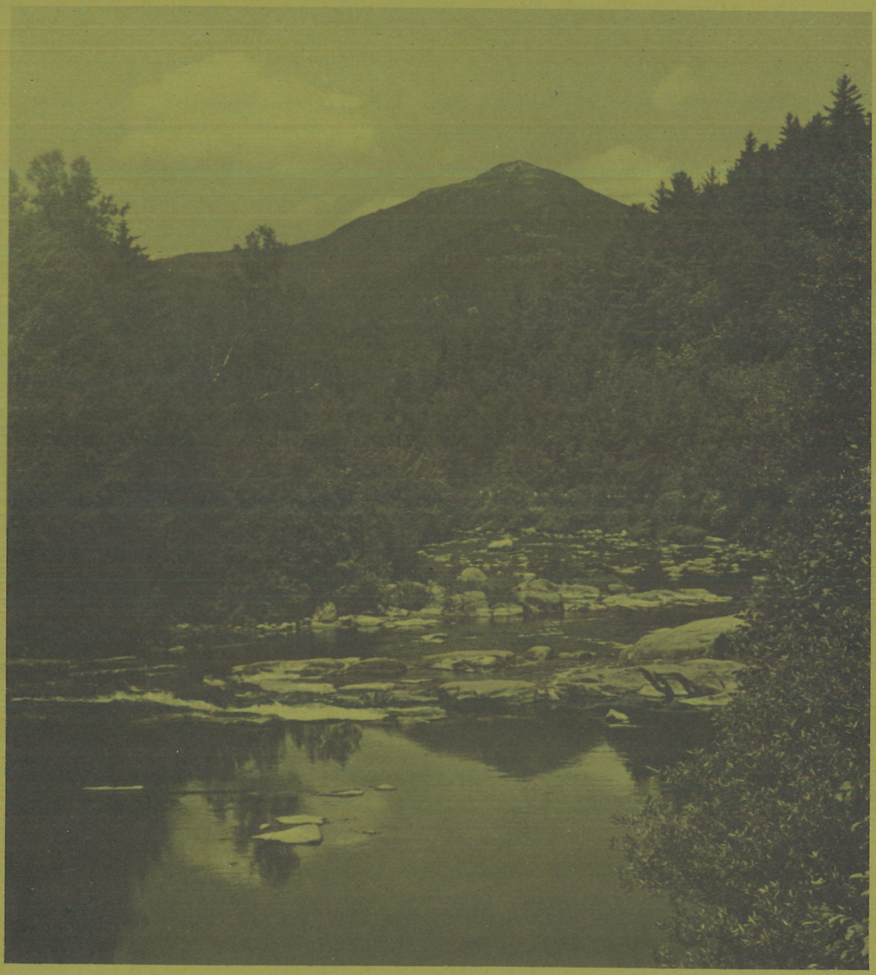
Vegetation-Environment Relations

at Whiteface Mountain in the Adirondacks

J. Gary Holway • Jon T. Scott
Co-Investigators



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VEGETATION-ENVIRONMENT RELATIONS AT WHITEFACE MOUNTAIN IN THE ADIRONDACKS

Report No. 1

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INTRODUCTORY REMARKS

This report is the first in a planned series on the ecology of Whiteface Mountain. The research included began in 1964 as a summer program sponsored by the Atmospheric Sciences Research Center. In 1967 further support was provided by the National Science Foundation.

While some of the papers in this report have been completed or nearly so for periods of one to three years, it was decided to hold their printing until all of the reports were finished. It was hoped that the result would be a more complete picture of the Whiteface ecology studies. Certainly, there are desirable features of having these eight related studies in one report. Unfortunately, this procedure has delayed publication of the early results. We apologize for the inconvenience to the many interested persons who have written to us for reports.

The results presented here represent the early phases of a planned long-term study of vegetation-environment relations in the Whiteface Mountain region. The first four papers deal with the nature of the vegetation, its variation with topography and comparison with other regions. The next two deal with special aspects of the vegetation; one with the alpine tundra and the other with an important species. The last two papers represent beginning studies of the environment.

The investigators are in accordance with the viewpoint that an important approach to the study of nature lies in understanding the ecosystem. The ecosystem, no matter how it is defined, cannot be understood except in an environmental framework. Much of our present and planned future studies deal with measuring the environment and understanding its relation to the living component of the ecosystem.

ACKNOWLEDGEMENTS

The co-investigators wish to thank the many persons and organizations who have contributed to the work leading to this report. Many of these are acknowledged in the individual papers. We wish to express special thanks to Vincent Schaefer, Director of the Atmospheric Sciences Research Center and Raymond Falconer, Director of the ASRC Field Station at Wilmington, N.Y., whose cooperation has been invaluable. We thank the Natural Sciences Institute sponsored by the Kettering Foundation for the help provided by many of its student participants and are grateful to the Whiteface Mountain Authority and New York State Conservation Department for cooperation on use of the mountain facilities.

Many persons provided useful advice and discussion on various aspects of the research. These include in particular Richard Arnold, Earl Stone, and Lee Miller of Cornell University, Edwin Ketchledge of Syracuse University, Orie Loucks of the University of Wisconsin, Richard Park of Rensselaer Polytechnic Institute and Stanley Smith of the New York Museum.

We are especially grateful to the Atmospheric Sciences Research Center and the National Science Foundation (GB-7020) for support of this research.

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by

J. Gary Holway, Jon T. Scott,

and Stuart Nicholson

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ABSTRACT

One hundred and eighty-two forest stands located by both selective and systematic means were sampled for the standard ecologic parameters of frequency, density and basal area. Under the systematic stand selection method altitude and slope aspect were the determining factors in site selection. Selective stand location was used to increase the sample size of 'undersampled' association types.

The tree species presence list for all stands includes 30 species. At least one or the other of the three leading stand dominant species, red spruce (*Picea rubens*) 143 stands, balsam fir (*Abies balsamea*) 120 stands, and sugar maple (*Acer saccharum*) 80 stands, occurs in all but 9 of the stands and dominates 103 of them.

The altitudinal ranges 1500 ft and under, 1500-2500 ft, and 3000 ft and over are primarily dominated by species associations representative of the Appalachian oak and pine, the northern mesic-hardwood and the boreal floristic provinces, respectively. Less expected than the altitudinal relationships was the apparent effect of slope aspect on composition. While north facing slopes are typically envisioned as being more boreal, on Whiteface the west slope was in all stands except those above 4000 ft.

INTRODUCTION

The forest vegetation of the Adirondack Mountains in northern New York has received little attention from ecologists. This is difficult to understand in view of the floristic diversity of the region and its strategic location between boreal forests to the north and the Catskill and Appalachian mountain forests to the south.

This paper is the first in a planned series concerning the relation between vegetation and environment in the region of Whiteface Mountain in the northern part of the Adirondacks. It deals primarily with a description of the study area, its dominant vegetation and how this vegetation is distributed over the wide range of topographic habitats on Whiteface Mountain. The present findings are based upon standard ecologic measures from 182 forested stands taken during three summers from 1964-1966. Later papers will emphasize more detailed statistical treatment of the data including a comparison of several techniques for obtaining the vegetation gradient (or ordination) similar to those discussed by Goff and Cottam (1967), methods of measuring forest environments and techniques of relating vegetation and environment gradients.

THE STUDY AREA

General

One of the high peaks within the protective boundaries of the Adirondack Forest Preserve seemed a reasonable choice as a site representative of forest vegetation in the Adirondacks. To be compatible with the research aims, the mountain selected had also to meet the requisites of floristic and physiographic diversity and preferably be readily accessible without being excessively disturbed. Whiteface Mountain, northernmost of the high peaks of the Adirondacks,more than met these criteria.

Whiteface Mountain (4867 ft) is the fifth highest peak in New York State. It is located just west of the village of Wilmington, in the Town of North Elba, Essex County. The base of the mountain, which varies from about 1000 ft on the east to over 1900 ft on the west, rises quite abruptly on all sides to a horn-like summit. The east and west sides of the summit exhibit well developed cirques, with a moderately-developed cirque on the northern exposure.

The cirques are separated by rather sharp, arete-like ridges which broaden out or slope up again to form minor peaks at some distance from the summit (see Figure 1). Compared to the other Adirondack high peaks, Whiteface is relatively isolated. Except for Mount Esther (4200 ft), and Lookout Mountain (4000 ft), which are, in effect, sub-peaks, of the Whiteface massif, the nearest 4000 foot peaks are more than 10 miles to the south. This isolation allows more critical evaluation of mountain physiographic effects on microclimate and vegetation distribution because of the reduction of modifying influences by nearby peaks.

