly closer to the augmented dam. It may also be worthwhile to do a lake-wide survey of one or two ubiquitous species, taking into account such things as tree growth density, elevation, DBH, and soil type.

In the year-by-year analysis of variance for the means of each species of tree within a single location, only the upland white ash showed any significant difference between any years. The only dates which showed significant difference in their means were 1959, 1960, 1961, 1962, 1964, 1965, 1966, and 1967 against 2000. The earlier dates showed significantly greater growth than the later date. If this significant difference of means from one year to the next is indicative of some environmental change through that time, it is probably not associated with the dam construction for a variety of reasons. One is that the trees are significantly upland, and with only an 18 inch water level change from the construction, the probability of a significant impact from it is minimal. Another is that the data do not even reach back to the date of the dam construction, so it is impossible to draw a correlation between the growth effect and the construction. One might wish to hypothesize another impact upon these upland trees that would create such a significant reaction and then perform further studies on this particular tree sample.

CONCLUSION

Overall, the lack of definitive results calls for additional and more widespread study rather than the abandonment of hypotheses. If, as a result of further study, there is still no quantitative indication of distress upon lowland trees as a result of change in lake level similar to what occurred in 1955, one would then be urged to consider why the trees sampled showed so little impact. It is possible that there are other, unaccounted for variables that would decrease the impact of the varying lake level upon lowland trees.

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