HARVARD UNIVERSITY
HARVARD FOREST
PETERSHAM, MASSACHUSETTS
U.S.A. 01366

AREA CODE 617
724-3302

April 27, 1987

Mr. Wilbur F. LaPage, Director
Division of Parks and Recreation
Department of Resources & Econ. Development
P.O. Box 856
105 Loudon Road
Concord, New Hampshire 03301

Dear Wilbur,

The last time David Foster, ecologist on our staff, took a group of students to our Pisgah tract he found one of your cards on the vehicle. Since then he has had a chance to talk with John Twitchell and understands that you are in the process of promulgating new rules for the use of the park.

When the state forest began acquiring the park land Ted Natti and I talked over the Harvard holding and its use. We acquired the land back in the 1920's before the New England Box Co. started to cut over the rest of their holdings. The funds to buy it were raised with the understanding that the 20-acre tract would be set up as a study area to watch the development of an old-growth forest undisturbed by man. This purpose seemed so compatible with the park concept that Ted decided the tract should be left in our hands. So far some excellent studies have been done that considerably improve our understanding of long-term forest development. An example is enclosed and we will send you new publications as they appear. These may be of some help to your people who are interested in natural development in the park.

Currently, Dr. Foster is using the area for studies of succession and Peter Schoonmaker is doing a doctoral thesis on the land. With all this, it has been very helpful to be able to have a key and drive as far as the lake. I realize that this may cause a problem if you decide to keep motors out of the park.

I wonder if it would help to allow motor access only for research work? We would be happy to notify the superintendent before each visit. I think it would also save confusion among visitors and local residents if we had some official sign, like "Harvard Forest Research Vehicle," to display in the vehicle any time it is in the park. I hope it will be possible to continue to drive part way to our tract as that will save a good deal of research time.

Sorry to cause you problems and hope that otherwise all is going well.

Sincerely yours,

Ernest M. Gould, Jr.
Assistant Director

Encl.
bf

FOREST RECONSTRUCTION in a Hemlock stand, Southwest New Hampshire

Nathan Faulkner
Biology 204
Prof. David Foster
5/14/87

Abstract

The effects of major disturbance on the pattern of canopy growth and composition were studied in a hemlock (*Tsuga canadensis*) stand in the Pisgah State Park in New Hampshire. Large numbers of overstory trees consisting primarily of white pine (*Pinus strobus*) were blown down in the 1938 hurricane in the direction of the prevailing winds (to the northwest). Other trees were damaged or killed but not knocked over in the hurricane, but subsequently fell over in random directions. The hurricane essentially wiped out the overstory, knocking over large volumes of trees. The hemlock that had made up the understory were released, but usually not immediately after the hurricane, and now the canopy is almost pure hemlock.

Introduction

The role of disturbance in stand formation and composition is a question that has been debated extensively. Studies (Henry and Swan, 1974; Foster, 1987) show the importance of repeated windstorms and fires in vegetation dynamics. Disturbance is the crucial factor in controlling the growth of the forest. Other studies conclude that while disturbance may be important for certain regions, large areas can remain intact for centuries and eventually reaching the steady-state level (Bormann and Likens, 1979).

Two models of stand development dominate the descriptions of the patterns of stand growth and composition. The even-aged, single canopy model is applied to those stands which form after a single major disturbance that eliminates the original canopy (Kelty, 1986). The model holds that trees of similar age continually segregate into different crown classes in the canopy. This is an ongoing process that leads to greater differentiation with increasing stand age. Overstory trees dominate resource recruitment and tend to exclude trees lower in the canopy. This model implies the prediction that stand development will follow the pattern of differentiation, and upper canopy trees will continue to dominate (Kelty, 1986).

The other model posits that stand formation is the result of small canopy disturbances. Small, even-aged aggregations establish in response to these small scale disturbances, and these stands mix throughout the forest to comprise a mosaically structured unit. The canopy of this sort of stand is considered irregular, and crown classes can only be designated within each even-aged aggregation, not for the stand as a whole. As the size of the disturbance increases this model merges with the other (Kelty, 1986).

Study Area

The study area is situated in the Pisgah State Park in Winchester, southwestern New Hampshire (see Map 1). The Harvard Tract in Pisgah is composed of a number of small, roughly parallel, north-south running valleys and rises. It is an excellent site on which to study forest reconstruction because the tract has never been disturbed by human activity and has been the subject of numerous rigorous studies since its purchase in the 1920's. The overstory and understory of our site is now dominated almost entirely by hemlock (*Tsuga canadensis*), with a few beech (*Fagus grandifolia*), and white birch (*Betula papyrifera*), and some very large standing white pine (*Pinus strobus*) that were not removed in the 1938 hurricane, along with some dead snags that have not yet fallen.

Materials and Methods

After a brief period of entitation a site was subjectively chosen on the crest of one of the rises. A 20x20 meter plot was set up in order to evaluate hurricane damage, and largely within that an 8x8m plot was established in which to core trees. The direction of the felled trees (n=24) was calculated using a compass. The lengths and diameters at the base were also measured for volumetric calculations. Trees in the 8x8 plot (n=21) were cored for later analysis and the dbh for each tree was taken. Species of both standing and fallen trees were noted. Cores were examined in the laboratory under a dissecting microscope. Ages and growth rates were calculated from the rings. The beech core was dyed to facilitate ring analysis.

Results

The 20 trees that were blown over were pointed between north and west, with peak in the northwesterly direction (Figure 1, 2). The four broken trees did not exhibit any pattern in the direction of breakage. The volume of downed trees was calculated on the basis of a parabolic relationship v=1/2*(base area)*(length). The total volume was 365 m^3 ha^{-1}. The volume of trees that were blown over was 271.5 m^3 ha^{-1}.

The ages of the cored trees ranged from 40 for the youngest hemlock to greater than 250 for a pine too large to measure with our core. The oldest hemlock was 143 years old, and a beech tree was aged at 97. Establishment patterns show peaks in 1845-50, around 1875, 1890, and 1900-15 (Figure 3, 4). The dbh ranged from 3.1 cm on a hemlock of unknown age (the core was well off the center; it was at least 74 years old) to 32.6 cm on the 143 year old hemlock. The large pine had a dbh of 64.1 cm.

Years of release, or in one case establishment, closest to the 1938 hurricane can be found in Figure 5. Of the thirteen trees released after the hurricane ten had been released before 1942, with the remaining three being released in 1942, 1944, 1949, and one tree establishing in 1947. Rates were calculated for three hemlocks (Figure 6), and diameter increment is shown for pine, hemlock, and beech in Figure 7.

Discussion

What is most noticable now is the distinct lack of pine in any of the canopy layers. Because several seed trees remained following the hurricane it might be expected that pine would be dominant among seedlings. The major establishment period for pine was in the mid to late seventeenth century, with a primary episode following a large fire that occurred in 1665 (Foster, 1987). Presumably this fire devastated the forest and provided ample growing space for pine initiation. The hurricane, however, did not destroy all the forest, only the upper canopy on some sites. Windstorms do not cause the same sort of blanket damage expected in a fire, but instead most substantially affect exposed areas such as hilltops, southeast slopes, and northwest lakeshores (Foster, 1987). The hurricane left enough of the understory to exclude the initiation of pine, and this understory (on our site hemlock) has grown to replace pine as the dominant canopy species.

The effect of the hurricane on the understory hemlock was to release them from a suppressed state of growth. The trees did not exhibit release immediately following the disturbance, but often remained suppressed for several years after the hurricane. This is similar to what was observed by Lorimer (1985). He attributes this lag time to readjustment to new conditions. Foster (1987) observes an initial decline in growth in overstory trees followed by a release in disturbance related events. Foster attributes the decline in growth to damage caused by the disturbance, and following a period of readjustment to damage the trees begin to increase growth rates in response to higher levels of light, water, and nutrients. This model currently seems most applicable to our observations. It seems unusual that trees would take years to react to favorable growing conditions. A simple explanation for this interval to respond is that the remaining trees suffered some damage from the large numbers of large trees that fell in the hurricane. This is supported by the fact that trees in close proximity often released in the same year, but in different years from trees farther away. While this was only a cursory observation made in data analysis it may merit further examination.

The stand is now characterized by an uneven-aged structure. This observation might lead one to think that it has grown as the result of small disturbances creating highly localized gaps in the canopy that are exploited by a relatively few individuals. Even-aged stands are considered strong evidence for past catastrophic disturbances. The presence of hemlock, a shade tolerant species, changes the scenario. A disturbance that removes the overstory, but leaves much of the understory intact will develop into a broadly uneven-aged stand (Lorimer, 1985). The oldest trees are the largest ones that survived the disturbance, and within this group there can be large variation.

Conclusion

Disturbance is an important factor controlling stand dynamics on our central New England site. The present structure is the result of the 1938 hurricane. Large volumes of overstory pine were blown down and the understory hemlock were released following a short interval to become the dominant canopy species. Pre-hurricane composition was largely influenced by fire, storm, and pathogens (Henry and Swan, 1974; Foster, 1987). Further study on a much broader scale will give invaluable information concering the role of disturbance in stand dynamics.

Literature Cited

Bormann, F. H. and G. E. Likens. 1979. Pattern and Process in a Forested Ecosystem. Springer-Verlag, New York.

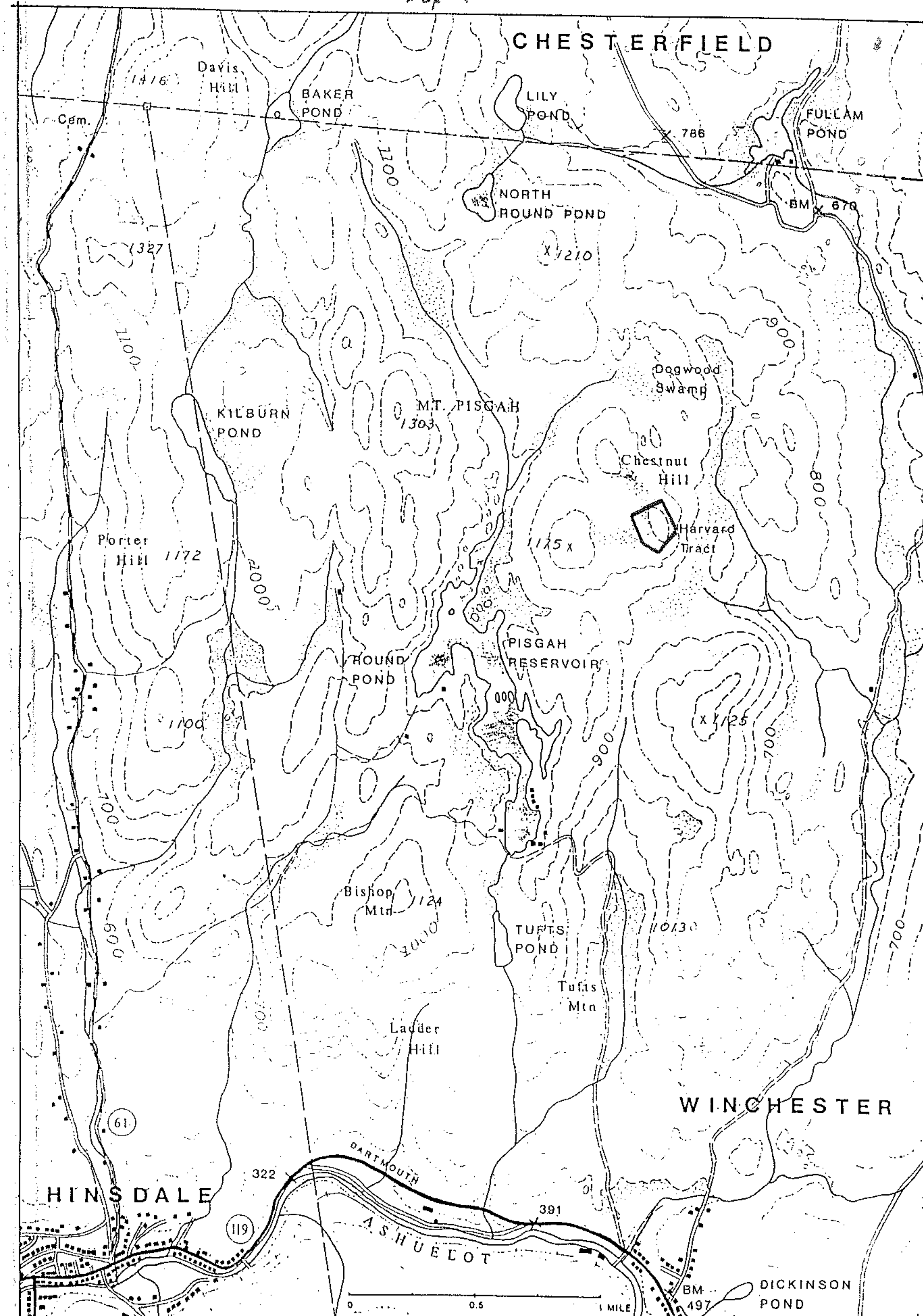
Foster, D. R. 1987. Disturbance history, community organization, and vegetation dynamics of the old-growth Pisgah forest, southwestern New Hampshire, USA. Revised manuscript.