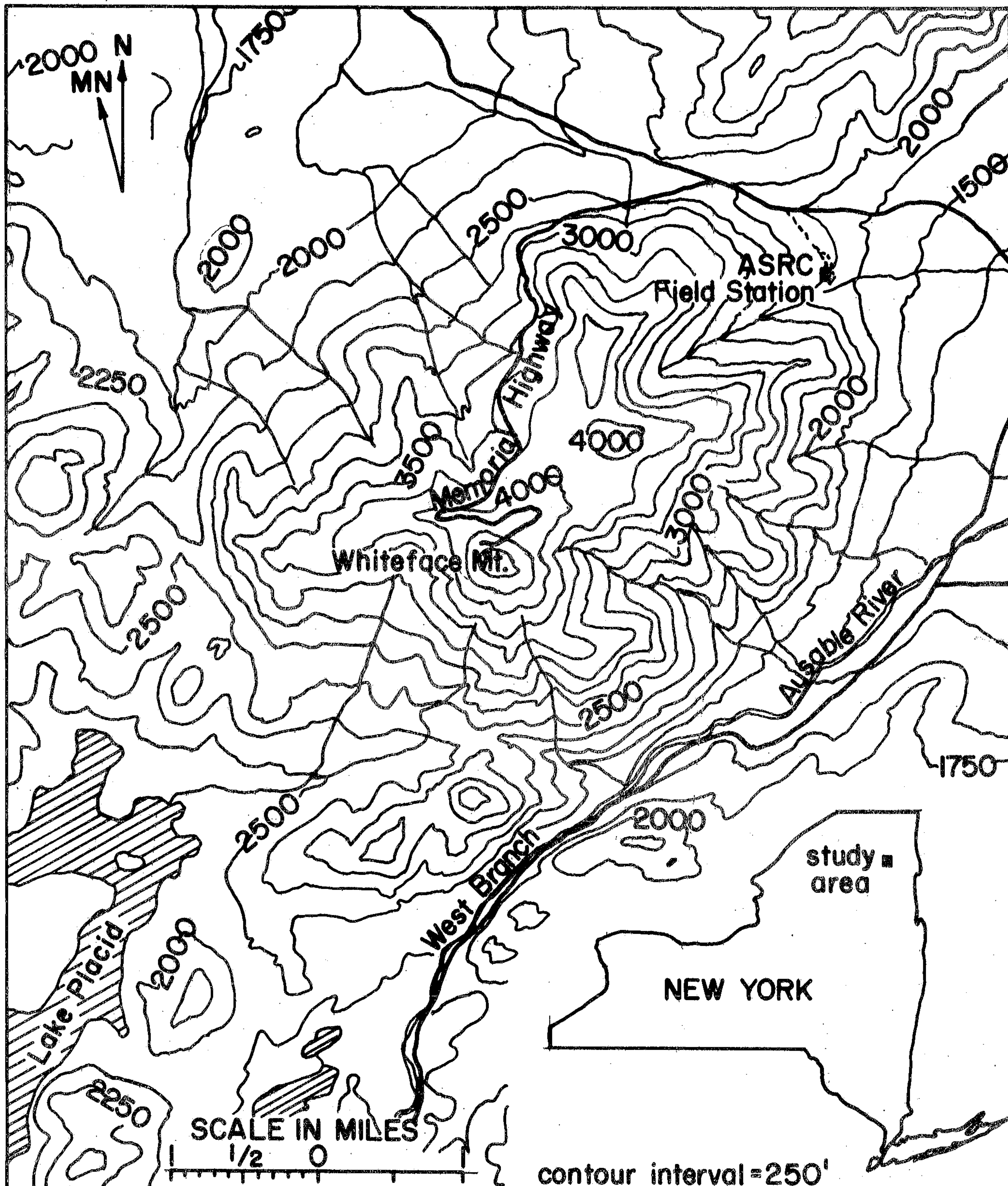
The flora of Whiteface ranges from a sparsely developed alpine tundra with extraneous elements of arctic tundra present on the summit, through dense spruce-fir boreal elements to mixed hardwood and coniferous types near the base with many species typical of more southerly climates. In addition, there are abundant oak, pine, and bog (spruce and tamarack) associations in the vicinity. Indeed, it is not uncommon to find elements of arctic, boreal forest, and deciduous forest biomes existing within the same square mile of area.

Accessability was another of the strong attributes of Whiteface. It is 150 miles from the State University Center at Albany and 35 miles from additional facilities at State University College at Plattsburgh, New York. Whiteface Memorial Highway allows ready access to the summit, and the Whiteface ski area facilities provide similar ease of access to the east and southeast sub-prominences. In addition, there are hiking trails, and roads of one form or another (county highways or closed fire-access roads) virtually encircle the basal perimeter of the mountain. All of these have contributed to the ease of obtaining the vegetation data.

Another attribute of Whiteface that might seem contradictory to the accessibility of the area is the relative freedom from modern disturbance. While the summit and roadway show marked effects of heavy tourist impact, and the ski site development has created severe localized disturbance, the greater portion of the mountain has been free of significant human disturbance since the passing of the "Forever Wild" legislation in 1896.

A final factor which strongly influenced the selection of Whiteface was an invitation extended by the Atmospheric Sciences Research Center of the State University of New York to base operations at their Marble Mountain Field Station located at 1980 feet on the east slope of the Whiteface complex.

Figure 1: Map of Whiteface Mountain study area. The area shown contains 132 of the 182 stands sampled.


N
MN
2000
1750
2000
1500
2500
3000
2000
2000
ASRC
Field Station
2250
Memorial Highway
4000
3500
4000
2000
3000
Whiteface Mt.
2500
Ausable River
2500
1750
2500
2000
West Branch
study
area
Lake Placid
2000
NEW YORK
2250
SCALE IN MILES
1
1/2
0
1
contour interval = 250'

Geology

The Adirondacks are one of the oldest mountain ranges on earth. Metamorphic rock beds form the bulk of Whiteface and were intruded into sedimentary rocks of the Grenville series, about 1.1 billion years ago (Bird 1963). The mountain consists primarily of Whiteface anorthosite. Only the lower western portion of the mountain is granitic. Erosion since early Cenozonic has completely removed deposits formed during the Paleozoic submergences (Miller 1918). The major features evident today are the result of Pleistocene glaciation which culminated in the Wisconsin age about 10,000 years ago generally, but ended much more recently at the higher elevations. Cirques, U-shaped valleys, and the many lakes and ponds, all bear testimony to this glacial impress. Glacial moraines are also well dispersed over the Whiteface terrain. Isachsen (1964), reports that striations on the highest Adirondack peaks imply a minimum ice thickness of 6000 ft. Craft (per. comm.), who has been studying the Pleistocene geology of the Adirondacks, with particular interest centered on Whiteface and the high peaks area, can present data to support a lower thickness for the continental ice sheet during the last glacial advance in the Adirondacks. He has found no evidence of continental glaciation above approximately 4200 ft, although there is considerable evidence below this elevation throughout the high peaks area. Craft hypothesizes that near the end of the Wisconsin stage the peaks above 4200 ft appeared as nunataks sticking up out of the continental sheet and that the till and debris from earlier advances became eroded from these peaks. This would help to account for the very shallow mineral soils to be found on the summits of the higher Adirondack peaks.

Adirondack Forest Soils

There have been few studies of the forest soils in the Adirondacks to date. Heimburger (1934), emphasized that drainage conditions and the geological origin of the soil are of primary importance in the distribution of vegetation in the Adirondacks. In this report he also superficially describes a number of Adirondack forest associations in relation to soil types.

Donahue (1940) reported on a forest-site quality investigation, and McFee and Stone (1965) made a quantitative analysis of the physical and chemical nature of an Adirondack forest podzol near Paul Smith's, approximately 20 miles west of Whiteface.

Reilly, (1964), has described broad soil features encountered in a study of the mosses of Whiteface, but these are primarily qualitative observations.

Our observations show that there is considerable variation in the characteristics of the soil under the various forest associations. Near the summit the forest is rooted in many cases in thick peaty mats overlying virtually structureless and poorly differentiated mineral soil horizons containing many boulders. Conversely, the deciduous forest associations have the typical brown podzol characteristics with shallow organic layers, well developed A_2, and well defined structures and mineral horizons. The soils are primarily acidic even though most are derived from the underlying anorthosite which is basic.

An intensive study of the soils in the Whiteface region was made by Witty (1968). His main emphasis was to establish a set of criteria for classification of the Adirondack forested soils. He identified and described 18 subgroups including 12 histosols and 6 spodosols for the Whiteface area. Witty's extensive quantitative data will form the basis of our own evaluation of forest soil environment in later studies.

Climate

The Adirondacks are a region of cold snowy winters and cool wet summers. Under the Koppen-Geiger system the typical lowland Adirondack climate fits a Dfb, or very nearly a Dfc, the cold-summer, humid continental type. Near the summits of the higher mountains the climateis colder, more windy and more moist with a high frequency of cloud caps. Rime icing may occur in any month of the year.

The Adirondacks receive from 37 to 53 in. of precipitation annually with an excess precipitation over evapotranspiration of from 25 to 40 in. The region is the source of the Hudson and other rivers.

The growing season in the Whiteface region is about 80 to 105 days in the lowlands with much shorter periods near mountain summits. The cumulative monthly degrees over 40°F is below 100 in the lowlands. Mean monthly temperatures near the summit of Whiteface are from 10°F to 15°F lower than at Lake Placid with summer monthly means of 50°F to 58°F.

Vegetation History

Historical records, filed evidence, and interviews with long-time residents, indicate some marked differences between many of the original forests and present cover. Damage to vegetation by Indians and transient visitors appears to have been negligible prior to permanent settlement in the 1800's. Wood was cut only for local use until cutting of hardwoods for charcoal production began east of Lake Placid in 1815, and near Wilmington in 1832. Charcoal cutting continued in the lowlands until the late 1800's. These clear-cutting operations were frequently followed by fires of varying intensities. A severe fire on the summit in 1867 (Watson, 1869) is the only other known disturbance of major proportions before pulp logging began in 1892. As late as the 1860's, much of the total forest area on Whiteface Mountain was apparently untouched.

