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Mt. Pisgah Virgin Forest Study.

Introduction – Professon Fisher

Location & Description of tract } Branch, Lotti, Daley
Method of Study }

Factors influencing composition – Branch

Analysis of Data by forest types:
- Introductory paragraph – Daley
- Protected Sites – Lotti
- Exposed Ridgetops – Daley
- Bulgarian V. F. abstract – Daley (translation by {Genth / Hosley)

Soil Data analysis – Daley.

Summary of Conclusions – Daley

Appendix
- Tables on Types of Protected Sites – Lotti
- " " " " Exposed " – Daley
- Titles to Photographs – Branch (Pictures taken by Cline & Hosley)

Daley.

Bibliography

Suggestions and Revision – Cline, Fisher, Hosley.

Tolerance of ... to Forest Succession (U.S. ...)

Old opinions - ~~one~~ climax, a climax because to components (eg. maple-beech, hemlock) were tolerant of shade. Tolerance ~~of~~ based on quantity not quality of light according to modern ecologists. Each species requires a ~~certain~~ amount of light which cannot be changed by environment - Zon. Diffuse, not direct light most ~~important~~.

What natural types present as influenced by physiography? What ... stable composition?

Ridgertop ... "Methods in the Study of Vegetation" - Tansley

Ref. Aims & Chipp

Stable & unstable (dominant) plant communities ~~Stable communities in~~ permanent equilibrium with their ~~environment~~ so long as this remains approx. constant. Vegetation, when left to itself, tends to change in a definite direction - broadly from communities of small ~~...~~ plants simple in ~~structure~~ to communities dominated by larger more complex plants. This change we call "succession". The stable type ultimately developed is called the climax type. The so called climax type ~~interpreted~~ in any absolute ...
...

climax "forest", for instance, may contain the seeds of its own decay"; in other words it slowly changes into something else as the result of such processes as slow impoverishment of the soil by leaching, for example, without any alteration in climate. All that can be claimed is that a climate is relatively permanent under the given conditions. The highest type of plant community that can exist in a given climate is known as the climatic climax, and this will always tend to develop on the most favorable soils.

Stable (climax) communities are divided into main classifications, namely, associations, consociations, and societies. Associations are characterized in four ways: (1) by a definite floristic composition, (2) by its structure, (3) by its habitat, (4) by the life forms of its dominants.

1. Floristic composition (abundance, frequency, constancy, replacement of species)
2. Life forms (Characteristic vegetative forms of community)
3. Structure (spacing & stratification [layers])
4. Habitat (site, climate, soil, topography, influence of man)

Succession (developmental changes)

5. Analysis of the data by forest types, with introductory paragraph describing types, distribution of types, etc.)

A. Protected sites.

1. Hemlock.
2. Hemlock-hardwood.
3. Hardwood.
4. Pine-hemlock.

B. Ridgetops and unprotected sites.

1. Pine.
2. Pine-hemlock.
3. Pine-hardwood.
4. Pine-hardwood-hemlock.

(Under each of the above-named types is a discussion of the following points)

a. Dominant stand (species, age, vigor, crown density, range in diameter, height, and distribution)
b. Intermediate stand (Species, age, etc.)
c. Advance growth (Species, age, etc.)
d. Site, slope, aspect, and relative elevation.
e. Possible origin of type.
f. Conclusions as to successions.

6. Soil profiles.

7. Summary of conclusions, ~~(dealt with separately for each of the two main site divisions-- protected and ridgetops and unprotected sites --.~~

8. ~~Bibliography~~. Appendix.

9. Bibliography

-- Outline --

Life History of the Virgin Forest of the Pisgah Mountain Tract in Southern New Hampshire.

1. Introduction
   A. Purpose of study.

2. Location and description of tract
   A. Geographic location and ownership.
   B. Climate.
   C. Topography. Physiography
   D. Soil. Geology & soils
   E. History.

3. Method of study
   A. Basis for selecting plots.
   B. Data obtained for each plot.
      1. Slope, aspect, and relative elevation.
      2. Evidence of fire, culling, etc.
      3. Upper story.
      4. Middle story.
      5. Advance growth.
      6. Ground cover.
      7. Soil.

4. Factors influencing composition in the virgin forest.
   A. Fires
      1. Lightning.
      2. Indian and early settlers.
   B. Wind and sleet storms.
   C. Insects and fungi.

LOCATION AND DESRIPTION OF TRACT

Geographic Location

The study was confined to an area known as the Pisgah Mountain Forest located in Cheshire County, New Hampshire, in the northwest corner of the township of Winchester, approximately two miles north of ~~the~~ town of Ashuelot village.

This forest covers an area of approximately 5000 acres owned by the Ansel Dickinson Heirs. The greater portion of the area has been logged over at some time during the past one hundred years, leaving only scattered patches of virgin forest in various parts of the tract. One of the largest of these was purchased by the Harvard Forest in 1926 to be left forever in its natural state as a museum specimen and for research purposes.

Climate

Weather records which are directly applicable to the Pisgah Forest are not available, nor is there a U.S. Weather Bureau Station in the near vicinity. At Keene, some ten miles to the northeast, Samuel Wadsworth has maintained a private weather station for the past forty years. It is considered that the weather conditions at Keene are in general comparable with those on the Pisgah Forest.

The mean annual precipitation at Keene is 38.28 inches, and is fairly well distributed throughout the year, being slightly heavier during the months of June, July, August, and September, each averaging over 3.2 inches. The average annual snowfall is 63 inches most of which falls during the months of January and February. The average date of the first frost is September 14; of the last May 29. The earliest frost recorded was August 29 and the latest June 21. The average growing season is 120 days. The prevailing wind direction is

northwest. Table 1 shows the mean monthly precipitation and temperatures.

TABLE 1 - MONTHLY TEMPERATURE AND PRECIPITATION
KEENE, NEW HAMPSHIRE #

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean Temperature °F	21.0	21.5	31.9	44.0	55.6	63.7	68.8	66.1	59.3	48.4	36.6	24.9
Mean Precipitation (inches)	2.70	2.80	3.10	2.89	3.09	3.24	3.91	4.01	3.64	2.90	2.91	3.09

Physiography

The topography of the area and that of the surrounding region is very hilly and uneven with the main ridges of the peneplain running in a north and south direction. With a few exceptions the hillsides are steep and often broken by outcroppings of bedrock, the valleys being correspondingly narrow. The summits of the ridges are of bare rock or are covered with a layer of soil so thin that it offers only very insecure anchorage for the tree growth found upon them. The region to the west of the Pisgah reservoir is of a more gently rolling nature than that to the east, having a few broad benches and valleys between the reservoir and the range of hills to the west of ~~Kilbourne~~ Kilburn Brook and ~~Kilbourne~~ Kilburn Pond. Elevations within the tract vary from 690 feet at the lowest point to 1400 feet at the highest. Numerous small brooks which have their origin within the boundaries of the Forest are tributaries of the Ashuelot River, which in turn empties its waters into the Connecticut River at a point about one mile south of the village of Hinsdale.

SOIL

The parent rocksof the Mount Pisgah region, and all of Cheshire County, are gneiss and granite of the Coös group. These rocks have the same basic composition; being composed of feldspar, quartz and mica, the gneiss ~~having~~ these minerals are arranged in parallel lines, while they are promiscuously mixed together in the granite. Geologists state that granite was the earlier of the two, the gneiss being later developed by pressure.

The soil on this area is resultant from the weathering of these rocks in situ, and from depositions during the period of glaciation. Soil depth varies from the thick fluvial deposits in the ~~bottom~~ valleys to layers of but a few inches in thickness on the high ridges and steep slopes, with limited areas of bare rock ledges. The existence of a complete virgin forest cover for centuries, over the area as a whole, has resulted in the accumulation of a thick layer of organic material—litter, duff, and humus — covering the mineral soil. Immediately below this organic layer is found a leached or impoverished top soil (podsol) varying in thickness with the character and composition of the forest cover type. Contrary to the common belief that soil conditions ~~are~~ under the virgin forest are ideal, examination shows that the soils under the old-growth stands are inferior to those found under neighboring second-growth stands.

In the year 1687, according to "The Gazetteer of Cheshire County", Colonel Willard purchased 65,000 acres of the Ashuelot valley from Chief Nawlet of the Squakheag Indians for the sum of $199.80. This purchase included the towns of Hinsdale and Winchester in which the Pisgah Forest is located. However, it was not until the year 1733 that the first settlement was established, within what is now the town of Winchester. Shortly thereafter, in the year 1736, the town of Hinsdale was settled.

Information as to the early development of the lumber industry is meager, but it is known that Colonel Willard erected the first sawmill at Winchester in 1734, for the purpose of supplying the construction material for the use of the settlers, which he did at the nominal sum of 20 to 30 shillings per thousand board feet. From this time on the lumbering industry gradually increased in importance until it reached its peak in the latter half of the nineteenth century.

In the year 1885 there were six sawmills, four box factories and two stave mills dependent for their raw material upon the region surrounding the villages of Ashuelot and Winchester. Since that period the industry has been on the decline until at the present time each of the towns has but one stationary sawmill. These sawmills cut little more than the amount needed for the two box factories which they supply.

During this extended period of lumbering operations, all of the virgin forest of the town of Winchester has been cut off, with the exception of scattered stands which comprise part of the Pisgah Forest. The reason for the present-day existence of these scattered stands is that they, with few exceptions, are inaccessible from a logging standpoint.