Henry, J. D. and J. M. A. Swan. 1974. Reconstructing forest history from live and dead plant material--an approach to the study of succession in S. W. New Hampshire. Ecology. 55: 772-783.

Kelty, M. J. 1986. Development patterns in two hemlock-hardwood stands in southern New England. Can. J. For. Res. 16: 885-891.

Lorimer, C. G. 1985. Methodological considerations in the analysis of forest disturbance history. Can. J. For> Res. 15: 200-213.

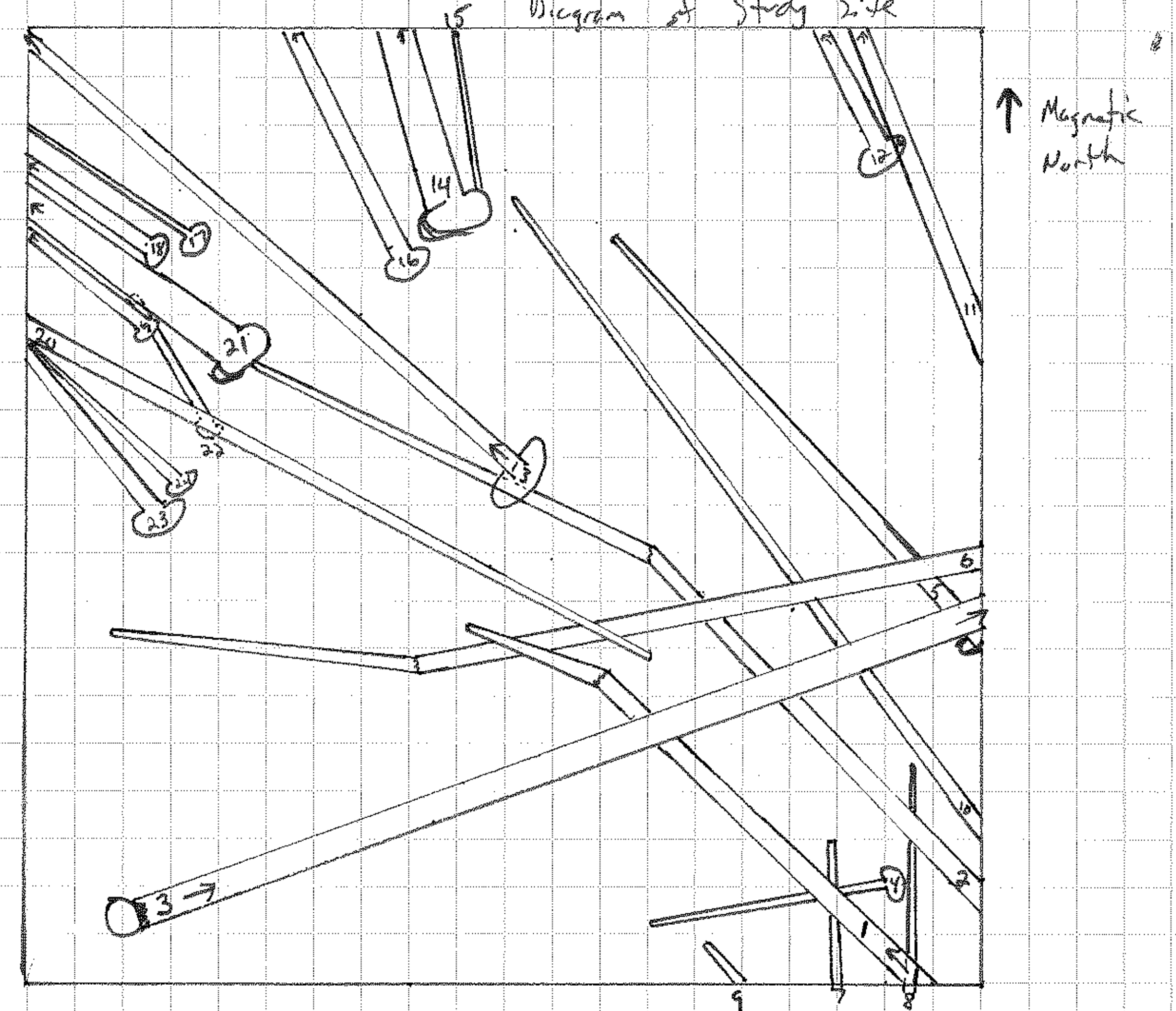
Map 1


CHESTERFIELD
Davis Hill
1416
BAKER POND
LILY POND
FULLAM POND
786
Cem.
NORTH ROUND POND
BM 670
1327
1210
1100
900
Dogwood Swamp
KILBURN POND
MT. PISGAH
1303
Chestnut Hill
Harvard Tract
800
Porter Hill
1172
1175
1000
PISGAH RESERVOIR
ROUND POND
1125
700
Bishop Mtn
1124
600
TUFTS POND
Tufts Mtn
Ladder Hill
WINCHESTER
61
HINSDALE
322
DARTMOUTH
391
ASHUELOT
119
BM 497
DICKINSON POND
0
0.5
1 MILE

Orientation of Fallen Trees

Figure I

Diagram of Study Site



1) d = .4m pine
h = 12.5m 318° blown

2) d = .5 pine
h = 19.4 337° blown

3) d = .08 pine
h = 13.9 70° broken

4) d = .17 hemlock
h = 5.1 261° broken

5) d = .46 pine
h = 11.5 328° blown

6) d = .5 pine
h = 18.4 262° blown

7) d = .17 unknown
h = 3.2 358° blown

8) d = .14 hemlock
h = 4.7 0° blown

9) d = .27 unknown
h ≈ [illegible] 322° blown

10) d = .35 pine
h = 16.7 323° blown

11) d = .40 pine
h = 7.0 341° blown

12) d = .36 pine
h = 2.7 333° blown

13) d = .36 pine
h = 14.1 310° blown

14) d = .78 pine
h = 3.6 343° blown

15) d = .14 birch
h = 3.2 352° broken

16) d = .39 pine
h = 5.5 337° blown

17) d = .16 unknown
h = 3.8 303° blown

18) d = .30 pine
h = 3.1 305° blown

19) d = .42 pine
h = 3.1 305° blown

20) d = .44 pine
h = 14.9 115° broken

21) d = .82 pine
h = 5.0 305° blown

22) d = .32 unknown
h = 2.8 330° blown

23) d = .30 unknown
h = 4.3 330 blown

24) d = .23 birch
h = 3.6 310° blown

$V = \frac{1}{2}$ (area of base) × height

V_{total} = 14.6 m^3

= 365 m^3/ha

V_{blown} = 271.5

Orientation of Fallen Trees

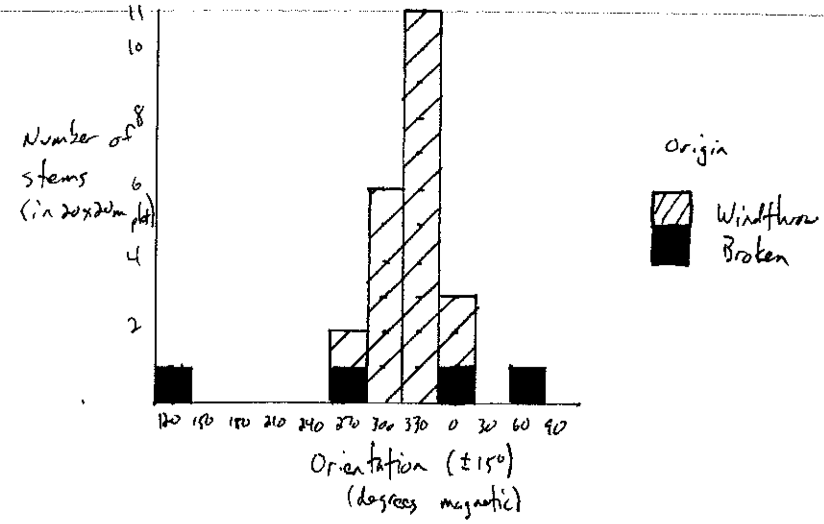
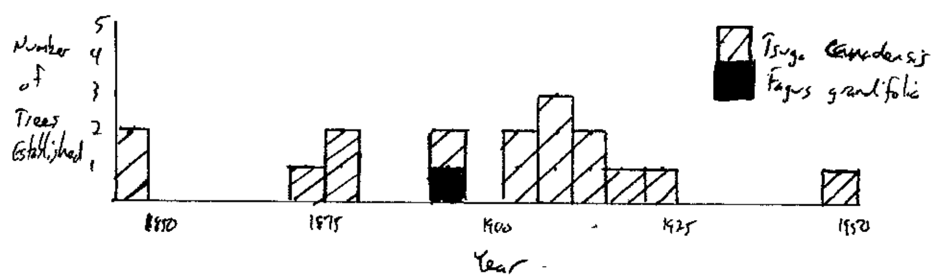