Virtually all of the spruce-fir was first-growth when pulping began. Street (1869) emphasized the "gloom of the terrific forests" on the east side of Whiteface, and Stoddard (1879) pictured the coniferous forests on the north as "dark and thick."

Pulp cutting began on the east side of Whiteface and ceased before 1900, but not before much of these first growth forests had been completely decimated. Marketable size spruce and balsam (6" basal diameter) were cut wherever they grew in profitable numbers. The last trees were taken from the west side of the mountain which was least accessible and now shows the least disruption. These despoiling practices and the prevalence of fires throughout the Adirondacks prompted protective forest legislation in 1896.

In 1909 a fire tower was built on the summit of Whiteface. Nonetheless, reports of fire and disturbance during the last 60 years are fragmentary and somewhat contradictory. W. C. Petty, District Conservation Officer, states that there has been no appreciable fire damage since 1909, but France and Lemon (1963) mention an extensive fire on the mountain in 1915. Mr. Rogers, son of the mill owner in charge of the logging recalled that Whitebrook Valley was burned about that time, and O'Kane (1928) confirms this. Other long time residents, however, recalled no major fires after 1900. Aerial photographs and field studies confirm a large burned area of uncertain age at 2000 to 3000 ft on the northwest side, a large burn over much of the east side from about 1500 to 3000, and several other smaller burned areas.

COLLECTION OF FIELD DATA

Stand Selection

The selection of stands was primarily based upon a systematic procedure. It was arbitrarily decided to sample at 500 foot altitude intervals over a range of slope aspects and magnitudes. To reduce the field time promising sites were "preselected" by examining aerial photographs and topographic maps with the criterion that the photograph revealed that the site was not markedly disturbed. If upon reaching the predetermined sites they were judged to be recently disturbed by conditions such as logging, fire, wind damage, etc., then the nearest "undisturbed" site was sought and sampled. If none could be found in the immediate vicinity, the preselected location was left unsampled.

Preliminary analysis of the first 2 years of stand data showed that only small samples of certain species which are relatively common in the study area, particularly at lower elevations, were included. Because white pine (Pinus strobus)[1] and hemlock (Tsuga canadensis) were undersampled, these species could not be well located on an ordination using the methods of Curtis and McIntosh (1951). No systematic stand selection method easily resolved this problem. Therefore, stands which contained these species were sought and sampled. Consequently, our selection procedure was not entirely systematic. Rather, because of the physiographic characteristics of the study area, a combination of systematic and selective stand location was employed.

Vegetation Data

Stands were sampled for density, basal area and frequency at points 20 paces apart. Normally, 10 to 40 points were used depending upon the vegetation type. For example, it was not deemed worthwhile to obtain a large number of points in stands containing a few species while larger samples (30 to 40 points) were used in diverse vegetation.

The sampling points were paced along the slope. No change in course was made because of the type of vegetation present. However, if the direction of the slope changed 45 degrees or more from the original point, the

1 - Classification is according to Fernald (1950).

course was altered. The sampling then proceeded 2 points (40 paces) downhill and then in the reverse direction to the original course. The same procedure was used when an area of disturbed vegetation, usually wind-throw, was encountered. The stand definition was therefore based primarily upon the topographic features of altitude and slope aspect rather than on composition.

Measures of the density, frequency and basal area were obtained for forested stands at elevations from just below 500 ft to above 4500 ft. In 1964 the quarter method (Cottam & Curtis, 1956) was used. In 1965 and 1966, the quarter method was used for frequency, while Bitterlich prisms (Grosenbaugh, 1952) were used to calculate basal areas and to establish circular radius plots for density determinations. The efficiency of this combination of methods has been cited by Lindsey et. al. (1958).

To ascertain a suitable radius to use for the circular plots, a test plot was established in a beech-maple stand. There was a complete counting of all trees and saplings within the test plot. The plot was then sampled by a quarter method and also by the combination quarter and Bitterlich prism method using 1/40 and 1/80 hectare plots. The 5, 10, 20, 30, and 50 factor prisms were compared. Statistical comparisons of the results of these sampling methods to the actual data for the test plot showed that the most efficient method was the 1/80 hectare radius plot with the 30 factor prism for density and basal area combined with the quarter method for determination of frequency.

Values of sapling density and frequency were obtained by the quarter method in all stands. Saplings in this study were considered to be any stems greater than 1 inch but less than 4 in dbh.

The frequency, density and basal area (dominance) values were relativized for both trees and saplings in order to determine the relative importance value in percent for ease of interpretation and interstand comparison.

Ground flora was sampled by 1 square meter quadrats placed at each quarter point within a stand. Frequency of herbaceous species and tree seedlings was recorded.

In addition to the collection of quantitative data at each stand location, the general features of the vegetation were described. Average height of the canopy, degree of cover, uniformity, or heterogeneity or age were estimated. Evidences of disturbance such as cut stumps, charcoal, wind throw, and insect damage were also noted. Any unusual or distinguishing characteristics of individual tree species were likewise noted.

Supplemental Data

Preliminary measurements of variables pertaining to the substrate included observations of slope magnitude and direction, and distance to the nearest ridge and drainage channel. Also measured were depth of litter, fermentation and humus layers in the organic matter zone and of leached and accumulation layers in the mineral zone when they could be readily distinguished. Qualitative observations of soil texture and general description of the overall physiography of the site were made. Any unusual or distinguishing site characteristics such as the presence of charcoal, buried horizons, erratics, mounds, and troughs were noted.

The summit of Whiteface Mountain was used as a Weather Bureau auxiliary station for a total of 8 years beginning in 1937. The standard meteorologic variables have been measured year-round by the ASRC staff at Marble Lodge Station and during the summer months at the summit and various other locations on or near Whiteface. Since 1964, net-radiation and solar radiation have been recorded year-round at Marble Lodge and during the summers at the summit.

Topographic Properties of the Sample

Because of the non-random stand selection procedure there was no guarantee that a representative sample of the vegetation was obtained. Because some regions on Whiteface Mountain were more disturbed than others, certain slope aspects and altitudes may have been undersampled.

A check on the representativeness of the sample was made by comparing its topographic properties (altitude, slope-aspect and slope magnitude) against those of a random selection of points on a map of the study area. Because the area containing the entire sample was rather large and not well defined only the stands on or in the close proximity of Whiteface were used for the comparison. Random points were then plotted on this same area and the topographic properties determined for these points which did not fall on lakes or roads. This comparison is given in Table 1 where percentages of the respective samples are given for the three topographic properties. Data for the total sample (182 stands), which includes much of the low-lying region surrounding Whiteface Mountain, are also included in Table 1. The vegetation sample of Whiteface-proximity area (156 stands) was over represented by stands at high altitudes and under represented by sites in the altitude ranges centered on 1500, 2000, and 2500 feet. The total sample was probably more representative of the region but over-sampled at the range centered on 1500 feet. The mean altitude of the stands near Whiteface (2710 ft.) was higher than that of the total sample (2310 ft.) and of the random points (2200 ft.).

The vegetation samples compared more favorably with the random points in the slope-aspect property (Table 1) but north facing and level sites were oversampled. Northeast and northwest sites were under-sampled. Comparing the slopes of the sample with the random sites shows an oversampling of steep slopes and undersampling of slopes in the 1 to 15 degree range.

TEST FOR HOMOGENEITY

The primary emphasis in this study was to describe the vegetation of a mountain with a wide range of environments caused by topographic variation. The selection of a stand was based upon topography and not upon the species or groups of species contained within an area. No effort was made to obtain homogeneous stands, but a test of homogeneity was desired for later analyses of the data. Therefore, a chi-square test was applied to all 182 stands. The test was the same as used by

Table 1: Percent of stands in various topographic groups for different cases. Data in the first column are for the total sample of 182 stands, in the second column for only those stands on or in the close proximity to Whiteface Mountain (156 stands), and the third column for random points on the map of the region in close proximity to Whiteface.

Altitude Range	Total Sample	Whiteface Proximity	Random Points
500	1.6	0.0	-
1000	6.5	0.0	5.6
1500	28.4	19.2	14.2
2000	19.7	19.2	38.6
2500	13.0	18.4	22.3
3000	8.7	12.0	9.6
3500	8.7	12.8	6.2
4000	9.8	13.6	3.5
4500	3.3	4.8	0.0
	100.0	100.0	100.0
Mean altitude	2310	2710	2200
Slope-aspect Range			
N	12.6	16.0	13.0
NE	8.2	7.2	16.1
E	7.1	8.0	9.9
SE	19.2	17.6	14.1
S	11.0	8.8	7.3
SW	6.0	11.2	8.3
W	12.6	11.2	10.4
NW	12.6	12.0	19.3
Level	10.4	8.0	1.6
	100.0	100.0	100.0
Slope			
Level	9.3	8.0	5.6
1-5	13.2	5.6	11.7
6-10	19.6	11.2	24.4
11-15	11.5	12.0	23.8
16-20	12.6	15.2	15.2
21-25	16.5	22.4	13.7
26-30	11.0	16.8	2.0
31-35	2.8	4.0	3.6
35 +	3.3	4.8	-
	100.0	100.0	100.0

Curtis and Mc Intosh (1951) and Buell et. al. (1966). This is essentially a test for heterogeneity. A stand was considered "homogeneous" if it did not pass the chi-square test at the 5% confidence level. The results showed that 42 stands were "non homogeneous". Inspection of the original data usually showed that this heterogeneity was caused by clumping of the major species in the stand although in some cases it was caused by a change in composition along the transect.