The original forest of the valley as a whole was characterized by the same species which are now found in second-growth stands. According to Hamilton Child, there were dense bodies of the finest white pine timber along the valleys of the Connecticut and Ashuelot rivers, while the higher lands had an abundant growth of hemlock with maple, beech, birch and red oak on the well-drained sites.

Method of Study

The first step in the field work was to locate stands within the Pisgah Forest in which no signs of any human disturbances such as cutting or culling were evident. After a suitable stand had been selected a sample plot of 0.1 acre in area was laid out within it by means of a staff compass and steel tape.

On each plot a determination of past present and future composition was of ~~primary~~ fundamental importance. It was essential to consider; first, what species were present in the preceding stand; second, what species made up the present type; and third, what species would make up the succeeding type. The past type was determined, wherever possible, by a study of the dead and down trees, bits of charcoal, and a reconnaisance of nearby cutover land. All dead and down trees were tallied by species. However, such data were very meager, and definite conclusions as to the former composition of the stand could not be drawn in many cases. Future or prospective composition was judged on the basis of the present subordinate stand and advance growth. To secure data as to the composition of the present and prospective types the forest cover on each plot was divided into three stories; upper story, middle story, and advance growth.

The upper story included all the dominant and codominant trees, which were tallied by species and by diameter and height classes. The species forming this story were used as the basis for classification of the various stands into types; that is, if one species composed 80 % or more, by number, of the upper story the type was considered a pure one. On the other hand, if if all species were represented by less than 80 %, by number, in the dominant stand, the type was considered as a mixture.

For example, a stand composed of 85 % hemlock, 10 % beech, and 5% red maple (in the upper story) would be classified as Hemlock; wheras, if the percentage of hemlock had been less than 80 %, the stand would fall under the head of Hemlock-Hardwood.

The middle story consisted of all the intermediate and suppressed trees down to a height of fifteen feet, which were also tallied by species, and diameter and height classes. In some types the components of the middle-story were found to be very tolerant of the shade cast by the canopy above, and of the root competition of their associates, and it is highly probable that at least some of these relatively long-lived trees will some day replace any member of the dominant stand that may drop out.

Because of the abundance of the advance growth a 100 % tally was quite impractical. A count of the advance growth on ten mil-acres laid out along the center line of each plot was considered sufficient for a record of both composition and distribution. Particular attention was given to the distribution of the advance growth in relation to holes in the canopy, thickness of the duff and humus layers, and other discernable influences. Seedlings and saplings were tallied in two classes as follows; one class included all seedlings up to one feet in in height, and the other all seedlings and saplings from one to 15 feet in height. The purpose of this division of the advance growth was to determine what species survived the small seedling stage and showed the ability to withstand the shading and root competition of the upper and middle stories. Undoubtedly such survivors could be considered as prospective members of the dominant stand.

In addition to a tally of the trees on each plot, by species and size classes

note was made as to their vigor and distribution, and in order to better visualize shade conditions under which the members of the middle story and advance growth grow, an estimate was made of the crown density of the overstory, using the basis of 1.0 as the density of a canopy through which no direct sunlight passes. Increment borings of several trees in each story were taken, and the ages thus obtained were used as a basis for determining the age of a stand, if even - aged, or, the range in ages if uneven-aged.

~~and such proofs of climax as may have been found was established.~~ ~~However, in many cases, such data was very meagre, and definite conclusions as to the former structure could not be drawn.~~

All recognizable disturbing influences such as wind, lightning, fire, insect and fungus attacks were noted, and an attempt was made to appraise such damage as may have resulted from one or more of these agencies. Such data would sometimes offer a clue as to the possible origin of the stand.

In order to correlate composition or type with physiography, the aspect, degree of slope, and the relative elevation of each plot were carefully considered and recorded. Plots were taken on all exposures and only extremes such as bare rock ridge-tops and swampy bottomlands were avoided.

All shrubby and herbaceous growth was noted and tallied by number in either one of three classes as follows:- if sparse in the "few" class, if in moderate amount in the "many" class, if very common in the "plentiful" class.

Three soil profiles were made on each plot and the thickness of the organic layer, the leached layer, and the dark brown or enriched ~~horizon were~~ layer was carefully measured and recorded to the nearest 0.1 of an inch. The purpose of these soil profile measurements was to seek a correlation between thickness of the organic and soil layers and ~~with~~ the type of cover.

Some difficulty was experienced in obtaining age data on many of the plots. This trouble was mainly due to the fact that many of the trees ~~being too~~ were large in diameter ~~thus making it impossible to reach the inner growth rings with an increment borer~~ to be bored with an increment borer. To obtain more conclusive age data, a total of twenty-eight 0.1 acre plots were laid out in recently cutover virgin forest. It was then a relatively simple matter to make age counts on the more or less freshly cut stumps. Clues as to the origin of several types were also

uncovered and the date of occurence of several more or less widely spread fires was established by means of ring counts of the woody tissue which grows over fire scars and in time covers them.

4 Fa ctors Influencing Composition in The Virgin Forest ?

(a) Fire

Since time immemorial there have been factors operating in the fores t which tend to upset the normal trends of succession. Theoretically a normal trend in succession would be one through which a forest a ssocia tion would pass, in the process of centuries, if it were undisturbed by fires, windstorms, ice-storms, insects, and fungi. Studies which have beem recently made in virgin forests, such as " The Vegetation of Hearts Content" by H.J.Lutz and " Aufbau Wuchs und Verjüngung Südeuropa ischen Urwälder", by Müller verify the opinion that these factors - of which fire is by fa r the most important - are and always have been intimately related with successiona/ cha nges in the virgin forest.

The ordinary conception of a climax fored t is built up on the assumption that fa ctors influencing tree growth on any one area of virgin forest are constant and unchanging, making possible a definite trend from one forest type to another, through to a climax type for a given site. It has been found in this s tudy, however, that there a re those factors, enumerated above, which tend to make instability rather than stability the rule.

The action of these either opens holes of varying sizes in the canopy of the virgin forest, or causes the forest to be entirely destroyed over large areas . The nature of the ensuing stands then depends largely upon the size of the opening and upon the reproductive ability of the remaining living trees, or the sprouting ability of the weakened hardwoods. In a very sma ll opening (a few sq uare yards in extent) tolerant species, or those of medium tolerance will compose the bulk of the new growth, while in the larger holes there will be a

greater
Larger pecentage ~~percentage~~ of ~~intolerant species~~ light demanding species. Where a large area of forest has been killed by one of these agencies it is taken over by either light-seeded species or by those which sprout vigorously. Thus it is seen that a virgin forest may at various times undergo a setback or advance in its progress toward a climax type through the action of one, or a combination of these factors.

Causes of Fires in The Virgin Forest

Lightning

In this country there have been several causes for either widespread or localized fires. The oldest cause is naturally lightning. Although lightning-struck trees do not as a rule start conflaggations in New England forests, it is conceivable that they may have in the past, after a particularly dry season when a thunder storm was accompanied by very little rain. In the course of the field observations for this study it was noted that wherever large white pines rea red their heads above the heavier canopy of hemlock and hardwood a fa irly high percentage of those pines had been at some time, struck by lightning. One particularly interesting example was found. A large white pine snag had been hit by a bolt of lightning which had jumped from the snag to a young oak tree, a nd thence to the ground. The white pine had been entirely consumed by the resulta nt fire, except for a few limbs and pieces of bark which had dropped free from the base, down to a depth of a foot below the ground level. One can easily picture how such a pitchy snag might burn for a day or two after a rainfall, eventually starting a ground

fire when the litter and duff became dry enough to be inflammable.

Even when lightning does not cause a fire it is a means of opening ~~minor~~ small holes in the canopy of the dominant stand, these openings varying in size from an area of several squa re yards to ~~a half~~ one tenth acre or more. It has been observed in second-growth stands, on the Harvard Forest, as well as in the virgin forest of Mount Pisgah, that a single bolt of lightning may kill all of the pines in the dominant stand which are located within such a restricted area.

Indian and ~~Scot~~ Early Settlers' Fires

The question as to the first occupancy of this country by Indians is open to conjecture. Neverthless it is certain that the various tribes of red men roamed about at will for centuries before the advent of the white man, their nomadic habit of living causing them to settle temporarily in places where game and fish were plentiful enough to furnish them food. Their only efforts a t agriculture seem to have been the raising of corn for meal. For this purpose openings in the forest were needed, and the red man resorted to the use of fire as his tool for the clearing of his cornfields. D. Hamilton Hurd, in his publica tion in 1886 of, " The History of Cheshire a nd Sulliva n Counties" states that, "although the Squakheag Indians sold 65000 acres of the Ashuelot valley to the whites in the year 1687 they did not abandon the territory until 1720. They set frequent fires in certain portions of the domain to keep down the underbrush for cultivable fields. These fires were generally set in the fall after the ~~lea~~ leaves and seeds had fallen, and in this way not only the smaller trees were destroyed, but ~~also~~ also the larger ones were sooner or later killed. By this method they kept q uite large areas treeless for the purpose of cultivation."

In his article,"New England Forests in Retrospect", Hawes states that " before the year 1600, areas near the sea coast, and river and lake shores were repeatedly burned over by Indian fires, set presumably to facilitate their hunting activities."

Thus it is clear that the virgin forests of New England, and possibly ~~that~~ those of all other sections of the country were subjected to fires set by the Indians. The majority of such

fires continued to burn until they reached a natural barrier or until extinguished by rainfall; the Indians ~~only~~ working to only those subdue fires which threatened their villages or cultivated fields. Indian campfires left untended were more than likely the cause of frequent forest fires.