Figure 2

Figure 3
Years of Establishment



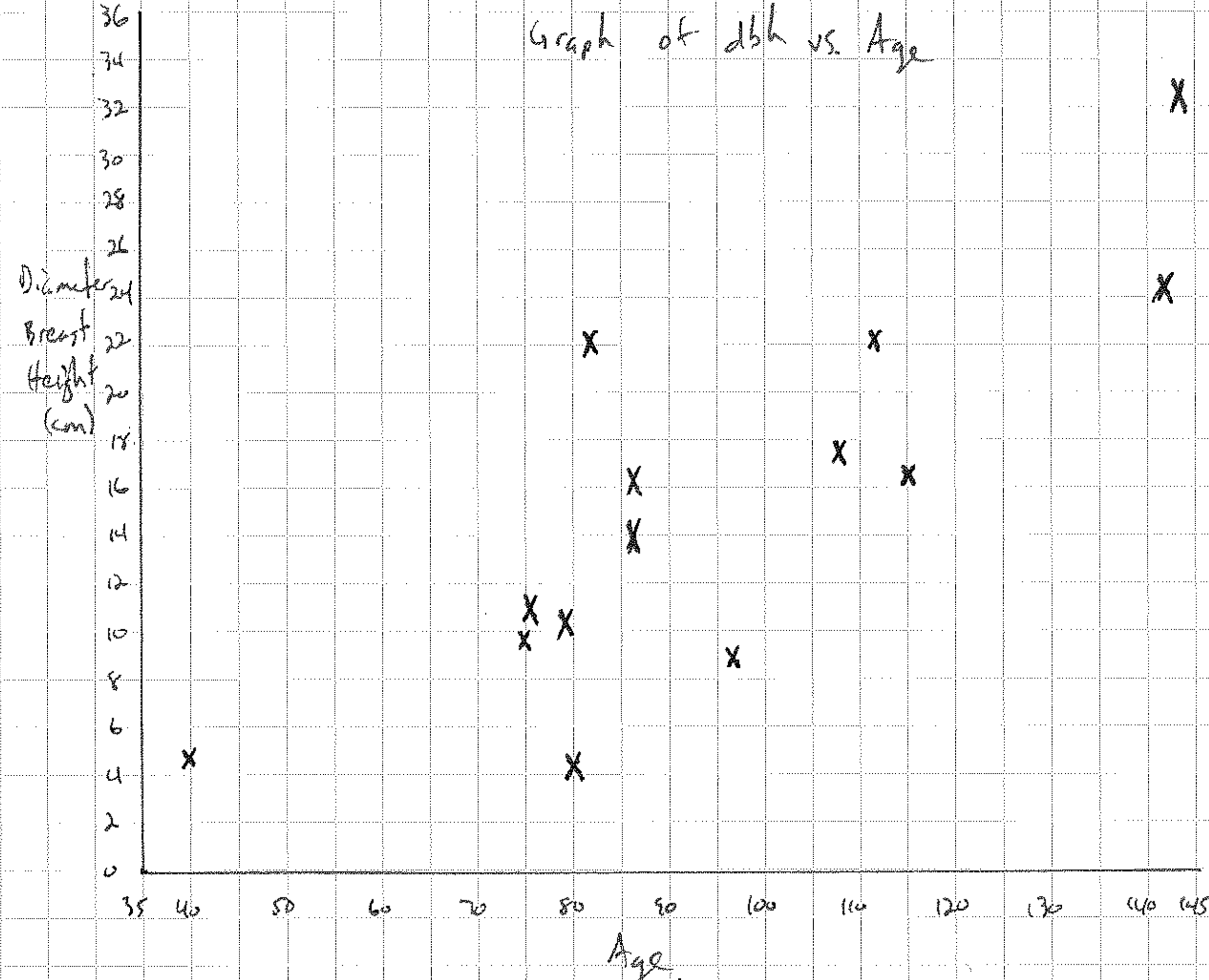


Figure 4

Figure 5
Years of Release

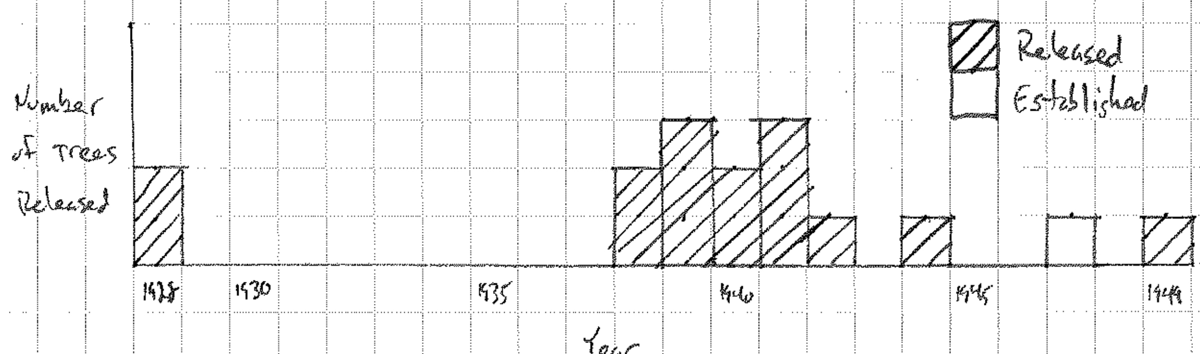
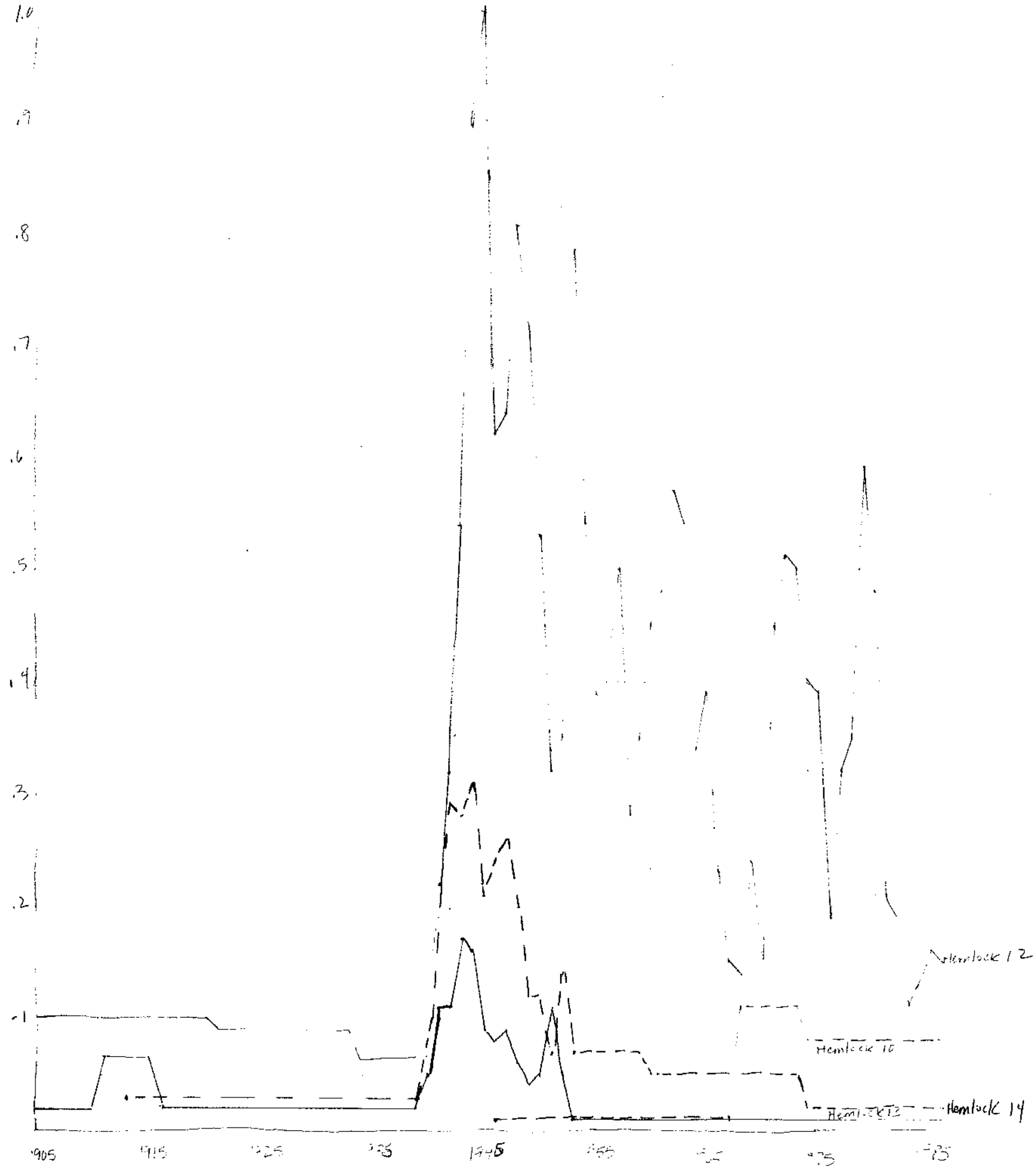


Figure 6
Diameter Growth Rates for 3 Hemlock



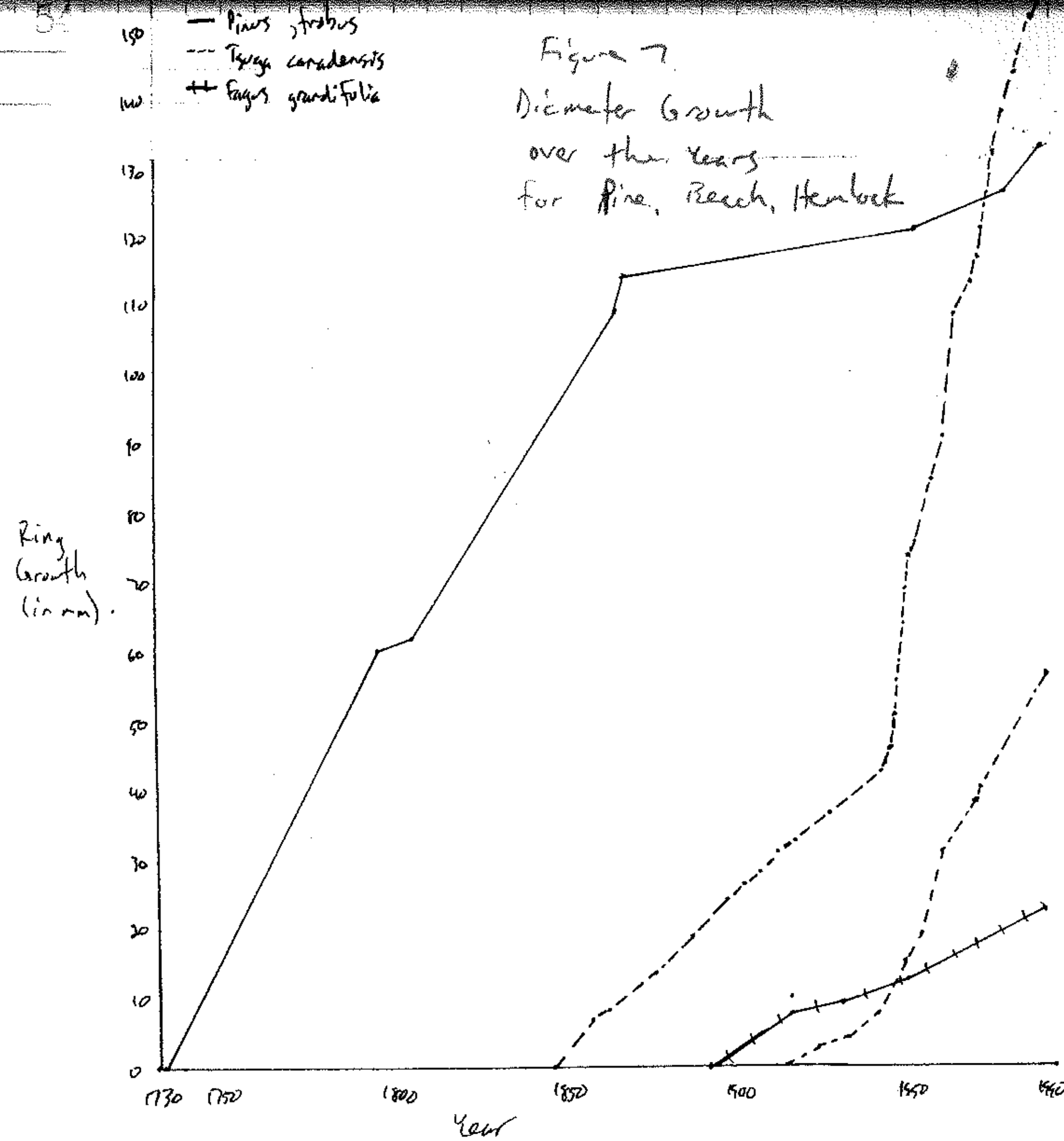


Figure 7
Diameter Growth over the Years for Pine, Beech, Hemlock

Yin Lam
Biology 204
5/13/87
Professor Foster

The Reconstruction of Recent Disturbance History in the Pisgah State Forest

Introduction:

Henry and Swan's reconstruction of several hundred years of history in the Pisgah Forest using live and dead plant material represents one of the most important ecological studies of its time. Their analysis was confined to a one-tenth-acre square within the 20-acre Harvard Tract. This study attempts to complement Henry and Swan's research, particularly with respect to the most recent disturbances, by examining another section of the tract. After species identification, the orientation of fallen trees was determined and their basal area estimated. A group of live trees were cored to determine age and growth patterns. The final results of the study provides insights into the adaptive strategy of various tree species, particularly hemlock, and their reaction to disturbance.

Materials and Methods:

This study was conducted in late April by the Biology 204 class in the Pisgah Forest of southwestern New Hampshire. The study site was consisted of a 20m x 20m plot in the Harvard Tract chosen due to its flat topography and abundance of hemlock. A smaller 8m x 8m plot was constructed in the southwest corner of the main site. In the smaller plot, all trees of reasonable diameter (> 0.05 m dbh) were cored 1 foot from their base until a continuous core containing the center was obtained in each case. One of the larger trees was cored at a height of 2m. Species and diameter at breast height was recorded for all sampled trees, and the position of the trees on the plot was mapped. On the main study site, all recognizable fallen trees were examined. The orientation, length, diameter, and condition (uprooted or broken) of the trunks was noted and their positions mapped. In the general area of the Pisgah Forest, we noticed certain characteristics of disturbance history, such as fire scars, porcupine damage, remnants of chestnut, and the regeneration of black birch on uprooted trunks.

In the laboratory, all the core samples were analyzed carefully. The rings on each core were counted carefully several times for a reasonable estimation of age. The widths of the rings were measured to determine changes in growth rate during the trees' life history.

Results:

Our data is presented in graph form in the addenda. The histograms representing the orientation of fallen trees and years of establishment show diagnostic patterns in both cases. Analysis of age versus diameter shows only a vague relationship, but the graphs illustrating growth patterns are distinctly correlated at various time periods.

Discussion:

Our results are fairly consistent with the interpretation of the local forest history made by Henry and Swan. Our analysis of the fallen trees suggests a forest dominated by large pine with hemlock and some hardwoods in the understory. Henry and Swan (1974) estimated that hemlock was more abundant than pine but that pine probably dominated the canopy. This would explain its overrepresentation in the windthrown sample.