COMPOSITION OF THE VEGETATION SAMPLE

Table 2 lists the 30 species reaching tree size diameters (4"dbh) in forest stands sampled in this study. Mountain ash (Pyrus decora), cherry (Prunus pensylvanica), mountain maple (Acer spicatum), striped maple (A. pensylvanicum), and ironwood (Ostrya virginiana) are included in the list but seldom reach diameters of 6 in. or more in the study area and more frequently are less than 4 in. dbh at maturity. Consequently, if included in discussions of forest dynamics, the high proportion of "saplings" to "trees" might seem to indicate an increasing importance of these species. Because field observation does not appear to support this contention, these 5 species are considered as components of the understory.

The remaining 25 species on the list more typically form trees with diameters usually exceeding 10-12 in. at maturity. Twenty-two of these occur 10 or more times in the forest sample, but only 14 of them are stand dominants.

Three of the stand dominants, big-toothed aspen (Populus grandidentata), basswood (Tilia americana), and red maple (Acer rubrum) are dominants only once. The first two of these are not widely distributed in the area and are found in only 17 and 27 stands, respectively, with mean RIVs (Relative Importance Values) of 6% and 7% in those stands of occurrence. Red maple is more widely distributed, being present in 70 stands, but with a mean RIV of only 6% it is not of great importance in the sample. Basswood and red maple are frequent associates of many of the mature vegetative groupings in the area, while big-toothed aspen is indicative of disturbance conditions in its sites of occurrence. The lack of recent disturbance of stands in the sample is indicated by the presence of the latter species in only 5 stands as a sapling with a mean RIV of 3% per stand of occurrence.

The 7 most common trees in the area are red spruce (Picea rubens), 143 stands; balsam fir (Abies balsamea), 120 stands; yellow birch (Betula allegheniensis), 86 stands; sugar maple (Acer saccharum), 80 stands; paper birch (Betula papyrifera), 75 stands; American beech (Fagus grandifolia), 72 stands; and cordate-leaved birch (Betula papyrifera var. cordifolia), 63 stands. All but one of these, paper birch, occurs as a stand dominant 4 or more times.

Paper birch is a common species in the Adirondacks and is dominant over several tracts within the study area. However, this dominance occurs in stands of obvious disturbance. These were not sampled because of the disturbance. In the sites which have been long undisturbed, this species plays only a minor role. Paper birch occurs 75 times in stands

Table 2: Number of stands of occurrence, occurrence as leading dominant, mean RIV (mean relative importance value) for the total sample and for stands of occurrence for tree species in the 182 stand sample. Numbers are rounded to the nearest whole unit of percent. T stands for "trace" or less than 0.5% mean RIV.

Tree Species	Species Abbre-viation	No. Stands of Occur. Tree/Sap.	No. Stands as Domin. Tree/Sap.	Mean RIV Tot.Samp. Tree/Sap.	Mean RIV Std. Occ. Tree/Sap.
Picea rubens Sarg.	Pr	143/127	30/19	16/11	20/15
Abies balsamea (L.) Mill.	Ab	120/115	45/71	21/30	31/47
Betula alleghaniesis B & B Small	Ba	86/51	10/0	6/2	13/7
Acer saccharum Marsh.	As	80/80	28/37	11/2	26/27
Betula papyrifera Marsh.	Bp	75/41	0/1	3/2	7/8
Fagus grandifolia Ehrh.	Fg	72/75	10/15	5/8	14/18
Acer rubrum L.	Ar	70/56	1/4	2/2	6/8
Betula papyrifera var. cordifolia (Regel) Fern.	Bpc	63/47	4/1	6/3	17/12
Tsuga canadensis (L.) Carr.	Tc	49/37	16/12	6/4	23/19
Fraxinus americana L.	Fa	39/19	0/0	1/1	7/6
Pinus strobus L.	Ps	36/22	10/0	5/1	26/9
Acer pensylvanicum L.	Apen	*37/81	0/0	1/7	4/16
Ostrya virginiana (Mill) K. Koch	Ov	*32/34	0/0	1/3	5/17
Pinus resinosa Ait.	Pres	30/22	15/6	7/2	38/18
Thuja occidentalis L.	To	28/15	5/3	2/1	15/17
Pyrus decora (Sarg) Hyland	Pd	*29/30	0/0	1/1	4/6
Quercus rubra var. borealis (Michx. f) Farw.	Qr	27/20	6/3	3/1	17/10
Tilia americana L.	Ta	27/15	1/2	1/1	6/6
Prunus serotina Ehrh.	Pser	20/12	0/0	T/T	1/3
Populus grandidentata Mich.	Pgr	17/6	1/0	1/0	6/3
Acer spicatum Lam.	Aspic	*16/52	0/0	T/3	3/10
Populus tremuloides Michx.	Pt	15/4	0/0	T/T	3/3
Ulmus americana L.	Ua	6/1	0/0	0/0	1/3
Populus balsamifera L.	Pb	4/0	0/0	0/0	2/0
Fraxinis nigra Marsh.	Fn	3/2	0/0	0/0	2/3
Juniperus virginiana L.	Jv	2/2	0/0	0/0	3/2
Quercus bicolor Willd.	Qb	2/2	0/0	T/T	8/6
Ulmus rubra	Ur	1/0	0/0	0/0	1/0
Larix laricina (DuRoi) K. Koch	Ll	1/2	0/0	0/0	1/3
Prunus pensylvanica L.	Pp	*1/3	0/0	0/T	T/4

*Typically understory species only occasionally reaching tree diameter (4"dbh) or greater, so not considered to be leading sapling even if leading in RIV.

as a tree, but in only 45 as a sapling with RIVs of 7.1% and 7.5%, respectively. These data support the pioneering nature of the species.

Cordate-leaved birch is a high altitude variety of paper birch. It dominates only 4 stands in the sample, yet it covers large tracts of area on the mountain. This area was not sampled because of disturbance due to such factors as fire, logging and wind throw. In these areas there is every indication that cordate-leaved birch is being replaced by spruce and fir. The four stands in which the species did dominate did not show these obvious signs of disturbance. Even here, however, in all four stands balsam fir is the leading sapling and the birch has a relatively low sapling RIV. Nevertheless, the cordate-leaved birch does appear to be a permanent minor associate of certain high altitude sites within the boreal complex. This is perhaps because the severity of the climate in these sites maintains disturbance-like conditions which typically favor the species.

Yellow birch shows a marked decline in sapling presence from 86 stands as a tree to 51 as a sapling. Unlike the other birches, it is a climax species in certain of the mature vegetation associations of the Whiteface area. As a tree it is extremely tolerant and survives easily in the deep shade of the mature hardwood forests. Its poor representation as a sapling is perhaps best explained by its substrate specific germination requirements. Kujawski and Lemon (1969) found that seedlings become established only on exposed mineral soil or mixed humus-mineral soil. Roots of seedling birch do not penetrate the leaf litter of the hardwood stands. Seeds typically find few such places suitable for germination in the vigorous, pre-degenerate forest stands of the area, so saplings are limited even though several mature, prolific seed-producing trees may be found in the stand.

The data for American beech give the impression that this species is increasing in its importance. It occurs in 72 stands as a tree and in 75 stands as a sapling with mean RIVs of 14% and 18%, respectively, per stand of occurrence. These data may be misleading because beech reproduces abundantly from root suckers which give the impression of vigorous regeneration. However, many of these suffer a high mortality rate in the "sapling" and young tree stages. Field observations indicate that beech may be in fact decreasing in importance as a tree in the majority of stands in which it is found.

Balsam fir, red spruce, and sugar maple are the most important species in the "undisturbed" sites of the study area. One of these 3 species occurs in all but 9 of the 182 stands sampled and as a dominant in 103 stands. Balsam fir is first in dominance with 45 stands, red spruce is second with 30, and sugar maple, which occurs in 65 less stands than red spruce, is third with 28.

Balsam fir is most common at the higher elevations, sometimes occurring in pure stands, but more frequently in association with red spruce. Red spruce assumes its greatest dominance at altitudes intermittant to those dominated by balsam fir and by sugar maple and is frequently associated with both of these species. Sugar maple reaches its highest importance in the 1500-2500 foot elevation range.