The fires set by early settlers can be placed in the same category as Indian fires. Forests were regarded by the settlers a s a hindrance to their progress and as a shelter for their enemies. In Hamilton Child's "Gazeteer of Cheshire County" he states that "the settlers method of clearing the land was to cut the trees and let them lie upon the ground until fairly well seasoned. They then burned them as they lay, afterwards drawing together the remnants of the unburned logs and again subjecting them to fire until completely consumed." It is certain that many of such fires became uncontrollable and were allowed to run their course. Forests - to early Americans - were considered to be inexhaustible, as well as a hindrance to progress, so that little precaution was taken to prevent their destruction by fires or exploitation.

Fires vary in intensity from ~~ground~~ surface fires which merely consume the litter and dry portions of ground cover and reproduction, through those intense fires consuming all of the organic horizon, to crown fires which cause the greatest immediate damage to the stand. It is generally known that their intensity varies with the type of cover encountered, with the topography of the burned area, and with weather conditions. Naturally the character of the fire has an influence upon the character of the resultant stand. A light ~~ground~~ surface fire for instance, may cause no more damage than to kill or retard the growth of the reproduction and ground cover. Within a few years after such

a fire, however, the composition of reproduction and ground cover will be essentially the same as it was before the intrusion. In such a case there would be no great upset in the progress of succession. However, the more severe fires, such as one which consumes most of the organic layer, or a crown fire, may decidedly alter the composition of the subsequent stand from what it would have been if fire had not occurred. Taking the more extreme case for illustration, a crown fire may kill all of the trees of one or several species on a given area, thus precluding the possibility of reseeding by those same species. It is clear that such an area would subsequently be given over to some light-seeded or light-demanding prolific species which could seed in from adjoining stands, or possibly to those species which possess sprouting ability.

The behavior of severe ground fires is very interesting. The habits of such a burn were made available for study by a fire which occurred in the fall of 1929, after a particularly dry summer. It was extinguished after having burned over an area of about one half acre in a virgin stand of white pine, hemlock, and hardwood. The entire organic layer was burned off clean in all places where it was more than an inch and one half in thickness, and the fire was found to have travelled about over a very irregular course, burning through wherever the accumulation of litter, duff, and humus was heavy. These patches were naturally found in the hollows between outcrops of parent rock, which in that area happened to be quite close to the surface. Where the organic layer covering parent rock was less than about one and one half inches in thickness it was not burned. The reason for this is probably that the layer was too thin to supply enough reflected heat for the fire to maintain itself within such layers.

Wherever there happened to be a hemlock or hardwood of less than a foot in diameter at the base, the fire had burned the organic layer entirely from under the large roots close to the butt. A reexamination of this area on May 28, 1930 showed that the inner bark and cambium were badly scorched on more than 80 % of all trees within it. This scorched portion extended around the entire circumference of the butt and for a foot to one and one half feet up the trunk. The hemlocks showed a distinct "browning" of the needles, and the leaves of all hardwoods appeared to be in an unhealthy condition, being developed to only about two thirds the size of those on the same species outside the burned area. No effect was noticeable on the pines except that the inner bark and cambium were badly scorched. It is probably safe to estimate that the majority of the trees on the half acre will succumb within the next 2 to 15 years.This will then give rise to a small practically even-aged group of the same character as these encount ered in the stump analyses, and of the same composition as that of the adjoining stand.

The timing of fires, in relation to the age of the stand burned, may have an important bearing upon the composition of the forest type to follow. As an illustration we can assume that a crown fire runs through an area which is heavily stocked with a young stand (10 to 30 years old) of hardwood,hemlock, and some pine. Such a fire would undoubtedly kill all of the hemlock and pine. Consequently the ensuing stand would be composed chiefly of hardwoods of sprout origin. Thus these factors influencing composition may intrude upon the ordinary trends in succession, causing the establishment of a different type of forest on a given area than would have occupied the site if the intrusion had not occurred.

Fires occurring later in the life of ~~them~~ a stand would not cause such a radical change in composition for such fires do not ordinarily "crown" and, therefore would not cause all of any one species to be immediately killed.

That fires have been prevalent in the virgin forest is proven most convincingly by evidence left on the ground. Examination of the soil layers on every plot taken in the course of the study showed bits of charcoal, of varying size, usually on top of the mineral soil, although in some cases it was even found to have been worked into it. The dates of such fires cannot be ascertained from this evidence, but it ~~is~~ can safely be assumed that charcoal found on top of, or worked into the mineral soil - on areas where the thin-barked species are not fire-scarred - having an accumulation of several inches of litter, duff, and humus above it, is the result of a fire which occurred just before the establishment of the stand which now occupies that site. The examination of the stumps in recently cut-over virgin timber substantiates this theory, for several areas were found in which charcoal was abundant on top of the mineral soil, while none of the stumps showed evidence that the trees had ever been fire-scarred. These plots contained such thin-ba rked trees as paper birch and beech, which are relatively easily fire-scarred, in ~~the~~ mixture with ~~the~~ other species.

Fires that occurred within the life of the present stand can be dated by examination of the damaged trees.

Wind and Sleet Storms

Of the natural influences operating in the virgin forest wind is the factor which lends itself most easily to study. The effects of its work are very plainly seen. In this investigation we are fortunate in having several areas in which to study successions caused by wind. Damage to an unbroken forest through wind is naturally most severe on the high ridgetops where trees are fully exposed to its force. This is also partly due to the fact that the soil on ridgetops is usually much more shallow than on side-slopes and in the lowlands, being merely a thin layer covering the parent rock. Such soil provides poor anchorage for trees, causing them to have broad shallow root systems. On the Pisgah Tract it was found that that high ridgetops support the youngest and smallest trees found in any of the areas of virgin forest. The reason for this condition is that as a high ridgetop stand becomes older, and increases in height, the form point or center of wind pressure of each tree is becoming higher along the bole. Eventually it reaches a point at which the pressure exerted by a wind of more than average velocity is more than the shallow root system can withstand and the tree is windthrown. The majority of the trees on any one ridge will be thus prostrated within a period of from five to ten years, leaving only a few scattered individuals which are more deeply rooted in the occasional pockets or crevasses. The result of such openings is a practically even-aged stand composed of essentially the same species as the preceding one. Extensive blowdowns on ridges would favor such species as white pine, paper birch and red maple.

Windthrow on the more protected sites probably causes very little change of composition in the mixed hardwood-hemlock forest, for here destruction of the dominant stand

through windthrow is a very gradual process evidenced by the occasional uprooting of a decadent veteran. Such small holes are taken over by the hardwood and hemlock of the intermediate stand and advance growth. In a pine-hemlock mixture, however, in the absence of any other disturbance, the holes left by windthrown pines or hemlocks will be taken over by hemlock or hemlock and tolerant hardwoods, thereby ultimately changing the composition to either pure hemlock or hemlock-hardwood. In pure hardwood the composition would either remain as pure hardwood or be changed to hardwood-hemlock, depending on the hemlock seed supply and conditions for its germination and growth.

The above deductions are based on the assumption that windthrow on protected sites is limited to the prostration of an occasional tree or small group of trees. It is conceivable, however, that strong winds, in the past, may have caused larger openings (one half acre or more). In such openings it is possible that an occasional pine could enter into the composition in any of the obove-mentioned types, provided that there were pine seedlings on the ground before the blowdown and that these could compete with the hardwood or hemlock, or both, already established in the advance growth and intermediate stand.

In the event of a fire's occurring before this critical "wind-throw" height or age is reached, the life of the stand would probably be reduced by a number of years, depending upon

the severity of the fire. Their weakened condition would cause them either to be windthrowm earlier in life, or killed by the subseq uent attacks of insects and fungi.

Sleet storms are important allies of wind in the breaking up of the dominant stand before it reaches maturity. Trees are more easily uprooted by strong winds when ~~they whole tree is~~ they are heavily coated ~~by~~ with ice. Even if the dominant trees are not uprooted they suffer damage by having parts, or the whole of their crowns broken off, paving the way for the attacks of insects and fungi which shorten the life of the stand and cause a more sudden breakup of the canopy. ~~Along with~~ As in the case of wind, the damage from sleet storms is most severe in the most exposed situations.

Insects and Fungi

Comparatively ~~small amount~~ little is known ~~as~~ concerning the role of insects and fungi in the virgin forest of the type found on the Pisgah a rea . However,it is generally known that these agencies cause a minimum of damage to a forest composed of a mixture of species, while the dominant stand of such a forest is in a vigorous, growing condition. They play their part well along toward the end of the life of the ~~forest~~ stand, assisting in the final breakup and decomposition. The work of the Chestnut Blight (Endothia parasitica Murr.) ,however, is an exception to this ~~theory~~ fact. All of the Chestnut, which was once an important associate species in most of the types of this region, have been killed by the Chestnut Blight. This case of the extinction of a species from the virgin mixed forest is without parallel since white man first inhabited this country, although it is conceivable that it may have happened previous to that time.

Both insects and fungi play an importa nt part in ~~subsequently~~ speeding the death of trees damaged by other agencies, a s mentioned in the discussions of fire and ~~wind and sleet~~ storms. On the Pisgah Tract several areas were found, varying in size from one half acre to two acres, where the ~~Honey~~ Honey Fungus, (Armillaria mellea, Vahl,) had killed all of the hemlocks in the dominant stand, within a period of 15 years after a ground fire. Small groups of pines which had been struck by lightning were found to have been hastened along toward death by the parasitism of this fungus. It is therefore another agency tending to open sma ll or large holes in the canopy of the dominant stand. (6).