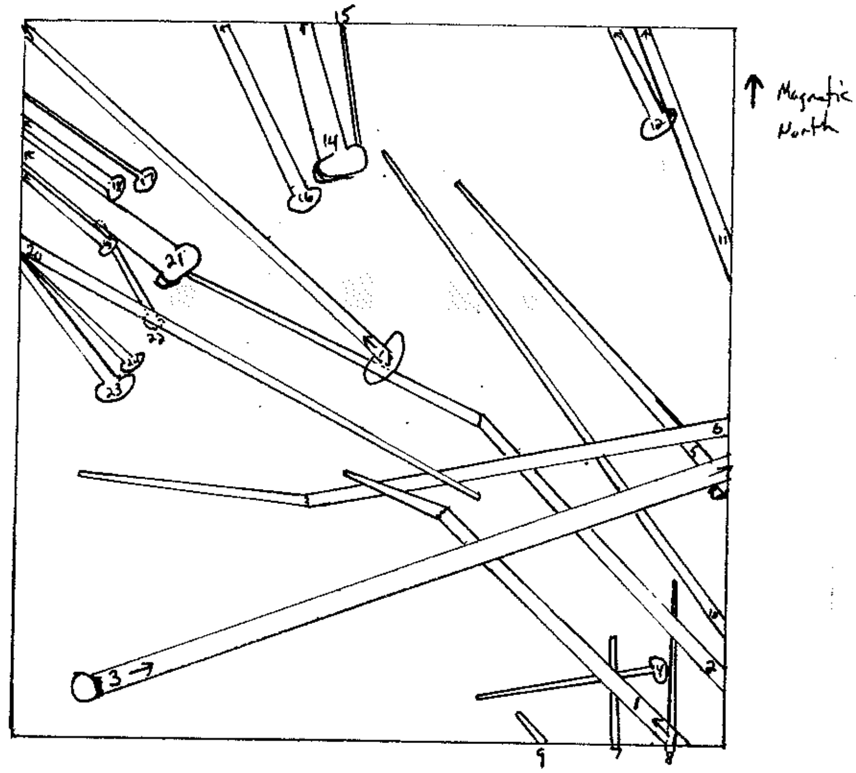
The uprooted trunks were all oriented in a northwesterly direction (approximately 300°-330°) while the broken trunks were randomly oriented. This data agrees with observations made by Foster (1987), and suggests a severe disturbance by wind, most likely the 1938 hurricane. Pine dominates the fallen sample, reflecting its dominance in height and high basal area in the pre-hurricane forest.

Examination of the growth rates of the sampled trees indicate a significant impact from the 1938 hurricane, especially among hemlock. Analysis of the establishment of the studied hemlock shows no distinct pattern or relation to disturbance, but the small sample size renders close examination infeasible. The patterns of growth, however, show significant reaction to the hurricane disturbance. The rate of growth among the hemlocks increased drastically after the 1938 hurricane without a 5-10 year transition period of slower growth (Mansour, cited in Foster 1987). There was no significant correlation with any other disturbance event.

The composition of the forest is probably as diagnostic of its disturbance history as the growth patterns of its inclusive trees. On the plot we examined. Hemlock was the dominant species in all size classes. There was a single dominant pine in the canopy, but there were no pine saplings in the area. The success of the shade-tolerant hemlock compared with the shade-intolerant pine indicates a disturbance that affected the canopy while leaving much of the understory intact. Pine generates successfully only in open conditions, i.e. after fire or cultivation, but cannot compete with understory hemlocks and hardwoods.

Conclusion:

Our study of the Pisgah Forest confirmed previous observations concerning recent disturbance history but provides little additional information on the effects of such disturbances.



1) d = .4m pine
h = 12.5m 318° blown

2) d = .5 pine
h = 19.4 317° blown

3) d = .08 pine
h = 13.9 70° broken

4) d = .17 hemlock
h = 5.1 260° broken

5) d = .46 pine
h = 11.5 309° blown

6) d = .5 pine
h = 18.4 263° blown

7) d = .17 unknown
h = 3.2 358° blown

8) d = .14 hemlock
h = 4.7 0° blown

9) d = .23 unknown
h = 6.1 322° blown

10) d = .35 pine
h = 16.7 323° blown

11) d = .40 pine
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h = 5.5 337° blown

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h = 3.8 303° blown

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20) d = .44 pine
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21) d = .82 pine
h = 5.0 305° blown

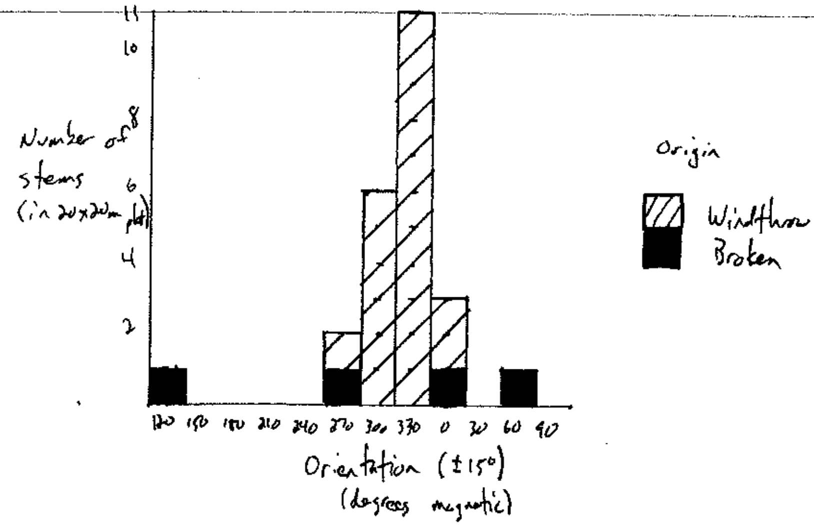
22) d = .32 unknown
h = 2.8 330° blown

23) d = .30 unknown
h = 4.7 330 blown

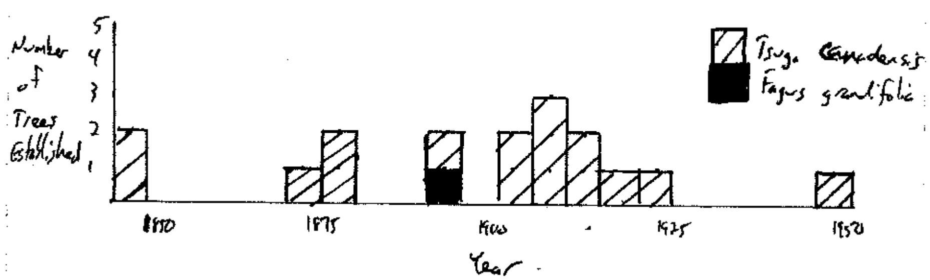
24) d = .23 birch
h = 3.6 310° blown

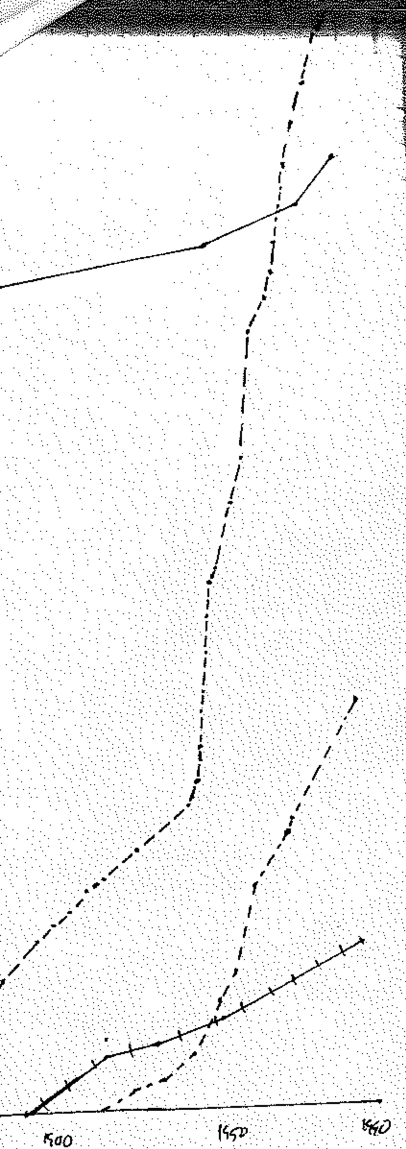
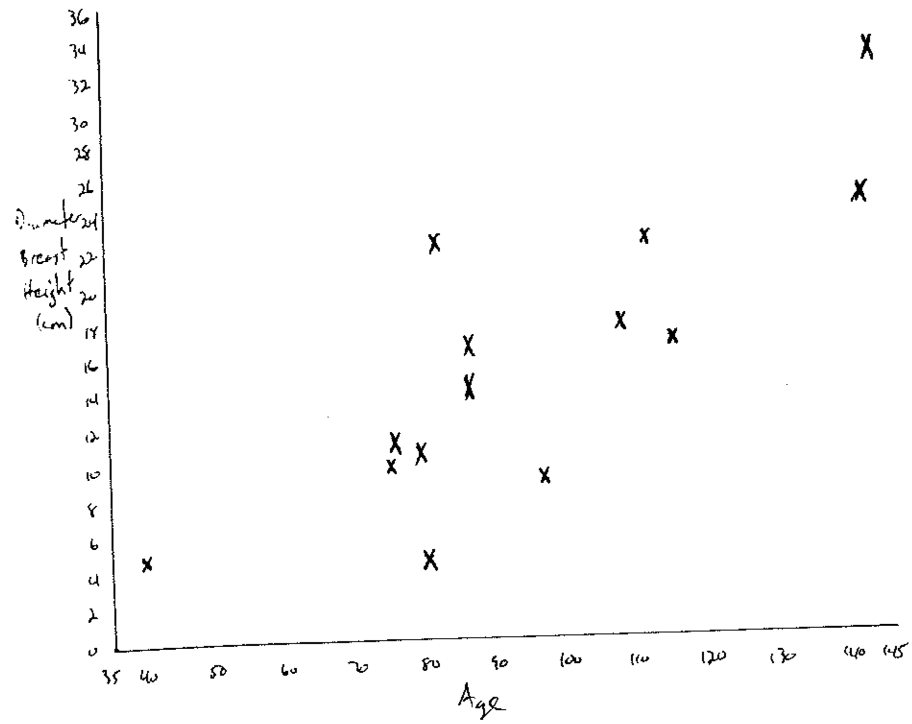
$V = \frac{1}{2}$ (area at base) × height