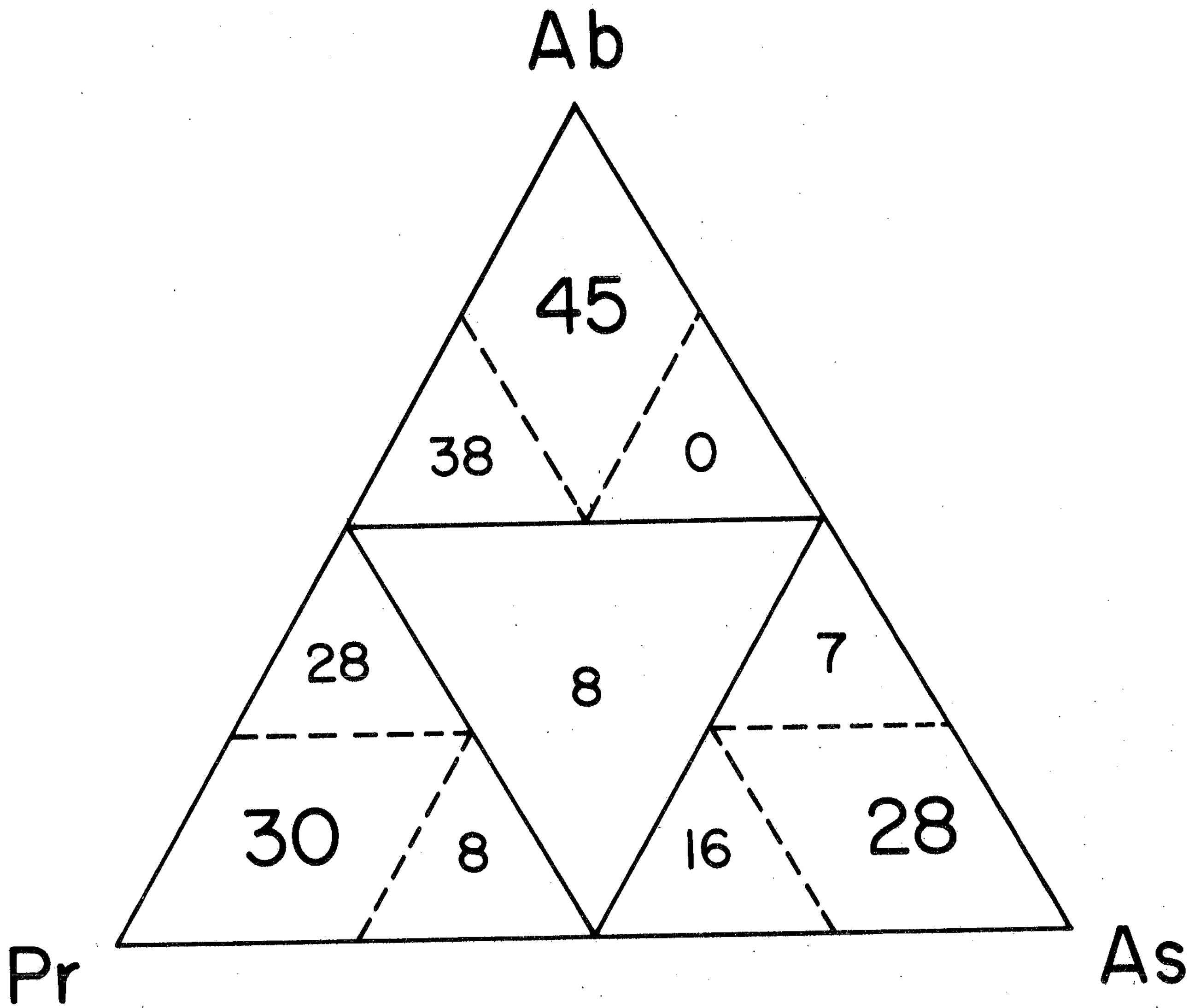
Figure 2 shows the relationship of these 3 species in stands dominated by any 1 of the 3 species. Only 8 of the 103 stands contain

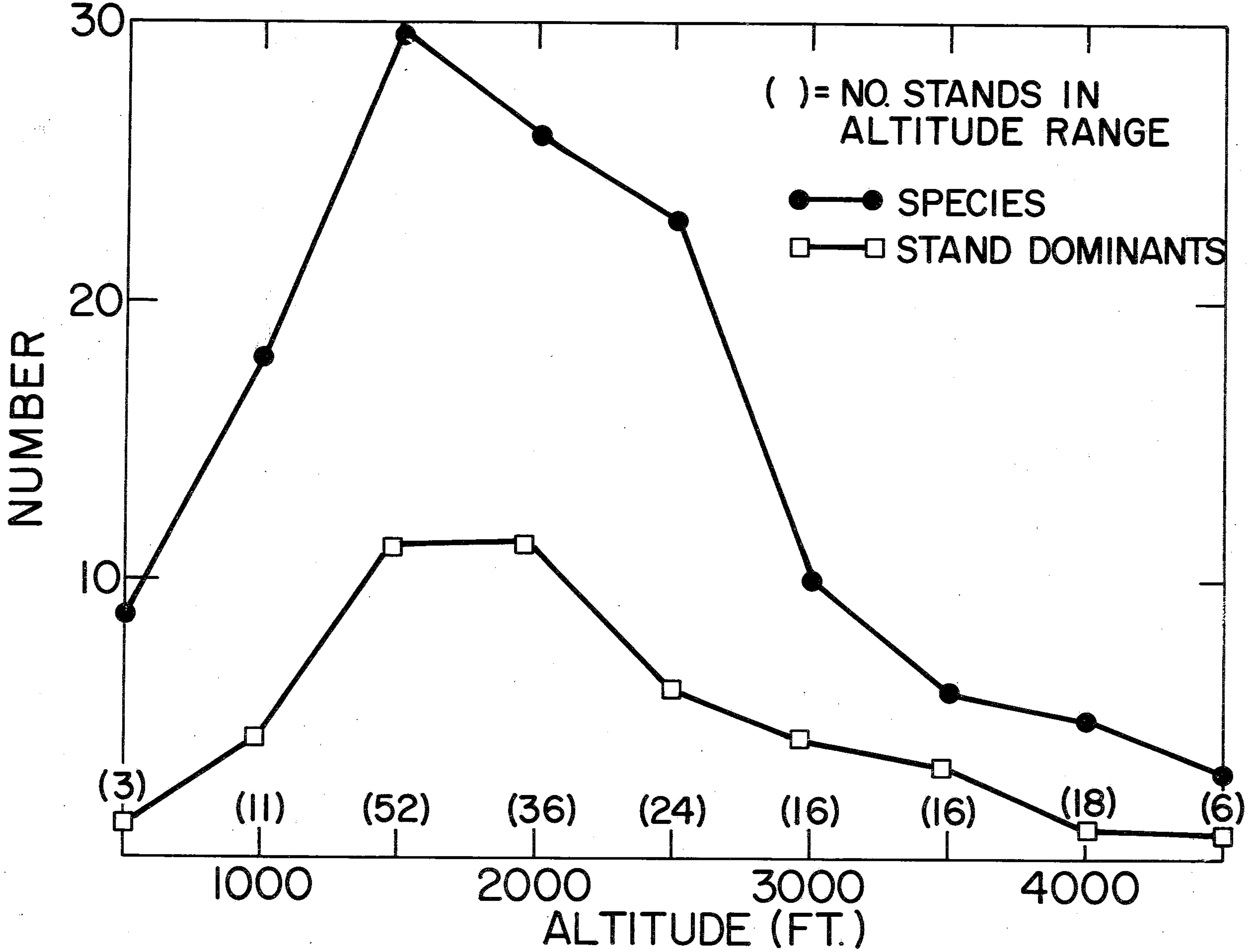
Table 3: Numbers of stands of occurrence and stands as a dominant for the three leading stand dominants by altitude intervals.