ANALYSIS OF THE DATA BY FOREST TYPES

The seven types of tree associations encountered in the course of this investigation may be divided into two groups on the basis of their physiographic location. The Hardwood, Hardwood-Hemlock, and Pine-Hemlock Hemlock types were found to be characteristic of the relatively undisturbed, most protected sites, namely, the slopes, the valleys, and the low ridges or knolls. On the high, exposed ridge tops, more susceptible to disturbances by high winds and lightning, and where fires were doubtless more severe in their effect on vegetation, the Pine, Pine-Hemlock, Pine- Hardwood, And Pine-Hardwood-Hemlock types predominated.

The virgin forest as a whole was unevenaged, all ages and sizes of trees being present at any one time. However, age counts indicated that the unevenaged forest was a composite of many groups and evenaged stands, variable in area. The ridgetops in particular tended to support evenaged stands, regardless of species. This was due to the greater liability for the occurence of extensive blowdowns and the more complete destruction caused by forest fires on these sites. Icestorms, lightning, insects, and fungous diseases also had an appreciable influence on the origin, composition, and age of virgin forest areas, as has been already explained.

Thus the old-growth forest of this region presented the following composite picture: (1) evenaged pine, hemlock, and hardwood mixtures on the high, exposed, ridge tops; and (2) hardwood, and hemlock associations, evenaged by groups, with a small percentage of pine, on the protected slopes, ### low Knolls, and in the valleys. The ridge top stands were almost invariably made up of younger and smaller trees than those stands found on the more protected sites. The hardwoods found on the exposed sites differed somewhat from those found on the lower slopes, ##########

The Northern Hardwoods (beech, birch, and maple) were mostly characteristic of the protected sites, while the ~~[illegible]~~ oak and paper birch associated (~~mixed~~) along with pine, predominated on the ridges.

Upper-story

The Hardwood type as a whole is mostly confined to the cool, moist, well-protected sites of the lower north and east slopes. However, it may also be found on the drier and less protected sites of low ridge tops and Knolls along with several other types, namely; Pine-Hemlock, Hemlock, And Hemlock-Hardwood.

In this division of the old-growth forest beech, black birch, hard maple, and paper birch form the bulk of the species constituting the dominant stand, with white ash, hemlock, basswood, a nd white pine occuring more or less frequently in the composition. That chestnut was once one of the most important members of this association is evidenced by the amount of it occuring in the dea d a nd down cla ss . In fact, it was only until the death of this species that, in many cases, the present stand of hardwoods became the dominant stand. The appearance of hemlock in the upper-story of only one in a total of twelve plots taken in this type is quite puzzling inasmuch as the species is found, in fair amount, in the middle-story and advance growth of over half of the plots examined. It is the authors' contention, however, that this condition is the result of a major disturbing influence, which in this case is fire, affecting the composition of the stand or type. To substantiate this contention three facts present themselves: (1) The majority, by fa r, of the trees now forming the upper-story are fire scarred - some of them quite badly. (3) Islands conta ining, in varying proportions, hemlock are found scattered thru the stand. (4) Groups of even-aged paper birch are found on the area examined (this species, when found in even aged stands, is the result of fire(U.S.D.A. Bul. 285)). Using these facts as a basis the following theory may be advanced: sometime during the early life of the present stand, one or more fires swept thru the area, killing most of the hemlock and some of

the hardwoods, leaving a residual stand, quite open in stocking, composed chiefly of hardwoods with scattered groups of trees untouched or only slightly disturbed by the fire in which hemlock was very much in evidence. The largest openings seeded in with paper birch and as time went on the stand has gradually become restocked and is now composed of an almost pure hardwood overstory. One must not infer, however, that the hardwood type is wholly of accidental origin. Hemlock perhaps would have been more prevalent if it were not for fire, as in case of the stand studied, but it would erroneous to say that this species would have been predominant over the entire area; hardwoods would have dominated some of the area at least.

The forest form of this type is that of a forest more or less ideally suited for selective logging. There is a wide range of diameter and height classes and such an abundance of advance growth that a sustained yeild would always be insured. Hardwoods as a whole do not reach the size of hemlock in diameter and height growth, but some individuals are found that attain diameters of 30 inches B.H. or over and heights of 100 feet. Usually these large trees are more or less decadent and of little value commercially. The canopy is somewhat more open than either that of the Hemlock or the Hemlock-Hardwood types; the maximum crown density noted is 0.7 and the average of all plots 0.5. In spite of this, little of the sunlight that reaches the forest floor is direct sunlight.

Middle-story

Essentially the same species found comprising the upper-story of the Hardwood type are present as members of the middle-story: Namely namely, beech, hard maple, hemlock, black birch, red maple, red oak, ironwood, and white ash. Paper birch, so prominent a member of the upper-story, is not found among the components of the middle-story. This is no doubt due to the characteristic intolerance of the species, ~~and~~ which is therefore found only as a member of the dominant stand, either as an individual or in even-aged groups. Pine, too, is entirely absent from this division, perhaps for the same reason. (The presence of red oak is more or less unexplainable in view of the fact that the tree is not found in the overstory of any plot examined in this type. Perhaps the few trees found in the middle-story were the result of the bringing in of acorns by either squirrels or bluejays, as they are known to sometimes do, from oak ~~stands~~ trees found elsewhere on the area.)

All of the elements forming this story are slow growing, but are relatively free from fungous diseases. With the exception of those trees damaged by fire, only a few of the trees which had occasion to be bored with the increment borer showed signs of decay. However slow the growth of many of the trees may be, they are relatively longlived, and with the exception ~~of~~ of ironwood which seems to remain content in the middle- story, they will no doubt have the opportunity ~~to~~ of becoming members of the dominant stand ~~in the advent of its opening up of the dominant stand in case it~~ when the old stands breaks up.

Advance- growth

The species common to upper and middle stories repeat themselves in the advance-growth and their occurence in either the one foot or the one foot to fifteen feet class is as follows: Hard maple, beech, red maple, hemlock, basswood, and white ash are found in both size classes, while red oak, black birch, white pine, and black cherry are represented in only the one foot class. This reproduction is usually found well distributed over the forest floor being somewhat denser where the openings in the canopy above allow the entrance of more sunlight. The trees are of fair vigor, and with the exception of the species found only in the one foot class, most of them seem able to survive and grow fairly well under the shade and root competition of the stories overhead, indicating that at some time or other these trees may become members of the dominant stand.

Upper- story

The Hemlock-Hardwood type is found chiefly on the cool, moist, well-protected, lower north and east slopes, however, it is not uncommon on the drier and less protected sites of the higher slopes and ###### the tops of low ridges or knolls. The type is confined to relatively small areas on these drier and less ########## protected sites, that is, only where fire has not been destructive enough to materially change the composition and where the wind has not been severe enough to open up the stand and allow species to enter which otherwise could not do so.

The dominant stand of this mixed high forest of evergreen and ~~coniferous~~ deciduous trees is ~~found to be~~ composed of hemlock and a mixture of hardwoods, of which beech is the most abundant, followed by black birch, red maple, and yellow birch in order of their abundance. Chestnut here too was a member of the association, but since its death it has been replaced by the hemlock and hardwood of this mixture. White pine which was occasionally found in the dominant stand of the Hemlock and Hardwood types is entirely absent from that of this type. Perhaps this absence of white pine indicates that the Hemlock-Hardwood type is too far advanced in the ~~life-history~~ succession of the virgin forest to permit the entrance of white pine into the dominant stand without there first being a decided disruption in the present composition of the type.

Both the hardwoods and the hemlocks attain large size. Trees 24 inches or more ########## in diameter ########## and 90 to 100 feet in height are not at all rare. These overstory trees are ~~more or less~~ usually uneven-aged even over a small area the size of a sample plot. In many instances variations of a hundred years or more between individuals of the dominant stand were noted. However, small groups containing not more than three or four hemlocks were found #

that were evenaged. These groups are considered as being survivors of a former pure, Evenaged stand of hemlock which has been replaced, for the most part, by the subordinate stand of hardwood and hemlock thru the gradual dropping out of the individuals forming the dominant stand.

The vigor of the trees forming the upper-story is, of course, quite variable, but the majority of them can be classified as being of moderate vigor, and these become poorer as they pass maturity and become more suseeptible to injury and disease. The canopy here as in the Hemlock type allows little direct sunlight to reach the forest floor, indicating that only shade tolerant species can long survive in the subordinate stand. The maximum crown density noted was 0.9 of a full canopy and the average for all of the Hemlock-Hardwood plots was 0.6.

Middle-story

Hemlock and beech comprise the bulk of the species forming the subordinate stand. However, a small percentage of other species such as black birch, hard maple, red maple, yellow birch, red spruce, and red oak, listed in order of their occurence, are found as their associates.

The presence of hard maple and red spruce in the middle-story ~~is more or less~~ seems unexplainable in view of the fact that they are entirely absent from the overstory of this type. Red oak, another species in the same category, can be accounted for by the fact that the plot in which it was found, was taken on a more or less unprotected site where the overhead canopy was quite open thus favouring the entrance of an intolerant tree such as oak.

The## middle-story trees, ~~as~~ like those of the Hemlock and the Hardwood types, are characteristically slow in growth and ~~only~~ not until some members of the dominant stand drop out do they accelerate their growth and become dominants. Many of these trees never reach the dominant stand, however. They become so enfeebled that they themselves drop out.