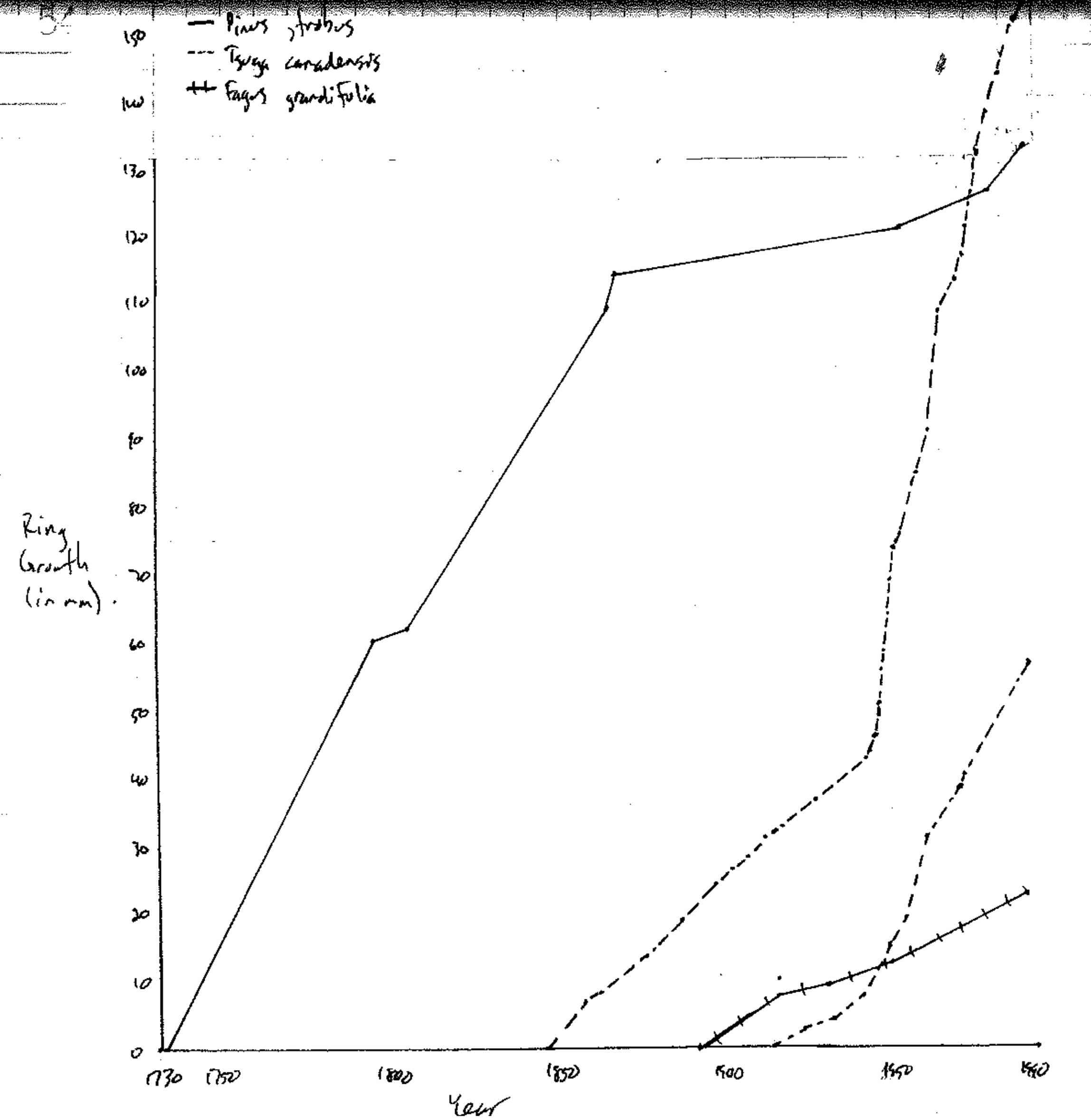
Orientation of Fallen Trees



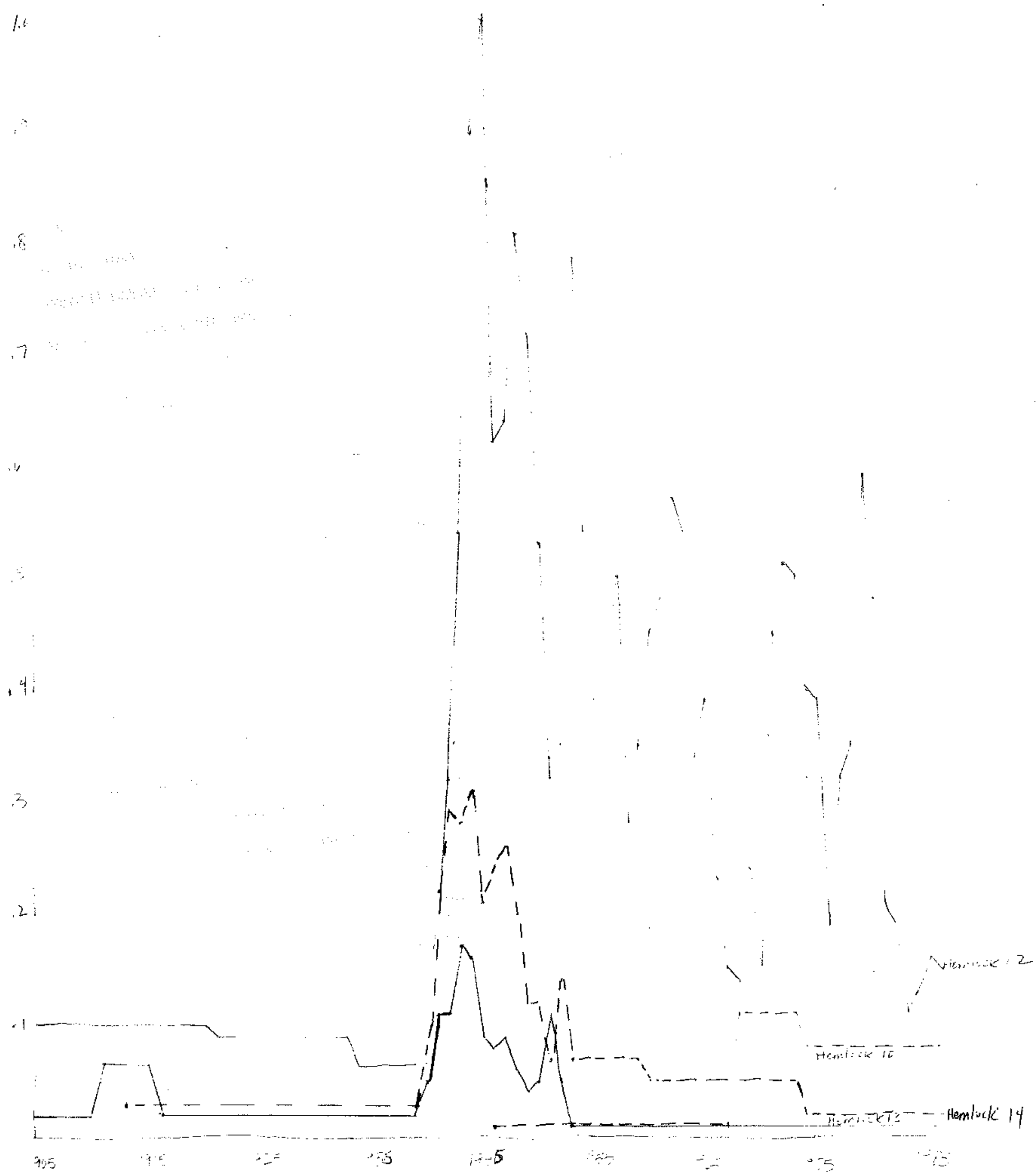
Years of Establishment





Diameter Breast Height (cm)
Age



— Pinus strobus
--- Tsuga canadensis
++ Fagus grandifolia
Ring Growth (in mm).
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
1730
1750
1800
1850
1900
1950
1980
Year


Hemlock 14

THE EFFECTS OF THE 1938 HURRICANE ON A HEMLOCK STAND IN THE OLD-GROWTH FOREST AT PISGAH, NEW HAMPSHIRE

KATHLEEN TREVER

BIO 204, Prof. David Foster

MAY 1987

Please return to:
(Via University Mail)
Geology Dept., Undergraduate
24 Oxford St.

In September 1938 a hurricane severely damaged much of southern and central New England. The area encompassed by this study, the Harvard Tract of the Pisgah Forest, located near the town of Winchester in southwestern New Hampshire, felt the full effects of the storm, with up to 70% of the standing volume of wood blown down (D. Foster, to Bio 204). Exposed southeastern slopes and northwestern lakeshores were the hardest hit. Sharp discontinuities in the extent of damage also occur along natural physiographic breaks, such as ridges, hilltops, and lake shores (Foster 1987--unpublished manuscript).

Prior to the hurricane, this region was dominated by hemlock and white pine, the latter seeding in after a fire in 1635 (D. Foster, to Bio 204). After the storm, these few large conifers, highly susceptible to blowdowns, were replaced by great numbers of saplings and shoots, mostly opportunists such as birches and cherries, with increasing amounts of the slower growing hemlock.

In an earlier study conducted in the Harvard Tract by Henry and Swan (1974), disturbance was concluded to be the most important mediator compositional changes in this forest; autogenic succession was viewed as relatively insignificant. The twenty acre Harvard Tract is one of the rare old growth stands still undisturbed by man in central New England, so it seemed a reasonalbe candidate on which to study the generalized patterns of landscape damage and stand development following a disturbance such as the 1938 hurricane (Foster 1987). Evidence of other disturbances was also apparent in a general survey of the tract; fire scars (from a 1923 fire?), scars left by porcupine damage, and stumps remaining from chestnut salvage and absence of chestnut from the present landscape due to the chestnut blight. The chestnuts in this region were too large to produce new shoots through vegetative reproduction, thus accounting for the total removal of the species (D. Foster to Bio 204).

Windstorms, however, appear to be the disturbances that most strongly affect vegetation patterns in the region (Cline and Spurr 1942, Stephens 1955, Raup 1957, and Bazzaz 1983 in Foster 1987). This study was undertaken to determine the effects of this type of disturbance (in this case the well-documented, both in written records and in photographs, hurricane of 1938) on an old growth forest. The 1938 hurricane provides an analog for structural damage from catastrophic winds that historically affected such old growth forests (e.g. storms in 1635, 1788, 1815) (Foster 1987).

Situated on an exposed hilltop and forested with old white pine and hemlock, the Harvard Tract was especially vulnerable to destruction. The woody debris of the fallen large conifers is still a major structural feature of the landscape (Foster 1987).

A small hemlock stand was chosen as a specific study area, and a 20m. by 20m. plot was erected on a fairly level portion of the stand. The relative positions of downed stems were mapped, as well as their species, orientation, and mode of falling (i.e. broken or tipped-up). A subplot of 8m. by 8m.

was created, and in this area the standing trees were mapped and their species and dbh were noted. Each of the trees in the subplot was cored with an increment corer at approximately one foot from the ground. These cores were brought back to the laboratory for determination of age and growth rate. The bigger trees, such as the old white pine, provided incomplete cores because of their large diameter. Growth rings of the hemlocks were generally easy to analyze under the microscope, but the samples from the white pine and beech in the plot needed to be sanded (and stained in the case of the beech) for proper reading.

The relative location of the downed stems is shown in Figure 1, and as expected, the tip-up stems, immediate results of the storm, have a preferential orientation to the northwest (Figure 2). The broken stems show no such preferred orientation, as their falls would be random in contrast to the tip-ups, which would fall in the direction of the wind. The species of the downed stems illustrate the forest type mentioned earlier--a forest dominated by large white pines, of which only one remains standing in the subplot.

The results of growth rate analysis are also somewhat predictable. The hemlocks and beech exhibit slow, steady growth rates prior to the hurricane, and then show releases (generally after a two or three year delay) after the hurricane with the opening created by the downing of the overstory. Such delays may be caused by injuries sustained in the storm, although this was not obvious in studies of the growth rings, or perhaps by a confinement or hindrance of growth created by the large volume (and upward extent) of downed wood. The one white pine in the sample shows surprisingly little reduction in growth rate after the hurricane, but it, too, shows a subsequent release around 1941 (Figure 3), a release resulting from a decrease in competition with other large conifers. This data is contrary to the expected result: a 5-10 year post-hurricane recovery period of slower growth in overstory trees, followed by growth rates exceeding pre-hurricane levels (Foster 1987).

The other trees in the plot yied results more compatible with previous studies. The diameter of the hemlocks is, as is often the case, not correlatable to their ages (Figure 5), and they show a fairly continuous pattern of establishment (Figure 2a). The growth rates of these shade tolerant trees, along with the beech, are characteristically marked by periods of little growth followed by periods of rapid growth with the creation of openings in the overstory (Figure 4).

The creation of a hemlock stand on this site also indicates something about the nature of the pre-hurricane stand. Hemlocks generally occur in the overstory only if left as residuals following disturbance. A minimum initial height of approximately three meters is necessary to provide a height advantage sufficient to prevent the hemlocks from being overtopped during the rapid initial growth of hardwoods (Kelty 1986). Thus the pre-hurricane understory would have been comprised of relatively tall hemlock saplings.

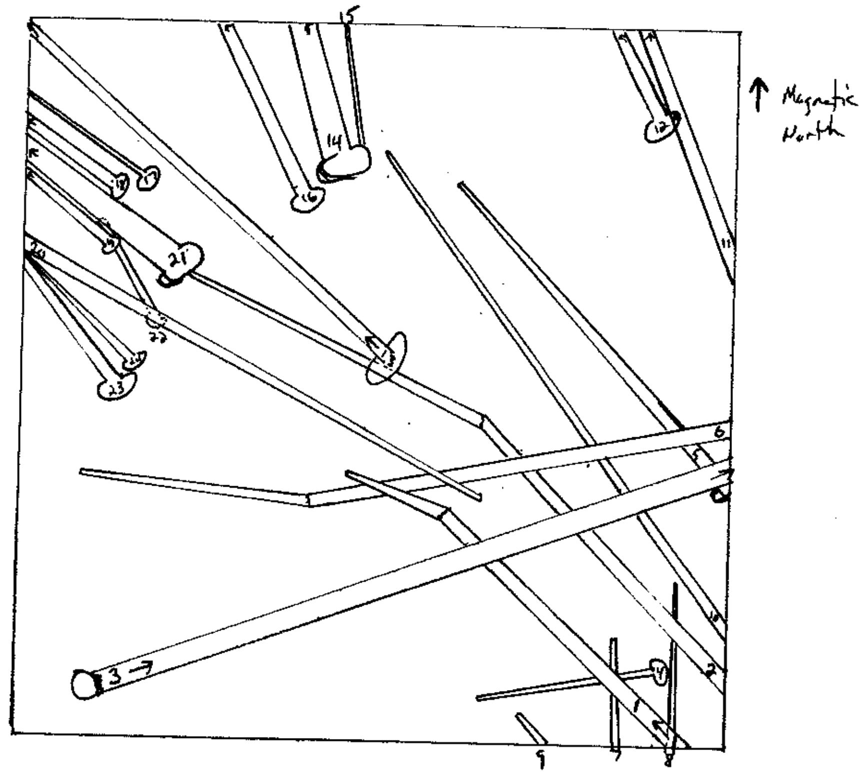
It should also be noted that growth rates are dependent on more than the creation of openings. Climatic variations such as drought, and the proximity of the tree to others also influence growth rates. Growth rate data should therefore be analyzed by taking into account several environmental factors.