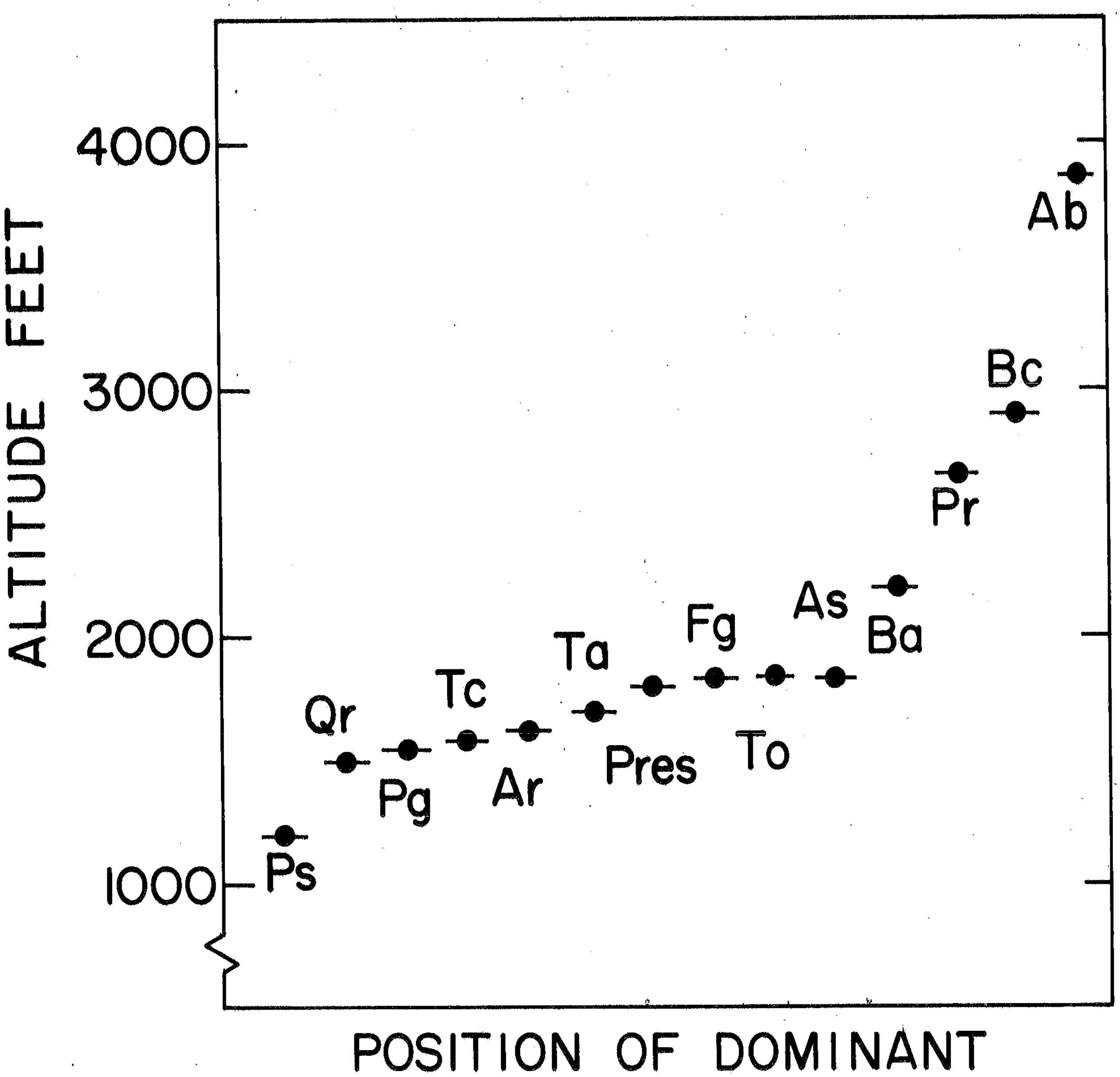
Elevational Range	Number of Stands	Abies balsamea		Picea rubens		Acer saccharum	
		Occurs	Dom	Occurs	Dom	Occurs	Dom
250-749	3	0	0	0	0	0	0
750-1249	11	2	0	3	0	3	0
1250-1749	52	30	3	38	6	38	13
1750-2249	36	16	1	31	5	26	8
2250-2749	24	14	2	22	8	11	7
2750-3249	16	16	3	16	8	2	0
3250-3749	16	17	12	15	3	0	0
3750-4249	18	18	18	14	0	0	0
4250-4749	6	6	6	4	0	0	0
4750-4868	0	0	0	0	0	0	0
Totals	182	120	45	143	30	80	28

Table 4: Number of occurrences of the various species in groups of stands of leading RIV. Arrangement of species is according to the mean altitude of stand dominants (Figure 4).

	Ab	Bpc	Pr	Ba	As	Fg	To	Tc	Pres	Ta	Pgr	Ar	Qr	Ps	Total
Ab	45	4	28	9	7	4	5	9	6	-	-	1	-	2	120
Bpc	37	4	16	2	1	-	2	1	-	-	-	-	-	-	63
Pr	38	3	30	10	16	9	5	16	11	-	-	-	-	4	143
Ba	7	1	16	10	20	10	3	15	-	1	-	1	-	-	86
As	-	-	8	7	28	10	-	13	2	1	1	1	5	3	80
Fg	-	-	5	7	28	10	-	15	-	1	1	1	4	-	72
To	1	-	8	2	-	1	5	6	3	-	-	-	-	2	28
Tc	1	-	10	3	7	3	2	16	5	-	-	-	-	2	49
Pres	-	-	3	-	-	-	-	1	15	-	-	-	1	10	30
Ta	-	-	-	-	13	2	-	4	1	1	-	-	5	1	27
Pgr	-	-	3	-	5	-	-	-	2	-	1	1	4	1	17
Ar	6	-	12	4	11	4	4	12	8	-	1	1	3	4	70
Qr	-	-	-	-	8	2	-	1	6	-	1	-	6	3	27
Ps	1	-	9	-	1	-	1	2	11	-	-	-	1	10	36


Ab
45
38
0
28
8
7
30
8
16
28
Pr
As


30
20
10
NUMBER
( )= NO. STANDS IN ALTITUDE RANGE
SPECIES
STAND DOMINANTS
(3)
(11)
(52)
(36)
(24)
(16)
(16)
(18)
(6)
1000
2000
3000
4000
ALTITUDE (FT.)


ALTITUDE FEET
4000
3000
2000
1000
Ab
Bc
Pr
As
Ba
Fg
Ta
Tc
Qr
Pres
To
Pg
Ar
Ps
POSITION OF DOMINANT

all 3 species. The most frequent association, as expected, was between balsam fir and red spruce. Red spruce was an associate in 38 of the 45 balsam fir dominated stands, and balsam fir was associated with 28 of the 30 red spruce stands. Red spruce was found in 16 of the 28 sugar maple dominated stands, but sugar maple was only found in 8 of the 30 red spruce stands. The spruce-maple relationship is not surprising because red spruce ranges well above the elevational limits of sugar maple, but is not restricted to higher altitudes. The altitudinal range of red spruce in the sample is from 4500 feet at the upper limits in a balsam fir stand to 980 feet at the lower level in a white pine (P. strobus) stand (Table 3). The maximum altitude at which sugar maple was found was 3100 feet in an east facing yellow birch stand.

The lowest degree of association of the 3 major species was between balsam fir and sugar maple. None of the balsam fir stands contained maple while 8 sugar maple stands contained balsam fir.

The tree to sapling ratios of balsam fir and sugar maple in Table 2 suggests that they both will increase. The ratio of occurrences for fir is 120/115 but the ratio of mean RIVs is 30/47%. The same ratios for sugar maple are 80/80 by occurrence and 12/27% by mean RIV. The increase of dominance of fir with increase in altitude is evident from Table 3. Field evidence of low mortality for sugar maple saplings indicates that it is strengthening its position as a dominant in middle and low altitude forests.

Red spruce occurrences are 143/127, with mean RIVs of 20% and 15%. Both these data and the field observations seem to indicate that balsam fir is a better competitor on most sites of mutual occurrence. For example, balsam fir is the leading sapling in 15 of the 30 red spruce dominated stands, while red spruce has gained leading sapling status in only 3 yellow birch and 2 red pine (P. resinosa) stands. This would indicate that while red spruce may remain an important associate, it may decrease as a dominant in the study area. On the other hand, field evidence shows that balsam fir has a high mortality rate as a young tree and is especially subject to wind and icing damage, while spruce tends to resist destruction and lives longer than fir. Thus, the relative dominance of these two species may not be changing as much as data in Table 2 indicate.

The 5 remaining stand dominants in the sample are hemlock (Tsuga canadensis) in 16 stands, red pine in 15 stands, white pine in 10 stands, northern red oak (Quercus rubra) in 6 stands, and eastern white cedar (Thuja occidentalis) in 5 stands. The lower number of stands dominated by these species compared to balsam fir, red spruce, and sugar maple is probably attributable to the lack of special sites which these species occupy or to past disturbance. For example, there is a suggestion from the early literature and from discussion with the older local residents that hemlock was once much more prevalent than now. Apparently, clearing of the land for agriculture and lumbering caused extensive reduction of hemlock in the more accessible sites. Possibly as a result of disturbance hemlock seems to be split into two major habitat sites. One is the low level wetlands and stream beds where it mixes abundantly with red spruce and balsam fir. The more common case seems to be lowland sites on small rounded drumlins or eskers with sandy or gravelly well-drained soils. On the latter sites hemlock often forms extensive nearly pure stands with abundant regeneration under trees of all ages and sizes. Hemlock is also a common minor associate in hemlock-yellow birch-sugar maple-beech stands of mesic sites.

White pine is predominantely a species of the low elevations of the area. It is generally found in nearly pure stands or associated with red pine on level or gently sloping sites with sandy soils. These soils often have a hardpan and are apt to be quite wet in the early growing season but very dry during the rest of the season. Lowland sites of this type are not common in the area. Again, logging and land clearing have probably greatly reduced its abundance compared to former times.

Red pine is found repeatedly on windswept, poorly drained ridges with shallow soils at the mid-elevations, and on sandy well-drained soils both on the level and on steep ridges at the lower elevations. It is without doubt the most drought tolerant of the dominant tree species of the area.

Northern red oak is also a lower elevation species associated with gentle to moderate slopes, usually on east facing sites. The soils in the oak stands are more mesic than those in the pine stands but too dry or rocky to support the sugar maple, American beech, and yellow birch forests.

Eastern white cedar has a distribution which is difficult to interpret. It is found in level wet areas as a dominant, but also appears on ridge tops up to 2500 feet or more in red pine or red spruce stands where soils are quite shallow and apparently quite dry. Habeck (1958) has studied this species in transplant gardens in Wisconsin and concludes there are two distinct ecotypes based on similar site preferences.