Advanced-growth

The forest floor of this type is usually found to be covered with an abundance of advance-growth. Hemlock and beech are, by far, in the majority in both the class below one foot and the one foot to fifteen foot classes of the advance growth in practically all of the plots examined in the course of this study. Black birch, yellow birch and hard maple, although not so common as the first named species, were nevertheless well represented in both size classes wherever found. White pine and black cherry were found able to reproduce themselves but were unable to survive for more than a few years after they had germinated from seed. This is evidenced by the fact that both species are found, in fair abundance, in the seedling to one foot class but are entirely lacking in the one to fifteen foot class.

Under a heavy canopy the distribution of these trees forming the advance growth has a tendency to be patchy, that is, the trees are most abundant and vigorous wherever a break occurs in the overhead canopy while those under the heaviest canopy are relatively sparse in number and poor in vigor beyond the seedling stage.

5 f: Protected Sites

Upper- story

At the outset of this study, it was thought that the Hemlock type was confined solely to th cool, moist, well-protected sites of the lower north and east slopes. However, field investigation showed that, although its best development was reached on the protected sites, the type was found to be well established near the summits of the more or less unprotected high ridges which are common to the area. In fact , thirty per cent of the stands studied were located near the tops of ridges.

In the old mature stands, one is at once impressed by the large size of many of the individuals found in the upper-story, especially that of the hemlocks, which often attain diamaters of over thirty inches and heights of one hundred feet ormore. The species is occasionally found as the sole occupant of the upper-story on areas no largerthan one of the sample plots, but usually small percentages of black birch, red maple, beech, red spruce, and now and then a white pine are found in association with it. Chestnut was once quite commonly found in this upper-story, but since the advent of the blight (~~Endothia parisitca~~) the species has passed out of the picture entirely and the possibilities of its return are nil. Five of the stands examined were evidently survivors of a Pine- Hemlock mixture, but the pinexbeing somewhat ## shorter lived than the hemlock has passed out of thexcomposition leaving the hemlock to form the dominant stand.

The vigor of these hemlocks and associated hardwoods is for the most part moderate. A study of hemlock in the cutover areas showed that, although a tree of slow height and diameter growth, it was relatively free from disease, its major defect being purely mechanical in the form of wind-shake. Several groups were found that had been killed by the fungus Armillaria mellea, but as this as this parisite was not widespread it cannot be considered as a serious menace to the welfare of the species.

These pure stands of hemlock are essentially even-aged, especially those which are the result of a former association with pine, the origin of which ~~will be~~ is discussed under the Pine-Hemlock type. With few exceptions, age counts in both pure hemlock and pine-hemlock cutover areas showed that the age differences between the individuals of the dominant stand are negligible, that is, not over fifteen or twenty years separate the youngest from the oldest member. That hemlock is long lived is evidenced by numerous trees being found that had reached the age of 300 years and in one case 374 years. No other species discussed in this study can surpass or even equal hemlock in longevity.

Middle-story

Here, as in the upper-story, hemlock forms an important part of the composition; however, the proportion of associated species greatly increases. Beech especially is much more in evidence, with black birch, red maple, and yellow birch in descending order of abundance. White pine and red spruce, although present in the upper-story are entirely lacking in this division.

On the whole these middle-story trees are of poor vigor. Their height and diameter growth is extremely slow and their struggle for existence one of great difficulty. The scarcity of sunlight here is more marked than in any other type studied and, no doubt, there is as keen a root competition as that offered by the members of other associations. Many of the beeches, especially those growing under the heaviest of shade, have dead tops and whether or not these will recover when released by the dropping out of members of the dominant stand is open to conjecture. In spite ~~spite~~ of this seeming poor vigor, many of the trees are relatively long-lived -(some of the hemlocks reach the age of 200 years or more)- and with this longevity in mind, it is quite safe to say that sooner or later these trees may become members of the dominant stand in the event of its breaking up.

Advance-growth

Hemlock, beech, red maple, and black birch are the species most commonly found forming the advance-growth of the Hemlock type, while red spruce, hard maple, yellow birch, white ash, black cherry, and white pine, in descending order of abundance, occur ~~more or less~~ with varying frequency in this division. Of these species, only white pine and black cherry show the inabilty of surviving the seedling stage and growing beyond the one foot class. Hemlock and beech are especially well represented among those trees having survived the seedling stage and which show signs of continuous growth under the adverse conditions present in this type.

The advance-growth is less abundant in the Hemlock type than that found in most of the types comprising the virgin forest. This may have been due to several reasons: namely, that in comparison with the types having a more abundant advance-growth, less sunlight reaches the forest floor, or the forest floor furnishes a poorer seed bed, or the moisture conditions are less favourable. One evidence that the absence of sunlight and proper moisture conditions are major factors in determining the amount of advance-growth under an overstory of hemlock is the tendency for the hemlock to become grouped in the openings whereas under heavy shade and stocking it is sparse or in many cases entirely lacking.

PINE - HEMLOCK TYPE

Upper-story

This type is most commonly found on the upper slopes and the tops of low ridges or knolls, that is, on the driest of the most protected sites. On these sites fire is more damaging than on the lower and more humid slopes and as a result of this the destruction of the overstory is usually more complete . Thus large openings are formed and the conditions for the entrance of pine into the dominant stand become quite favorable. Of the four types found on the most protected sites it is in this type alone that pine is a significant member of the upperstory . In the five plots taken in this type, hemlock shares the honors in abundance with the pine, while red maple sometimes red spruce enters into the composition. The stands are characteristically evenaged. The finding of charcoal in the duff of the older stands and the presence of charred remnants of a preceeding stand in the form of snags and prostrate trunks in the younger stands all point to the post fire origin of this type. Another proof of pine originating in a large opening such as would result from fire is the presence of wide growth rings in the center of the stumps examined in the cutover areas. This condition shows that the pine had an unhampered start and was free from much overhead shading and dense stocking. The most evident difference between the pine of the slopes and that of the ridge tops is its size in both diameter and height. Trees 36 inches in diameter and 125 feet in height are not at all uncommon in the older stands. The largest pine found measured slightly over 40 inches in diameter and 130 feetin height There is a marked absence of ground cover or advance-growth on the forest floor . The canopy is very heavy and there is a thick accumulation of litter , a condition brought about mainly by this density of cover preventing the

Pine approaches hemlock in longevity. In many cases, old pines 270-280 years of age ~~are found which are in~~ seemingly in good health, have been found. These trees are suprisingly free from defect of any kind except where fires occuring after the origin of the stand have so injured the trees as to make the entrance of rot a relatively easy matter; especially heart rot or red rot (Trametes pini). Groups of pine and hemlock are sometimes killed by the shoestring fungus (Armillaria mellea) but as in the Hemlock type the damage is not very widespread.

There is a marked absence of ground cover or advance-growth on the forest floor. The canopy is very heavy and there is a thick accumulation of litter, a condition brought about mainly by this density of cover, preventing, to a great degree, the action of sun and wind on this ~~more or less hard to decompose~~ slow-decaying pine-hemlock litter.

PINE - HEMLOCK TYPE

~~Upper-Story~~ Middle story

The outstanding difference in composition between the upper and middle stories of the Pine-Hemlock type is the absence of pine from the latter. The amount of hemlock in the middle-story is comparable to that of the upper-story, but in place of the pine we find hardwoods, namely, beech and red maple, while in some stands black birch, hard maple, and red spruce enter into the composition. It is evident then, that the pine of the overstory cannot ~~cannot~~ depend on the middle-story for successors of the same species, even in the event of a complete downfall of the dominant stand. The vigor of these middle-story trees is poor, especially in the case of the beech which here, as in the Hemlock type, is often found with the uppermost branches dead. Some of the trees, however, are relatively longlived and no doubt will replace some of the dominant stand in case of its breaking up.

Advance Growth

White pine enters into the composition of the advance growth but only in moderate amount, few in the seedling to one foot class, and ~~not at all~~ rarely in the one foot to fifteen foot class. This condition surely cannot be due to a deficiency of seed, but must, as in the hemlock type, be due to one or more of several reasons; ~~such as~~ a moisture deficit, a poor seedbed composed of an almost impregnable mat of needles and duff, or ~~to~~ a lack of sufficient sunlight for the growth of the species. In spite of the inability of white pine to establish itself under these conditions, other species such as hemlock, beech, red maple and black birch are found in the one foot to fifteen foot class. However, even with these species there is a very high death rate among the seedlings, there being a much greater number of them in the seedling to one foot class than in the one foot to fifteen foot class.

SUCCESSIONAL RELATIONS *On the Protected Sites.*

A forest composed of tree species which continually reproduce themselves and are relatively longlived under forest cover, can be ~~be~~ considered as being near or as having reached the climak. On the other hand, if the tree species are lacking in these characteristics they could be considered as only temporary occupants of the site and if Nature's methods are not interfered with by any major disturbances they will eventually be replaced by the climax species.

On the protected sites as a whole, hemlock, beech, and black birch stand out as being predominant in not only the upper-story but in the middle-story and advance-growth as well. Species which do not occur as frequently but which are nevertheless found throughout all stories are: hard maple, yellow birch, red spruce, and white ash. Paper birch appears only as a member of the dominant stand and white pine is found in the dominant stand and the smallest size class of the advance-growth. Red oak, basswood, ironwood, and pin cherry are comparatively rare.