The pattern of vegetation development in this hemlock stand following the broad-scale disturbance posed by the hurricane offers a variation on the "typical" pattern in which post-disturbance stand formation begins with the establishment of fast-growing species such as birches and cherries. Hemlock and beech are represented by two groups: those originating before the disturbance (usually establishing following earlier windstorms) which resurge from a suppressed condition after the hurricane, and smaller saplings which established soon after the hurricane (Foster 1987). As discussed previously, shade-tolerant species are usually overtopped by faster-growing hardwoods and remain suppressed until released by subsequent distrubances or until death (Oliver and Stephens 1977; Hibbs 1982, 1983 in Foster 1987). Because the pre-hurricane understory was composed of relatively tall hemlock saplings, the opportunistic hardwoods were given little chance to establish.

The stand thus formed is of comparitively homogeneous composition and at the peak of autogenic succession, as the hemlocks and beeches will be undergrown only by others of their species. The development of a stand following disturbance is therefore dependent of factors such as the composition of the original forest and the differential removal of species and height classes by the disturbance (Foster 1987). The nature of the disturbance is also a major factor in the stand type formed. The present absence of the white pine, for example, is probably due to the absence of fire, as seed sources are still present for regeneration.

The mosaic landscape of the Harvard Tract, composed of such stands of hemlocks and stands of faster-growing hardwoodds, stress the importance of disturbance in the vegetational development of this region. The selective actions of disturbance along exposure gradients, combined with previous stand history and composition at the time of the disturbance and climatic factors, have led to such varied development patterns.

Figure 1: Position of Downed Stems



1) d = .4m pine
h = 12.5m 318° blown

2) d = .5 pine
h = 14.4 387° blown

3) d = .08 pine
h = 13.9 70° broken

4) d = .17 hemlock
h = 5.1 261° broken

5) d = .46 pine
h = 11.5 309° blown

6) d = .5 pine
h = 18.4 263° blown

7) d = .17 unknown
h = 3.2 358° blown

8) d = .14 hemlock
h = 4.7 0° blown

9) d = .27 unknown
h = 6.1 322° blown

10) d = .35 pine
h = 16.7 323° blown

11) d = .40 pine
h = 7.0 341° blown

12) d = .36 pine
h = 2.7 337° blown

13) d = .36 pine
h = 14.1 310° blown

14) d = .78 pine
h = 3.6 343° blown

15) d = .14 birch
h = 3.2 352° broken

16) d = .39 pine
h = 5.5 337° blown

17) d = .16 unknown
h = 3.8 303° blown

18) d = .30 pine
h = 3.1 305° blown

19) d = .42 pine
h = 3.1 305° blown

20) d = .44 pine
h = 14.9 115° broken

21) d = .82 pine
h = 5.0 305° blown

22) d = .72 unknown
h = 2.8 330° blown

23) d = .30 unknown
h = 4.7 330 blown

24) d = .27 birch
h = 3.6 310° blown

$V = \frac{1}{2}$ (area of base) × height

Figure 4.

Annual Growth Rates for Four Hemlocks in Plot, from Origin to Present

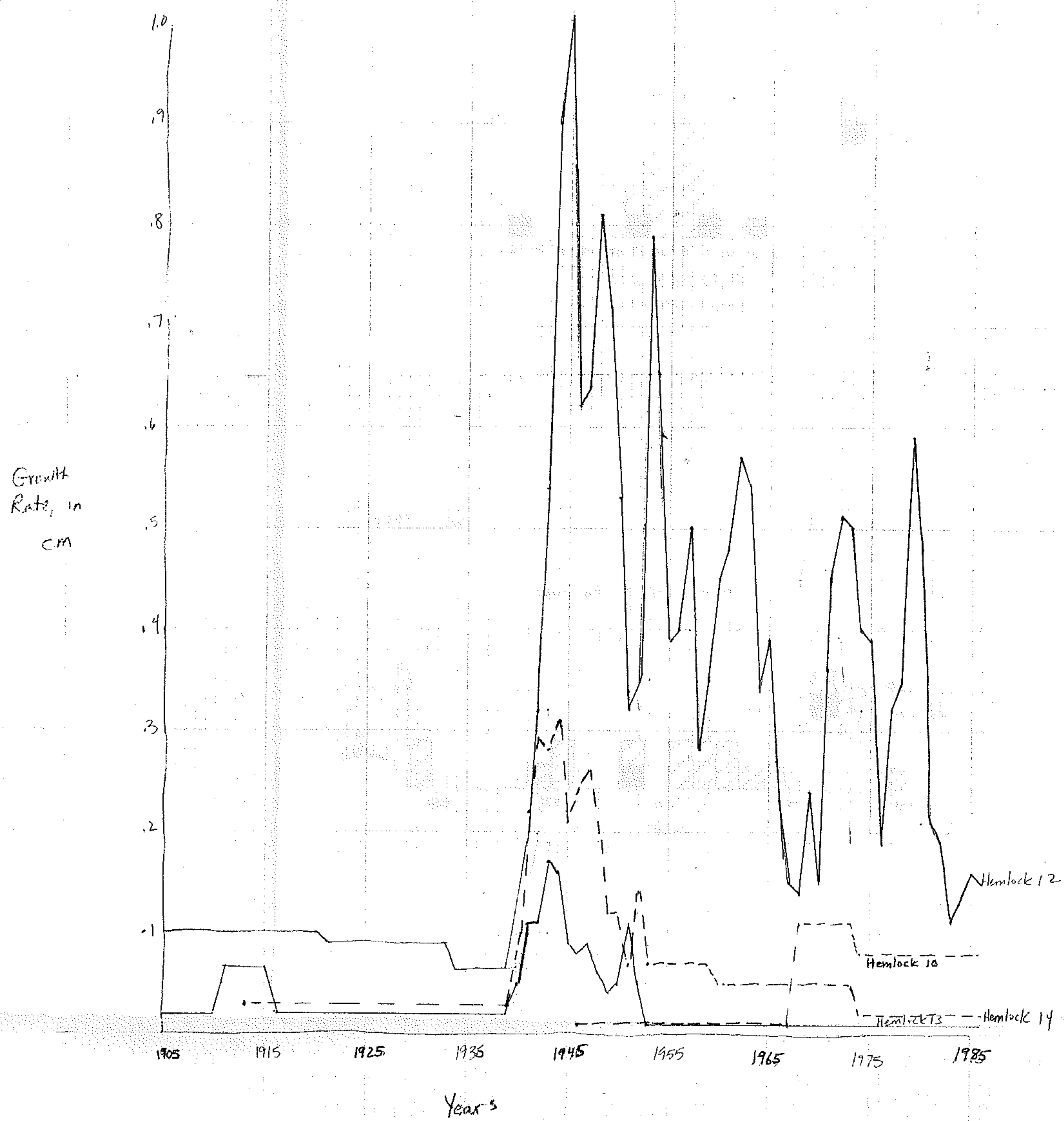


Figure 2 Orientation of Fallen Trees

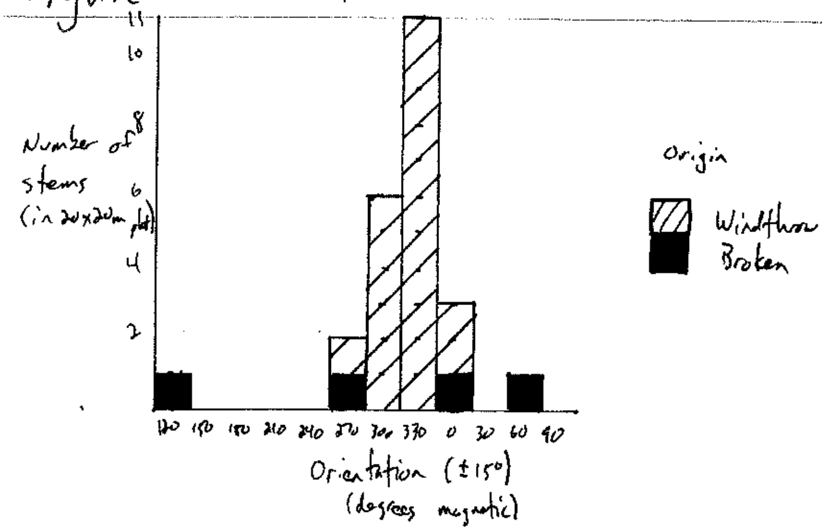
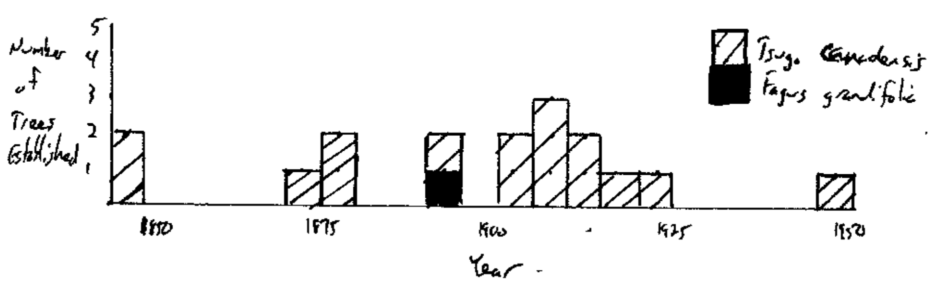
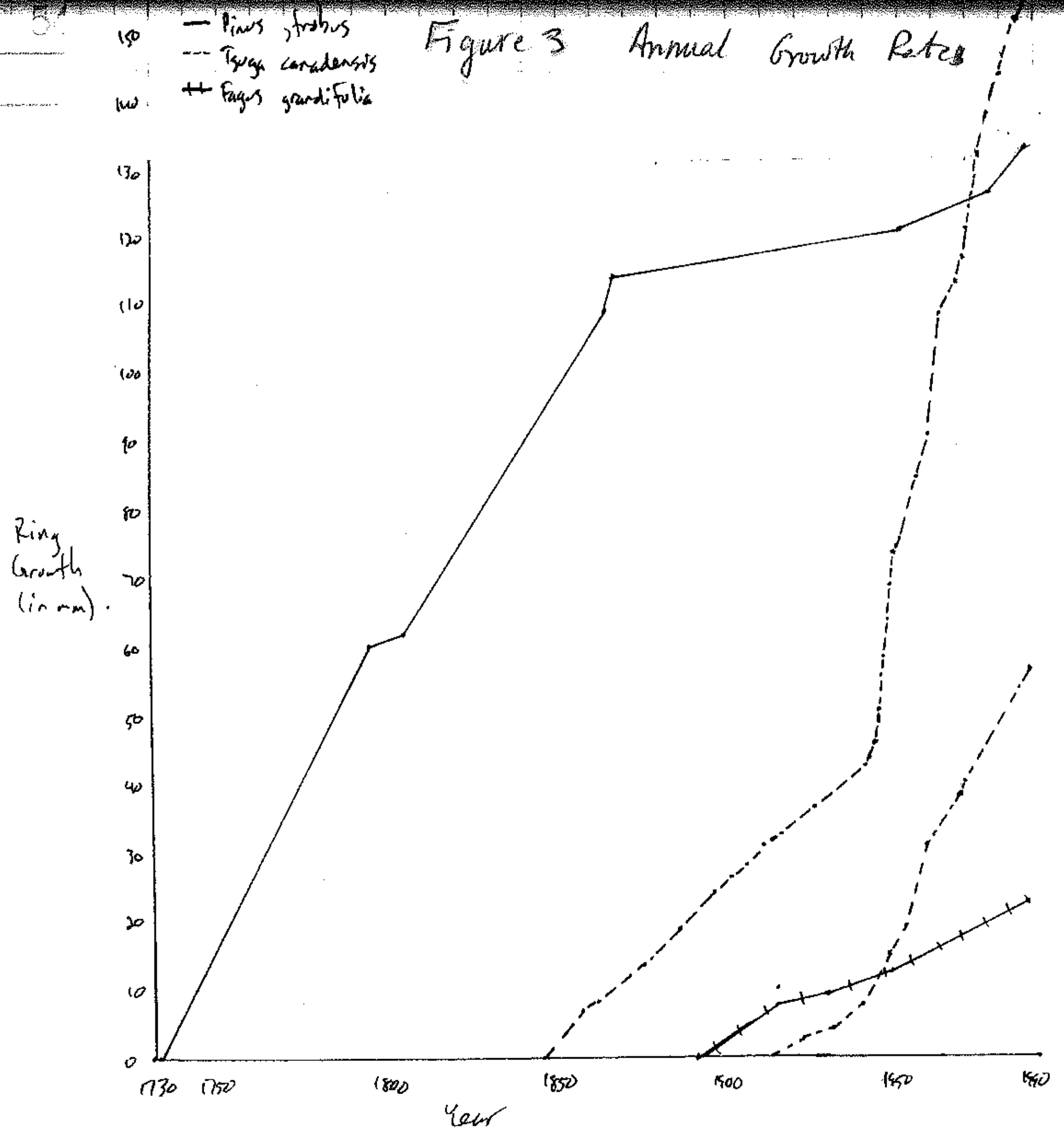