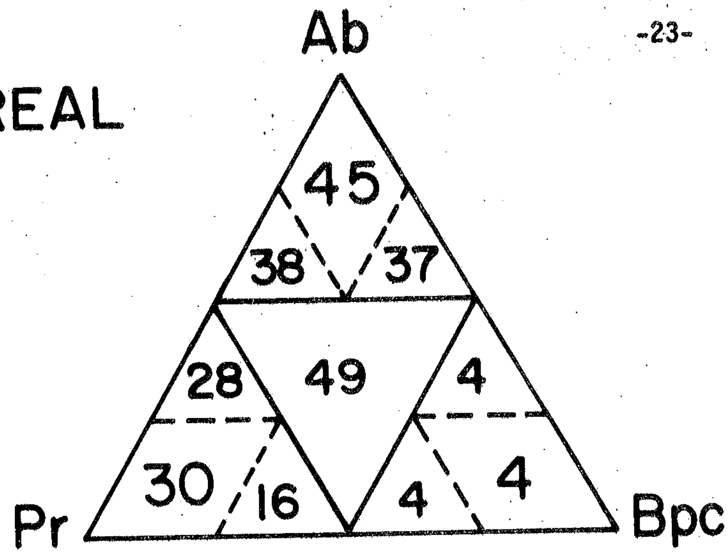
THE RELATION OF FOREST COMPOSITION TO TOPOGRAPHY

Altitude Variation

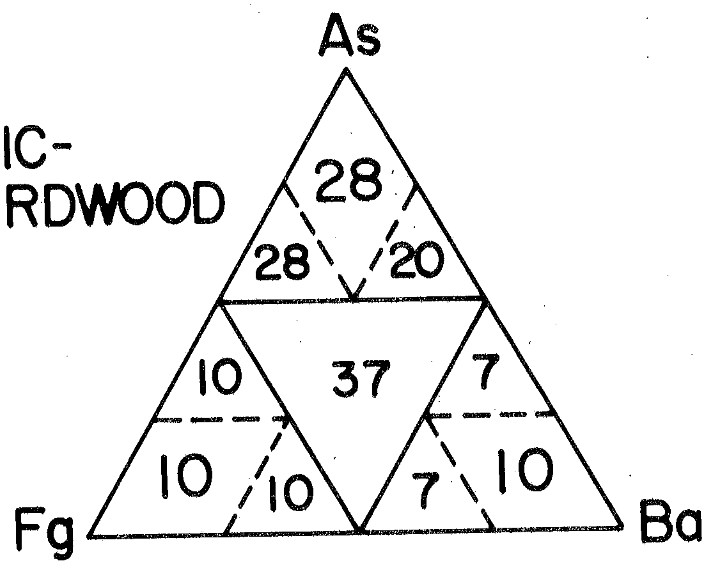
In an area of physiographic diversity such as the Whiteface Mountain it is expected that the severity of climatic and edaphic parameters would be greatest at the extremes of elevational range, and hence, the numbers of species able to occupy the habitat sites at these extremes would be reduced. Figure 3 shows this relationship of species by altitude groups as they occur on Whiteface Mountain and in its vicinity. The 1500 foot level is the area of maximum diversity for both numbers of species and numbers of stand types. It is also the altitude of highest sampling frequency. Much of the basal portion of Whiteface is between 1200 and 2000 feet. The small amount of area partly accounts for the reduction in number of species and stand dominants at the 500 and 4500 foot ranges, but the more severe habitat variables to be found at these elevations must also be considered.

Figure 4 shows the mean altitude of the species occurring as leading stand dominants. Casual observation of this figure seems to imply a fairly smooth transition from species to species through the elevational range of Whiteface Mountain with the hint of a possible natural clumping