White pine in other than the Pine-Hemlock type is found occupying the upper-story of only two plots, and is entirely absent from the middle-story and the larger size class of the advance-growth, and only poorly represented among the seedlings under one foot in height. It remains then, that although white pine reproduces itself, it is unable to endure the conditions existing under the forest canopies of the Hemlock, Hardwood, Hemlock-Hardwood, and Pine-Hemlock types and dies out after a few years growth. Unless some major disturbance occurs, it cannot survive to enter into the upper-story of the forest, thus precluding the possibilities of white pine ever forming part of the climax forest of the most protectes sites.

The presence of red oak seedlings in the protected sites is more or less unexplainable, for oak, being a heavy seeded tree, cannot seed in areas far distant from the parent tree. Perhaps squirrels

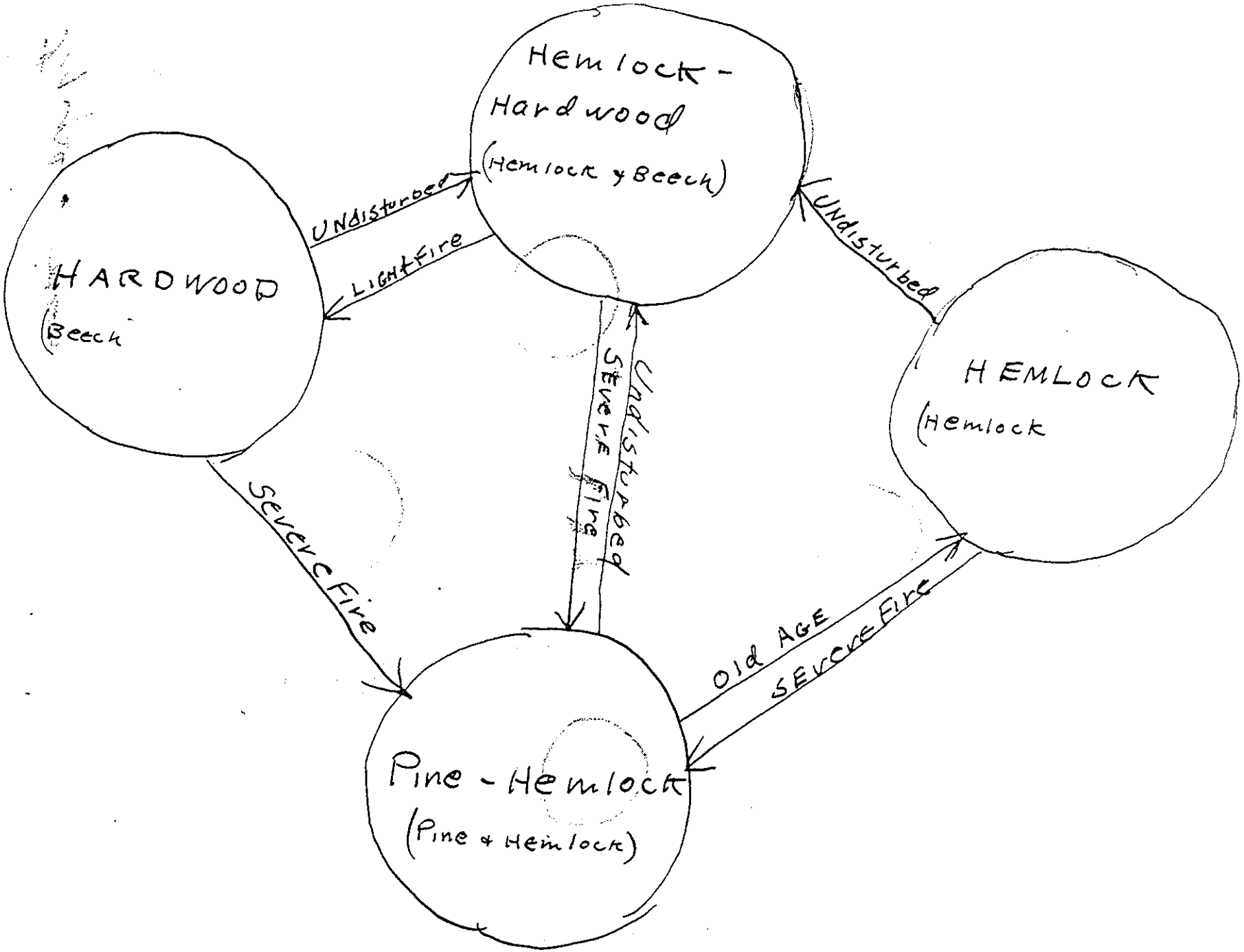
exposed sites, carry the acorns down slope and store them in the duff. Blue jays are also known to transport acorns, and perhaps they too are instrumental in the appearance of red oak. The presence of paper birch in evenaged stands has already been discussed. Basswood, ironwood, and pin cherry may have a place in the climax stand, but they are so few in number ~~so~~ as to be almost insignificant.

Toumey states, "The climax is reached when the occupation and the reaction of growth forms prevent the establishment by other dominant growth forms." Thus, of the types forming the forest on the protected sites, the Hemlock-Hardwood type illustrates these characteristics of the climax forest. Species comprising the dominant stand are the components of the subordinate stories; while species which are not typical of the overstory are only found in the advance growth , and then only as seedlings whose existance is of relatively short duration. For example, hemlock and beech which form the bulk of the species found in the dominant stand are ~~in~~ of similar abundance in the middle-story and the advance-growth, ~~thus~~ indicating the ability ~~of~~ to reproduc~~ing~~e themselves and ~~of being~~ to be relatively longlived under their own canopy. On the other hand, white pine (a member of the dominant stand in the Pine and Pine-Hemlock types and occasionally in the Hardwood and Hemlock types) reproduces on the forest floor of this Hemlock-Hardwood type but does not exist for long under the conditions there present. Thus we have a type in which only the elements similar to those occupying the overstory can enter into the dominant stand or, in other words, only the species forming the dominant stand can reproduce themselves and grow beneath the forest canopy.

In the Hemlock and the Hardwood types, however, the story differs somewhat from that of the Hemlock-Hardwood mixture. Here, in both types, a number of the species found in the dominant stand do not evidence the ability to perpetuate themselves beneath the

shade of the forest canopy. Take, for instance, the case of paper birch in the Hardwood type and that of pine in the Hemlock type, both of which occur only in the upper-story, are entirely lacking in the middle-story, and only poorly represented, if at all, in the seedling to one foot class of the advance-growth. It may be seen, then, that this condition surely is not indicative of a climax type of forest. However, the bulk of the trees forming the overstory, namely hemlock and beech, do have the power to reproduce themselves and to carry on their growth under the conditions existing beneath the canopies of these two divisions of the old-growth forest. Therefore, the presence of these species can be used as ~~a proof~~ an indication of the nearness of the types to the climax.

The Pine-Hemlock type seems the farthest removed from the climax than any other of the types forming the forest of the protected sites. As before mentioned in the description of this type, it is in this type alone that pine is at all a significant member of the dominant stand. However, it is in the dominant stand only that ~~the~~ pine is an importat element of the composition. In the middle-story the species is entirely absent, and it is only poorly represented, if at all, in the seedling to one foot classof the advance-growth. On the other hand ##### hemlock is well represented in all stories. It remains then that this type, if left undisturbed, does not continue as a Pine-Hemlock mixture but has a tendency to revert to a Hemlock ########################## type through the dying out of the pine and the leaving of a residual stand of pure hemlock, or, a Hemlock-Hardwood type as a result of the upper-story being replaced by the hemlock and hardwood of the middle story and advance-growth through the gradual droppingout of the dominant trees.



Successional Trends on Protected Sites of the Virgin Forest.

THE HIGH RIDGE STANDS.

The high ridge top stands may be divided into four types on the basis of the proportion of each species in the upper-story, ~~in any given area studied.~~ These four types (Pine, Pine-Hardwood, Pine-Hemlock, and Pine-Hemlock-Hardwood) are ~~here~~ discussed together because of their similarity in origin, growth requirements, site factors and successional relations.

Dominant Stand.

White pine, red oak, paper birch, black birch, and red maple were the principal species found in the overstory of the ridge top stands. (See Table --). The name of each cover type gives an adequate picture of the approximate percentage of each species in the overstory. The pines varied from fifty to eighty feet in height, ten to twenty-five inches in diameter, and fifty to 150 years in age. These figures give the extremes — any one stand was of course less variable in size and age. In fact, the ridge stands were quite even-aged in form. The hemlock and hardwood associates were as a rule appreciably smaller, though not necessarily younger, than the pines in the same story. Larger and older pines were not found in these high ridge stands because of the preva prevalence of windfall on such exposed situations. On every tenth-acre plot studied, four to six dead trees, their prostrate trunks in various stages of decay, were recorded. The crown density of the overstory varied from five-tenths to seven-tenths of a full canopy. In regard to distribution, the trees of the upper-story were for the most part uniformly spaced, although sometimes grouped by species.

Although, as their names imply, the dominant trees ~~or those~~ forming the overstory, varied in the proportion of each species present in the four ridge top types, the intermediate and the subordinate stories were to a marked extent similar in all respects. The middle-story in the high ridge ~~tops~~ types was generally composed of hemlock, black birch, red maple, beech, red oak, paper birch, and white pine, named in order of their abundance. In the case of a stand in the process of transition after a severe breakup of the upper-story due to windfall or fire or other major disturbances, pine and oak occupied a higher place in this ranking. The reasons for this difference will be elaborated ~~on~~ in a later paragraph.