Figure 2a

Years of Establishment





— Pinus strobus
--- Tsuga canadensis
++ Fagus grandifolia
Figure 3 Annual Growth Rates
Ring Growth (in mm).
Year

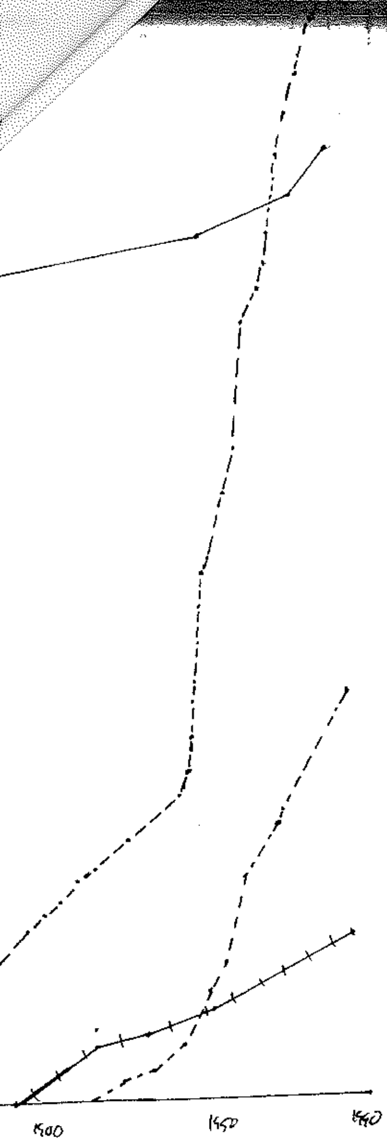
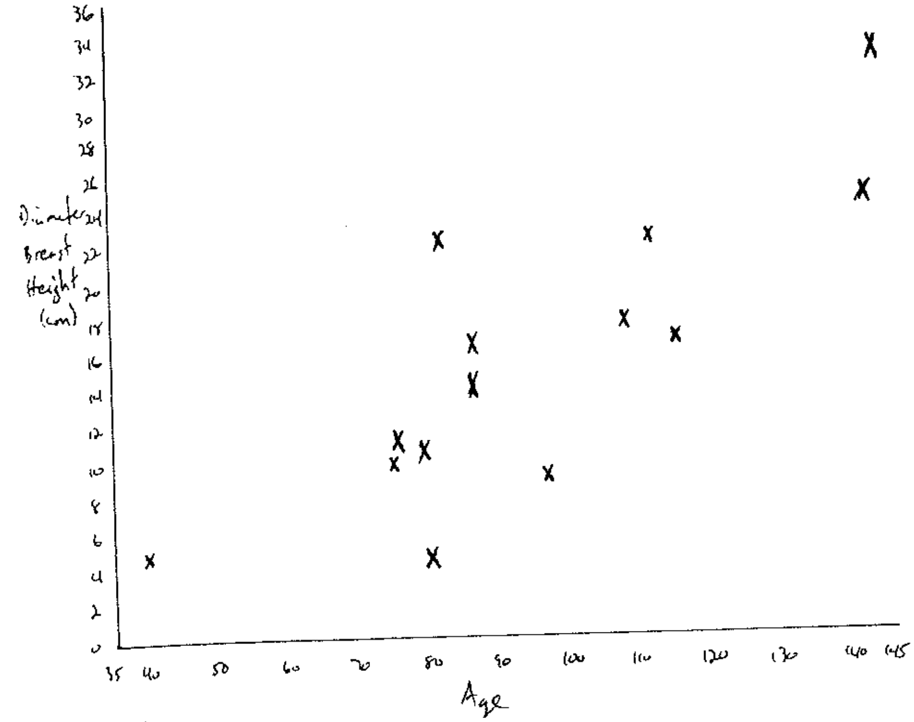
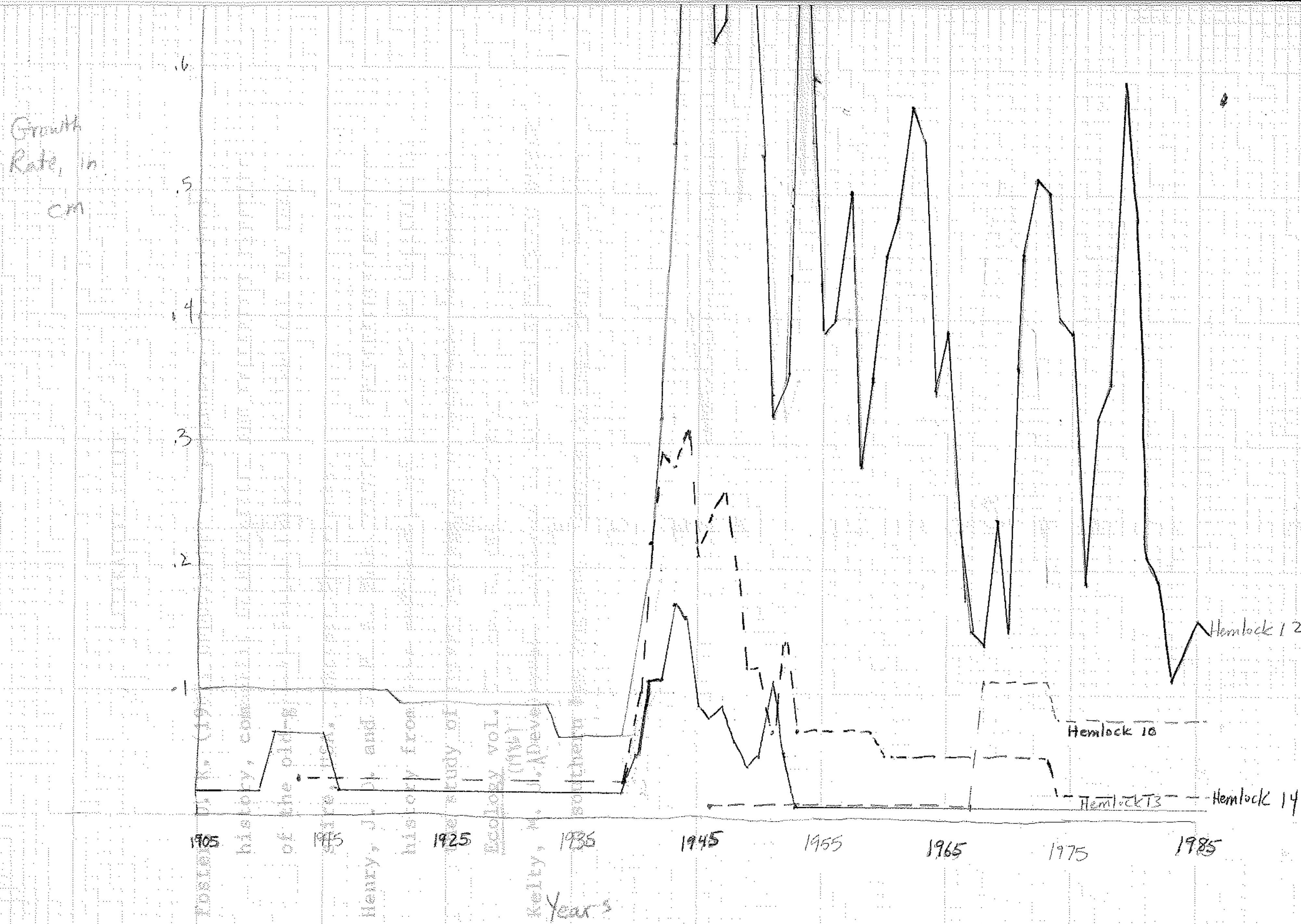


Figure 5: Comparison of Dbh with Age





Growth Rate, in cm
.6
.5
.4
.3
.2
.1
1905
1915
1925
1935
1945
1955
1965
1975
1985
Years
Hemlock 12
Hemlock 10
Hemlock 13
Hemlock 14

LITERATURE CITED

Foster, D. R. (1987, unpublished at present). Disturbance history, community organization, and vegetation dynamics of the old-growth Pisgah Forest, southwestern New Hampshire, USA. Harvard University.

Henry, J. D. and J. M. A. Swan. (1974). Reconstructing forest history from live and dead plant material--an approach to the study of forest succession in southwest New Hampshire. Ecology vol. 55, no. 4, pp. 772-783.

Kelty, M. J. (1986) Development patterns in two hemlock-hardwood stands in southern New England. Candian J. For. Res., vol. 16.

Wednesday, May 13

David -

I was unable to get the data from the Pisgah weekend until 2:30pm this afternoon. I went to the bio labs (where it was supposed to be) and tried to call Nathan - finally reaching him today at 2:00pm. Consequently, this paper is based on over-the-phone information from him. It was the best I could do with it in limited time.

I enjoyed taking this course very much. Although my lack of background in botany and geology was a slight hindrance, I feel I learned the basic information of Paleoecology. It was a welcome change in perspective from my usual courses.

Enjoy your summer, Jonathan

Reconstruction of a Hemlock Stand in the Harvard Tract of the Pisgah Forest

Jonathan Mermin
Biology 204
David Foster
May 13, 1987

Abstract

Previous studies of an old-growth forest in southwest New Hampshire (Henry and Swan, 1974) have shown the effectiveness of reconstructing forest history by thouroughly analyzing a small plot of forest. The results of their study of a 0.04 ha section of forest emphasized the importance of catastrophic disturbance in the changing vegetational history of a forest. Two questions arise from their investigation; first, they show the direction of windthrown trees to be mostly southwest, but the direction of wind from the 1938 hurricane was northwest; and second, they found that hemlock changed from an understory to an overstory tree after substantial clearing of the canopy. We analyzed a 20 x 20 meter plot for fallen trees, and an 8 x 8 meter plot for living trees, to substantiate or confute these data. Our results indicate that in contradiction to Henry and Swan, the majority of fallen trees lay in a northwesterly direction, and in support of their data, that hemlocks had a spurt in growth following the 1938 hurricane.

Introduction

Previous studies of an old-growth forest in southwest New Hampshire (Henry and Swan, 1974) have shown the effectiveness of reconstructing forest history by thouroughly analyzing a small plot of forest. The results of their study of a 0.04 ha section of forest emphasized the importance of catastrophic disturbance in the changing vegetational history of a forest. Two questions arise from their investigation; first, they show the direction of windthrown trees to be mostly southwest, but the direction of wind from the 1938 hurricane was northwest; and second, they found that hemlock changed from an understory to an overstory tree after substantial clearing of the canopy. This characteristic of hemlock supports the importance of examining interspecies differences in growth, germination, and spatial distribution within a forest, since their use may give a more complete picture of a forest's history.

Methods

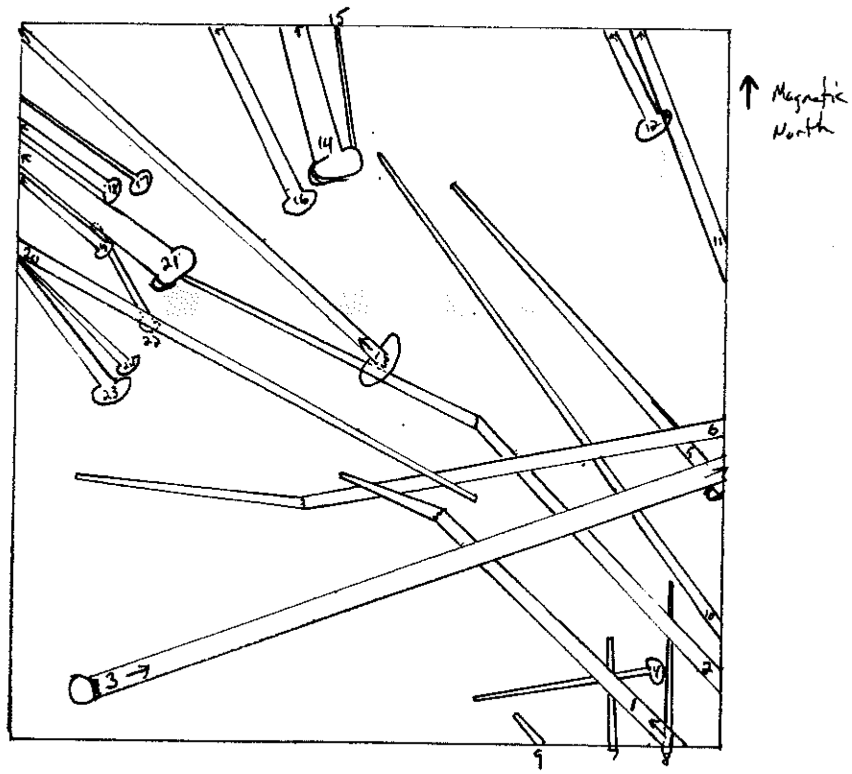
We analyzed a 20 x 20 meter plot for fallen trees, and an 8 x 8 meter plot for living trees. Species and orientation were recorded for fallen trees, and core samples were taken from the living ones. These samples were glued to small wooden boards, analyzed in the laboratory under a binocular light microscope, and growth rings were counted. Sequences of rings with similar growth rates were measured and this number was divided by the number of rings to obtain approximate growth per year measurements.