The distribution of the individuals in the intermediate stand was fairly uniform in all cases. The apparent viger of individuals varied to such an extent that no significant rule or tendency could be discerned. As a species, beech seemed to be the least vigorous. This observation is doubtless significant when we note the apparent scarcity of beech in the dominant stand on these exposed sites. It is not surprising that hemlock should rank high in abundance under canopies of fairly high density, because of its tolerance of shade, and its inherent capacity for withstanding suppression. On some of the very high and dry situations, however, this species could not find sufficient soil moisture for optimum growth and was in such cases noticeably stunted, offering little competition to its associates. A relatively small number of the red maple, paper birch, and black birch species managed to survive and to eventually secure a place in the dominant stand. In many cases the trees of the intermediate stand (~~arbitrarily separated from the dominant stand in the field tabulation~~) were of the same age as the ###### trees of the overstory but happened to be suppressed and overtopped by their more fortunate associates.

Thus the ridge top stands seemed to exhibit a more marked tendency

toward the evenaged form than did those stands of the more protected sites, the lower slopes and valleys.

##########################

ɜd form than did those stands of the more protected

slopes and valleys.

Advance-growth

The species comprising the advance-growth in the high ridge types were ~~found to be~~ hemlock, red maple, black birch, paper birch, red oak and white pine. The rank of species according to abundance tended to be in the order named, although there were minor deviations or local differences. ~~Nature does not usually conform to any set rules.~~ No one of the advance-growth species was abundant except underneath an opening in the canopy, occasionally found in these stands. The pines were almost entirely small seedlings destined to an early death unless a severe breakup of the dominant stand occurred. As in the intermediate stand, pine and oak assumed a higher rank in abundance following a major disturbance, often outnumbering the hardwood and hemlock species in such cases.

Where pine and oak were found taking possession of an opening ~~a clearing~~ there was a noticeable difference in the appearance of the ground cover and the condition of the soil organic layer. In the early stages the combined work of fire and solar radiation caused the lessening or disappearance of the undecomposed litter and duff and the exposure of friable mineral soil. The herbacious growth was then generally an association of several species of grass and vaccinium, an entirely distinctive type of habitat. White pine, red oak and paper birch found ideal or optimum conditions for ########## germination and growth in these burned areas and windfall openings.

Possible origin of the ridge types

The marked scarcity of white pine in the intermediate stand and the advance-growth zones seemed to indicate that a sudden, practically complete overthrow of the dominant stand (such as might be caused by high winds, fire, or both) was necessary for the reestablishment of the pine ridge types. In all cases the location and extent of these stands were dependent upon the operation of the disturbing factor in breaking up of the old stand and causing an opening in the forest. Of the seedling pines found, only those starting in a fairly ~~extensive~~ large opening (at least 0.1 of an acre) were able to survive to eventually become part of the overstory. The characteristic thin dry soil on the ridges, the exposed position from a climatic standpoint, the intensity of ~~the~~ forest fire peculiar to these sites, the occurence of occasional high-velocity winds, and the consequent periodic blowdowns, all play an important part in type determination in these habitats.

The fact that the ridges are of a general north and south trend also is significant in that gales from the west are more prevalent than those from other quarters, as shown by meteorological records taken at Keene since 1890. Storms with winds of sufficient velocity, to cause the breakup of a fairly extensive stand (60 or more miles per hour) occur often enough to blown down any stand whose resistance has decreased to the crucial point. There must necessarily be an ultimate limit to increasing root anchorage.

The majority of pine increment borings in standing trees and ring-counts on stumps in nearby cutover areas showed comparatively wide annual rings in the center of the stem, indicating that the pine had an unhampered start. These investigations as to age also showed the pine to be in evenaged groups , further evidence of the start of pine in an opening or clearing.

The role of fire, insects, ### fungi, and lightning in causing ### the overstory in the virgin forest has been

heretofore explained, Thus we see how pine is given the opportunity to again establish itself and to get ahead of its hardwood and hemlock associates. In a good seed year the capacity of pine to thickly seed in an area, ########## with other conditions favourable , insures a fairly good survival of pine seedlings. But, in order that a few individuals may reach maturity there must necessarily be a high mortality from the seedling sta ge on.## Pine is known to be a little less exacting in its soil moisture needs than hemlock or any of the hardwoods on the dry ridges and burns where there is full exposure to light, ~~conditions are at an optimum~~. Hemlock is very sensitive to fire ~~Hemmmmmm~~ and high surface temperatures Taking all things into consideration, white pine has the advantage over hardwoods and #### hemlock in the race for occupancy of openings at least 0.1 acre in size in the old-growth forest on such sites. A sufficient number of these latter species remain and thrive along with the pine to make up the typical pine, hardwood, and hemlock mixtures, the varying proportions of the dominant species giving rise to the several cover type names or associations.

Table —

Typical Tenth-Acre Stand in Pine-Hdwd-Hemlock Ridge Type Before Fire or Blowdown. Ave. Number of Trees by Species & Story.

Species		White Pine	Red Oak	Hem-lock	Paper Birch	Red Maple	Black Birch	All Others	No. Dead & Down	Ave. Diam. & Hgts.	Approx. Age
Dominant Stand		5	3	3	1	1	1	*	2 W.P. 1 Hem. 1 R.O.	16" DBH. 90' Ht.	100-150 yrs.
Intermediate Stand		4	3	18	2	3	1	*	1 Hem. 1 B.B. 1 other	7" DBH 55' Ht.	90-120 yrs.
Advance Growth	1' to 15'	10	10	100	2	10	*	*	—	2" DBH.	20-40 yrs.
	Below 1'	16	7	70	3	20	*	*	—	—	1-10 yrs.

Average Crown Density .7. Note meagerness of advance growth in these stands, especially that of W. Pine & R. Oak, important species in the dominant stand. The seedling pines are unable to survive beneath a dense canopy, and W. Pine fails to reach a dominating position in the future stand unless a major disturbance occurs.

Typical Tenth-Acre Stand in Pine-Hdwd-Hemlock Ridge Type After Light Fire or Blowdown. Ave. Number of Trees by Species & Story.

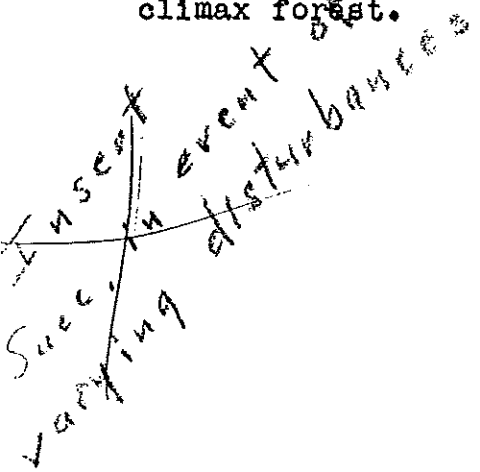
Species		White Pine	Red Oak	Hem-lock.	Paper Birch	Red Maple	Black Birch	All Others	No. Dead & Down	Ave. Diam. & Hgts.	Approx. Age
Dominant Stand		2	1	—	—	—	—	—	4 W.P. 2 R.O. 3 Others	16" DBH 90' Hgt.	130-160 yrs.
Intermediate Stand		14	3	7	17	10	3	2	5 Hem 2 W.P. 2 Others	7" DBH 55' Ht.	100-130 yrs
Advance Growth	1' to 15'	160	10	350	30	40	50	20	—	2" DBH.	20-40 yrs.
	Below 1'	20	6	80	8	2	3	4	—	—	1-10 yrs.

Average Crown Density .1. This table gives a composite picture of ridge top stands in various stages of transition following a severe breakup. Note relative abundance of W. Pine, R. Oak & P. Birch, all light-demanding, in the intermediate stand and advance growth. All the ridge-top types are similar in this respect.

Successions in the Pine Ridge Types.

In the event that a breakup does not again occur before the end of the normal life of a pine ridge stand originating through a previous breakup, what species will compose the ensuing stand? It has been shown that pine will establish itself in an opening, but what happens if fate or chance decrees no major disturbance?

According to data obtained on the plots studied, the Hemlock-No. Hardwood association is most likely to succeed the pine ridge type in the absence of any major disturbance. The species of the Hemlock-No. Hardwood type, ~~are~~ relatively long-lived and able to reproduce under a forest cover, are undoubtedly the climax dominants of the northern conifer-hardwood region within the limits of the area studied. In the case of the ridge top sites, however, there seems to be no prospect of the failure of fires and extensive windfalls to recur fairly regularly. Thus the pine ridge type is for this region a physiographic climax in itself. On the somewhat more protected habitats the pine groups becoming established following a major disaster may be considered as filling a gap in a damaged climax forest.



The average soil profile measurements, classified by types, are given in Table __. There are evidently no striking variations among the different forest types, except for a perceptible increase in thickness of the organic layer with an increase in the proportion of conifers in the stand. The leached layer also is slightly thicker under the coniferous stands, due to the fact that less light reaches the forest floor. Decomposition of the organic layers is greatly slowed up and the valuable mineral nutrients remain longer in a form not available for plant growth. The undecayed raw humus is made up for the most part of a mat of pine and hemlock needles, while the hardwood leaves decompose more readily. It follows as a corollary that the thickness of the dark brown enriched layer, indicative of the fertility of the soil, ~~increases~~ becomes greater with the increase in proportion of hardwoods in the stand.

Table —

VIRGIN FOREST SOIL PROFILES - MT. PISGAH, N. H.