Results

Of the observed windthrown trees withing the 20 x 20 plot, the majority were oriented between 300° and 340°. All living trees within the 8 x 8 meter plot were hemlock (Tsuga canadensis) except for one white pine (Pinus strobus), and one beech. Growth rates in the hemlocks were small until 1939 and after, reaching peak growth at 1945. Growth of the white pine was consitstant until 1850 when it reached a slower rate until the present, and growth of the beech was fairly consistant throughout its lifetime.

Discussion

Our data regarding direction of fall for the white pine agrees with most recorded observations of the wind direction in the northeastern U.S. during the 1938 hurricane and brings into question the data presented by Henry and Swan. The information regarding the surge in growth in hemlock soon after the hurricane agrees with the known growht patterns of hemlock which may maintain a very slow rate when the overstory is covered, but during clearing it is able to increase rate of growth dramatically. The lack of a similar observation of growth surges for the white pine and beech agrees with current information about their growth, since the white pine, which does establish and grow in low-shade areas, did not increase its rate after the hurricane since it was already an overstory tree, and beech is not a shade intolerant species.



1) d = .4m pine
h = 12.5m 318° blown

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7) d = .17 unknown
h = 3.2 358° blown

8) d = .14 hemlock
h = 4.7 0° blown

9) d = .27 unknown
h = 11 322° blown

10) d = .35 pine
h = 16.7 323° blown

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21) d = .82 pine
h = 5.0 305° blown

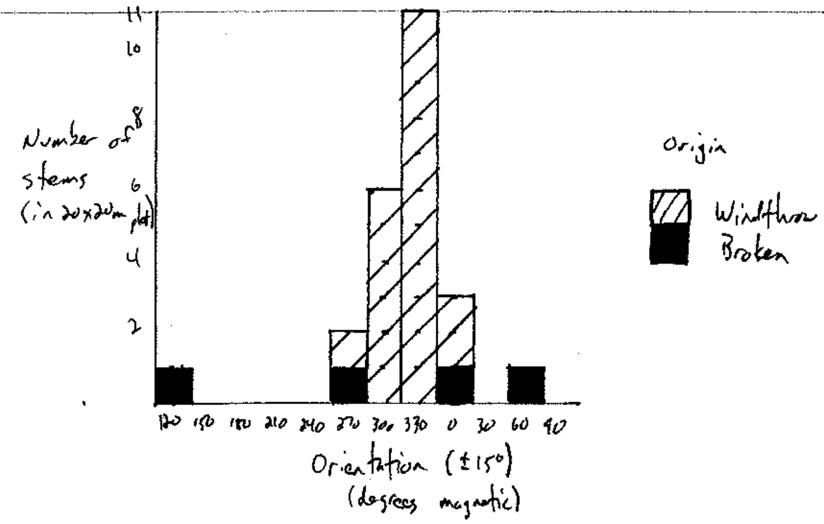
22) d = .32 unknown
h = 2.8 330° blown

23) d = .30 unknown
h = 4.7 330 blown

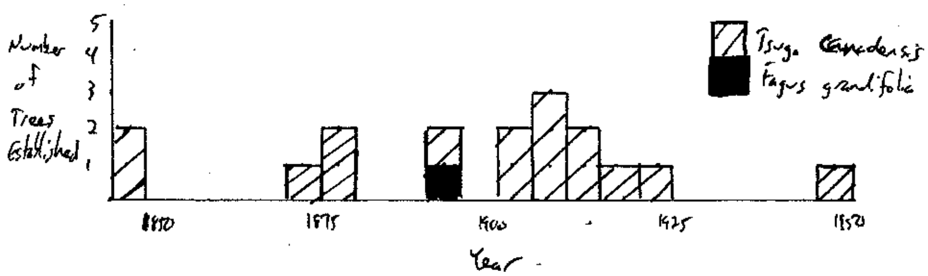
24) d = .23 birch
h = 3.6 310° blown

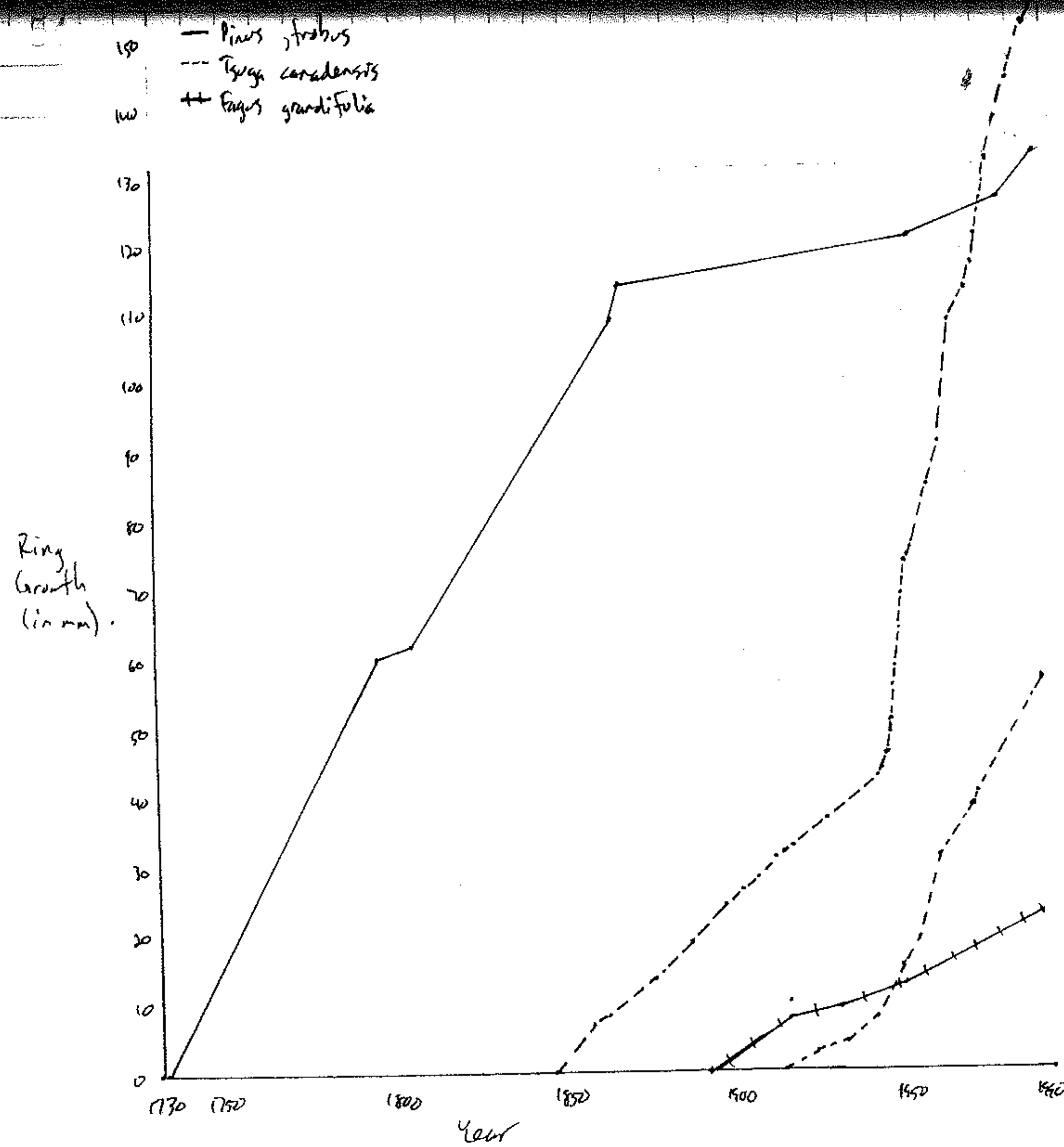
$V = \frac{1}{2}$ (area of base) × height

Orientation of Fallen Trees

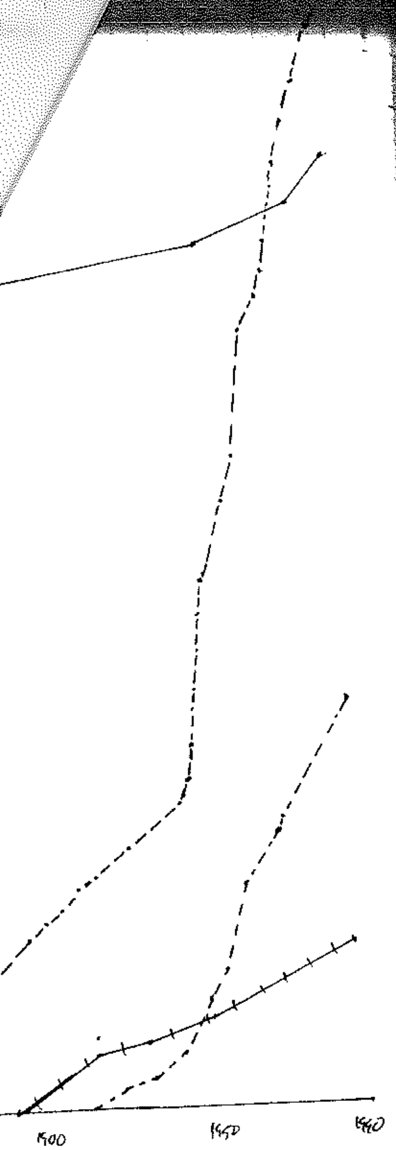


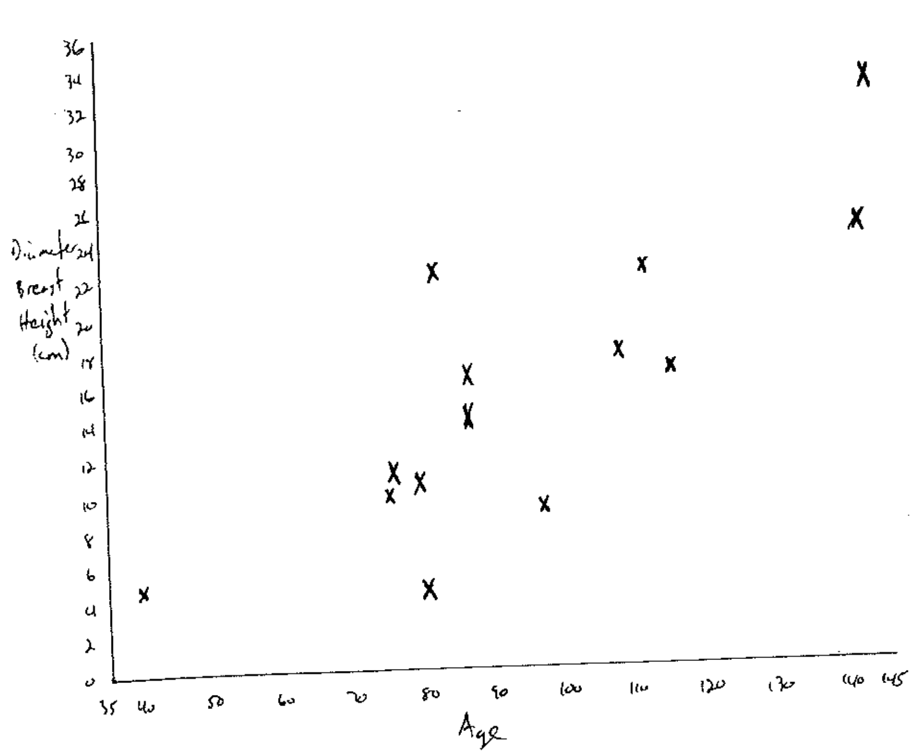
Years of Establishment





— Pinus strobus
--- Tsuga canadensis
++ Fagus grandifolia
Ring Growth (in mm).
Year




Diameter Breast Height (cm)
Age

Annual Growth Rates for Four Hemlocks, From Establishment to the Present