TYPE	← Average thickness (inches)				No. of Plots Basis
	Organic Layer (Litter, Duff + Mor)	Leached Layer	Dark Brown (Enriched Zone)		
Pine	2.6	0.7	0.6		13
Pine-Hdwd.	2.0	0.4	0.3		2
Pine-Hem.-Hdwd.	2.4	0.5	0.6		7
Pine-Hemlock	2.6	0.7	0.6		8
Oak Ridge	2.1	0.5	1.0		2
Hemlock	2.4	0.6	0.8		16
Hardwood	1.8 1.9	0.4	1.0		12
Hem.-Hdwd	2.0	0.8	0.8		11

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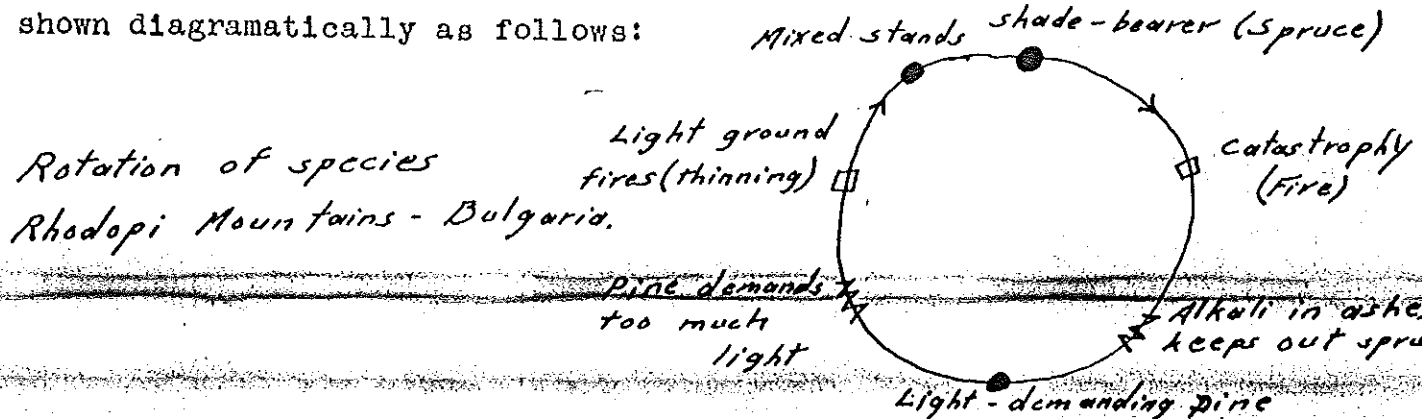
Europe (9) is given to show the similarity in origin between Pinus sylvestris, in that region, and Pinus strobus in Southern New Hampshire: In the Rhodopi Mountains of Bulgaria the natural reproduction of Pinus sylvestris in the undisturbed virgin forest is almost impossible on account of the raw humus, dry turf, and weeds. The seed does not germinate in such a seedbed. An occasional severe crown fire in that region clears, cleans, and disinfects the area and leaves a germination bed of ashes and mineral soil very favorable for the start of ~~the~~ Pinus sylvestris. Thus large areas of pure, even-aged stands of this light-demanding ~~species~~, fire resistant, and prolific ~~seeder~~ species, are found in the Rhodopi.

Following the establishment of the pure Rhodopi pine stands subsequent light ground fires thin out some individuals in the dense growth and permit the start and survival of a small amount of spruce (Picea excelsa), a "shade-bearing" species requiring a seedbed of wood humus. The spruce will not germinate in the alkaline ashes of the burned-over areas. In addition the seedlings require a greater amount of soil moisture than do those of the pine. The most stable type in the Rhodopi, in the absence of catastrophy, is a pure stand of "shade-bearers", mostly Picea excelsa. But since fire is an ever-present factor, the light-demanding type predominates. As soon as the moist, non-alkaline wood humus begins to form, in the interval between fires, however, the tolerant spruce slowly comes back until eventually there is a mixed stand of pine and spruce; the pine even-aged in form, the spruce younger and all-aged. This succession or rotation of types is shown diagramatically as follows:



Rotation of species
Rhodopi Mountains - Bulgaria.

TREES FOUND IN THE MOUNT PISGAH VIRGIN FOREST.

Common Name	Scientific Name
Ash, Black	Fraxinus nigra
Ash, White	Fraxinus americana
Aspen, Largetooth	Populus grandidentata
Aspen	Populus tremuloides
Basswood	Tilia glabra
Beech	Fagus grandifolia
Birch, Black	Betula lenta
Birch, Paper	Betula papyrifera
Birch, Yellow	Betula lutea
Cherry, Pin (Fire)	Prunus pennsylvanica
Chestnut	Castanea dentata
Gum, Black	Nyssa sylvatica
Hemlock, Eastern	Tsuga canadensis
Ironwood	Ostrya virginiana
Maple, Mountain	Acer spicatum
Maple, Red	Acer rubrum
Maple, Striped	Acer pennsylvanicum
Maple, Sugar (Hard)	Acer saccharum
Oak, Red	Quercus borealis maxima
Oak, White	Quercus alba
Pine, Northern White	Pinus strobus
Pine, Norway (Red)	Pinus resinosa
Serviceberry (Shadbush)	Amelanchier canadensis
Spruce, Black	Picea mariana
Spruce, Red	Picea rubra

SHRUBS AND HERBACIOUS GROWTH FOUND IN THE MOUNT PISGAH VIRGIN FOREST

Scientific Name	Common Name
Aspidium marginale	Wood (shield) ferns
Aspidium spinulosum	" " "
Aster spp.	Asters
Aralia nudicaulis	Wild sarsaparilla
Chimaphila umbellata	Pipsissewa
Coptis trifolia	Goldthread
Cornus canadensis	Bunchberry
Epigaea repens	Arbutus
Epipactis pubescens	Rattlesnake plantain
Gaultheria procumbens	Wintergreen (Checkerberry)
Gaylussacia baccata	Black Huckleberry
Gramineae	Grasses
Hamamelis virginiana	Witch hazel
Kalmia angustifolia	Sheep laurel
Kalmia latifolia	Mountain laurel
Lilium spp.	Lily-of-the-valley (& others)
Linnaea borealis	Twinflower
Lonicera canadensis	American Fly Honeysuckle
Lycopodium annotinum	Club Moss
" clavatum	" "
" lucidulum	" "
" obscurum	" "
Maianthemum canadense	Canada Mayflower
Medeola virginiana	Indian Cucumber-root
Mitchella repens	Partridge Berry
Nemopanthus mucronata	Mountain Holly
Oxalis acetosella	Wood Sorrel
Polypodium vulgare	Rock Fern

SHRUBS AND HERBACIOUS GROWTH (CONT'D)

Scientific Name	Common Name
Polystichum acrostichoides	Christmas fern
Pteris aquilina	Brake fern
Ribes prostratum	Skunk currant
Rubus spp.	Raspberry
Sambucus canadensis	Elder
Smilacina racemosa	False Solomon's Seal
Smilax rotundifolia	Green briar
Taxus canadensis	Yew (Ground Hemlock)
Vaccinium pennsylvanicum	Blueberry
Viburnum acerifolium	Arrow-wood
" lentago	Wild raisin (Nannyberry)
" alnifolium	Witch hobble
Viola spp.	Violet

SUMMARY OF CONCLUSIONS

1. In the Mt. Pisgah virgin forest in southern New Hampshire the exposed ridge top sites support even-aged mixtures of White Pine, Hardwoods and Hemlock.

2. On the more protected slopes and knolls the Hemlock, Northern Hardwood, Hemlock-Hardwood and Pine-Hemlock types are predominant.

3. These correlations of site and type are due mainly to the varying influences of fires, windfall, lightning, insects and fungal diseases on forest stands on the different sites.

4. The presence of White Pine in nearly pure even-aged stands on the ridge tops in this region is correlated with the prevalence of windthrow (blow-downs) and severe fires on such unprotected sites.

5. The presence of even-aged groups of dominant White Pine on the protected slopes and in the valleys is correlated with the work of fire, lightning, insects, fungous diseases, icestorms and an occasional blowdown in breaking up the old overstory and causing an opening at least one-tenth acre in area in the forest.

6. The physiographic climax association characteristic of the exposed ridge top is the Pine-Hardwood-Hemlock type. Red Oak and Paper Birch, both light-demanding species, are the principal hardwoods in this type.

7. The climatic climax association on the protected sites is the Hemlock-Northern Hardwood type.

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DISTRIBUTION OF STANDS ACCORDING TO ELEVATION AND EXPOSURE

Type	Low- or Mid-Slope		High-Slope		Ridge Top			Total
	N & E	S & W	N&E	S&W	N&E	S&W	All Sides	
Northern Hardwoods	8			1	1		1	11
Hemlock-Beech	7				1		1	9
Hemlock	7	2	1	2	2	1	1	16
Hemlock-White Pine		1	2	2				5
White Pine		1		2	1	4	4	12
White Pine-Hemlock-Oak		1	1		1	2	3	8
White Pine-Oak			1	1				2
Oak			1	1			3	5

NORTHERN HARDWOODS - HEMLOCK CLIMAX (Climatic Climax)

Lower Elevations
Most Protected Sites
Best Soils

COVER TYPES	
NORTHERN HARDWOODS	Low or Mid-Slopes
HEMLOCK - BEECH	
HEMLOCK	Mid or High-Slopes
HEMLOCK - WHITE PINE	High-Slopes

WHITE PINE - HEMLOCK - OAK CLIMAX (Physiographic Climax)

COVER TYPES	
WHITE PINE	High-Slopes and Ridge Tops
WHITE PINE - HEMLOCK - OAK	
WHITE PINE - OAK	
OAK	

Higher Elevations
Most Exposed Sites
Poorest Soils