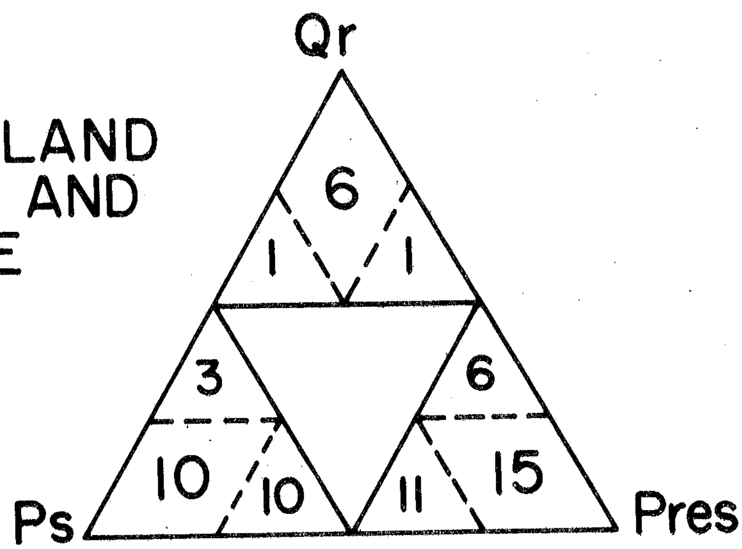
a. BOREAL

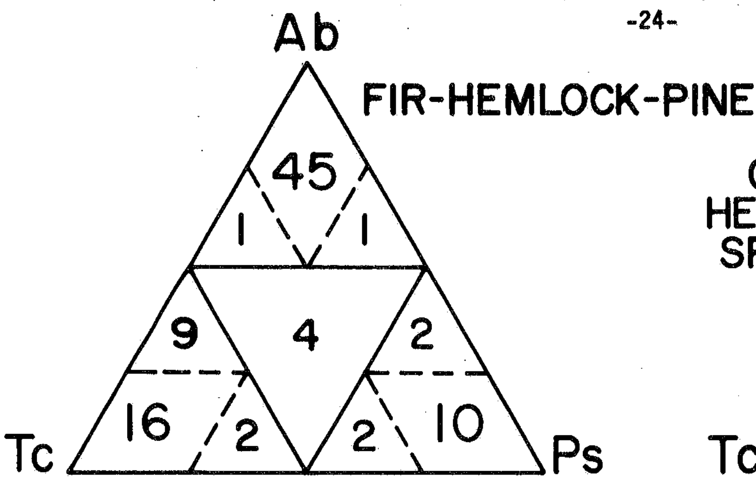


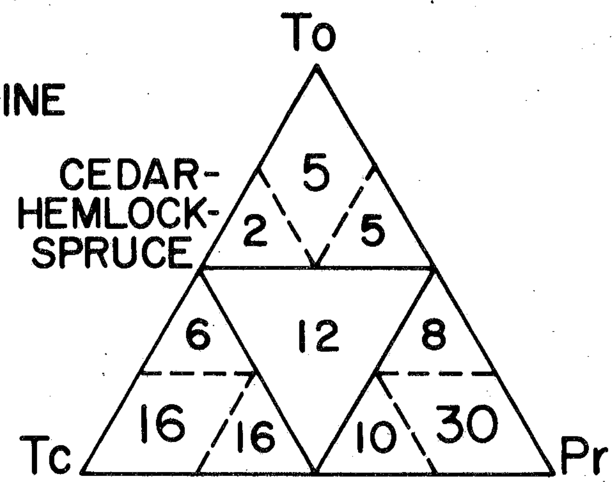
b. MESIC-HARDWOOD

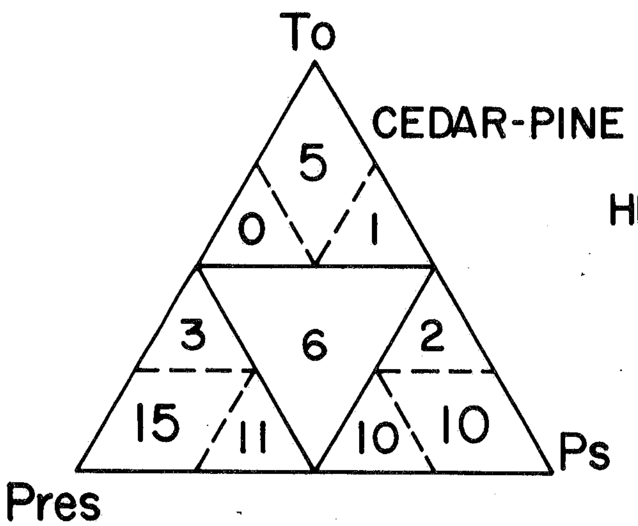


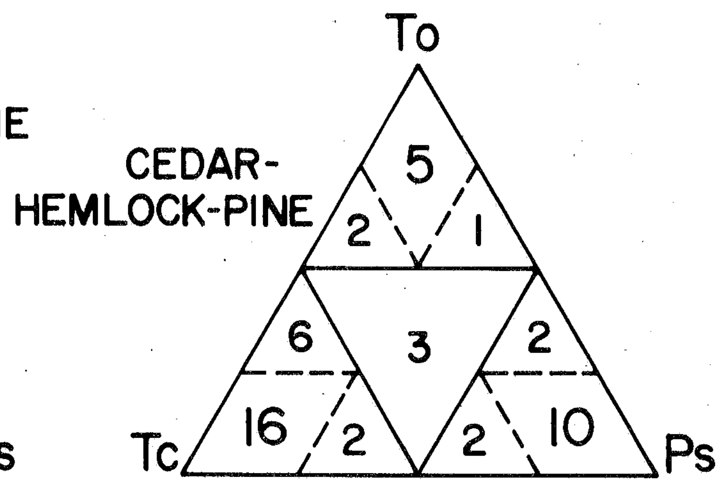
c. LOWLAND OAK AND PINE

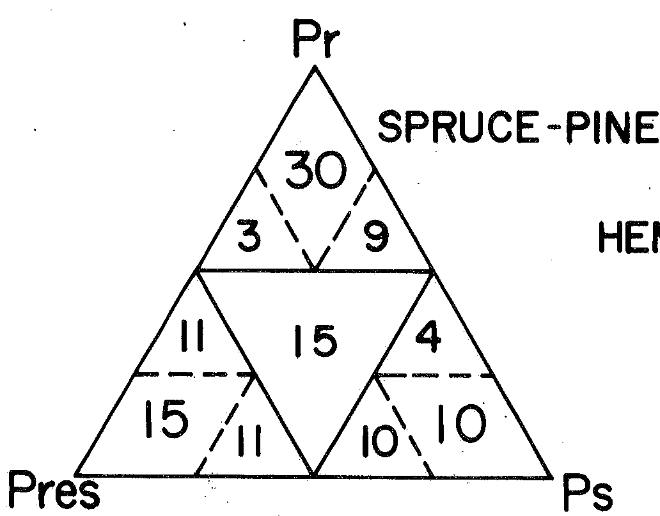


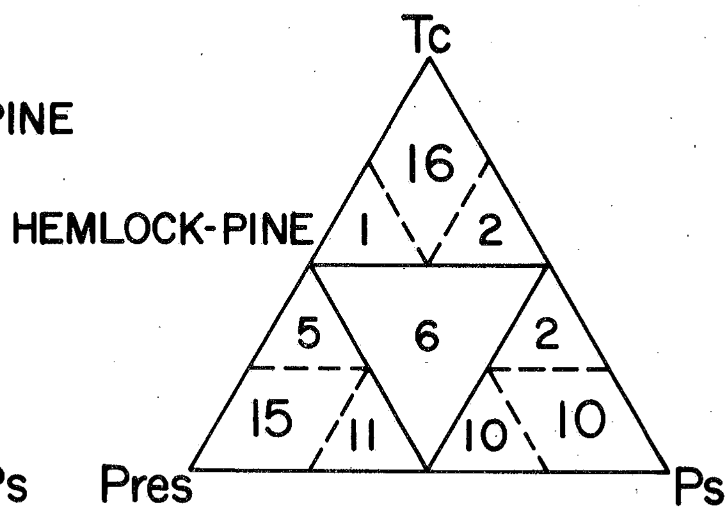

Ab
FIR-HEMLOCK-PINE
45
1
1
9
4
2
16
2
2
10
Tc
Ps

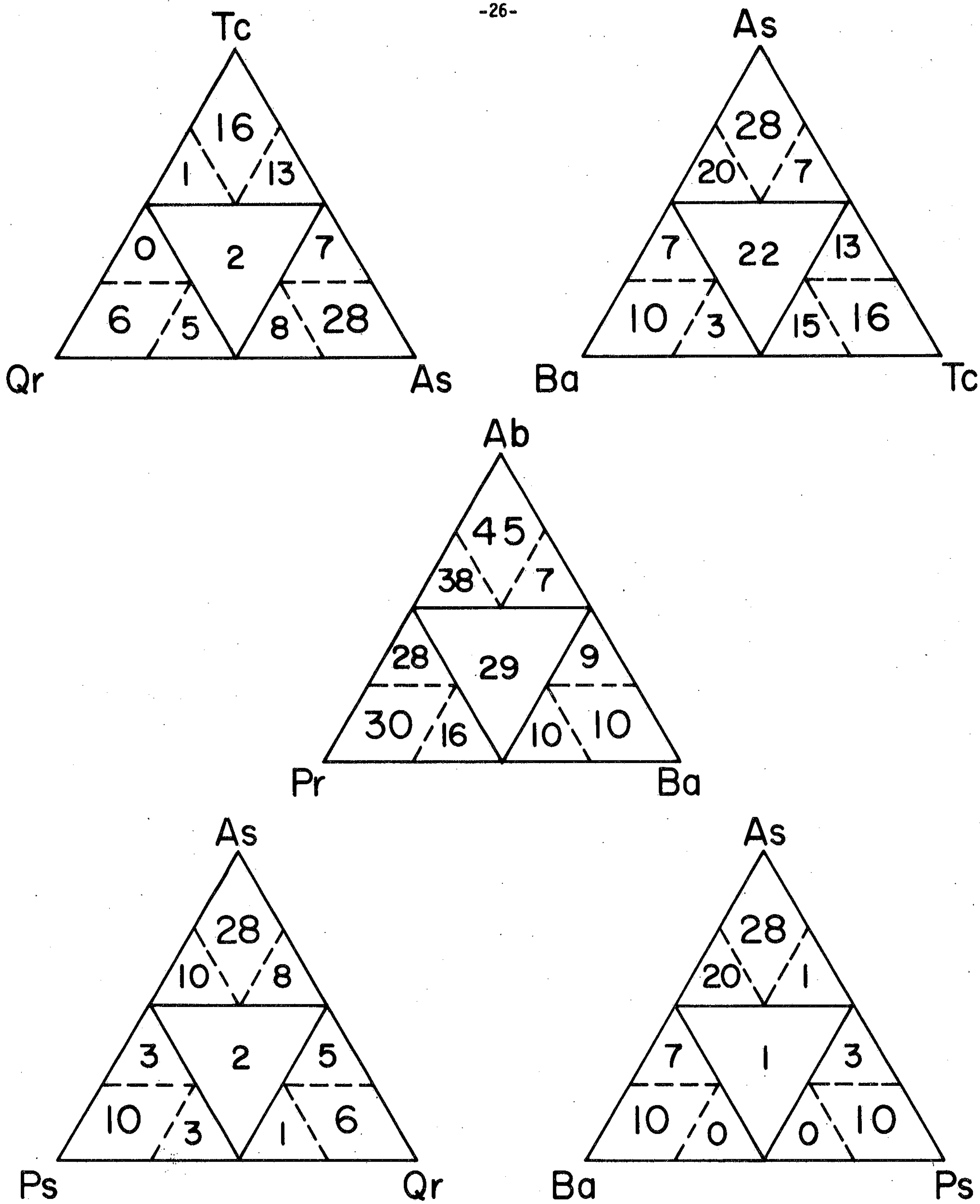

To
CEDAR-HEMLOCK-SPRUCE
5
2
5
6
12
8
16
16
10
30
Tc
Pr

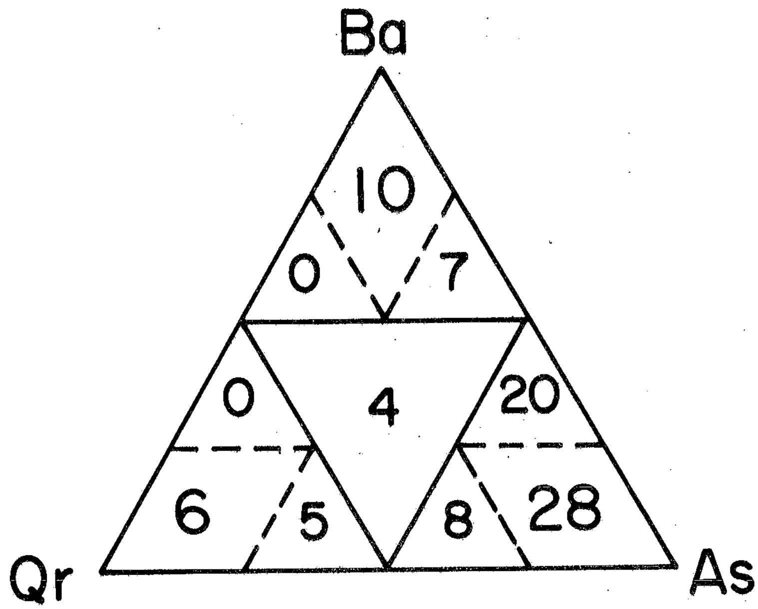

To
CEDAR-PINE
5
0
1
3
6
2
15
11
10
10
Pres
Ps


To
CEDAR-HEMLOCK-PINE
5
2
1
6
3
2
16
2
2
10
Tc
Ps


Pr
SPRUCE-PINE
30
3
9
11
15
4
15
11
10
10
Pres
Ps


Tc
HEMLOCK-PINE
16
1
2
5
6
2
15
11
10
10
Pres
Ps


Tc
16
1
13
0
2
7
6
5
8
28
Qr
As
As
28
20
7
7
22
13
10
3
15
16
Ba
Tc
Ab
45
38
7
28
29
9
30
16
10
10
Pr
Ba
As
28
10
8
3
2
5
10
3
1
6
Ps
Qr
As
28
20
1
7
1
3
10
0
0
10
Ba
Ps


Ba
10
0
7
0
4
20
6
5
8
28
Qr
As

of species groups. Only red pine seems to be out of place. This is due to its occupation of the dry, windswept ridges in the 1500-2500 foot range on the south side of eastward pointing ridges of the mountain.

Table 4, which has the species ordered primarily by their RIVs by altitude, shows the constancy of association of stand dominants with one another. The data in this table seem to further support this idea of natural clumping of the species into altitude related groups. The strong positive associative values of balsam fir, red spruce, cordate-leaved birch, and, perhaps, yellow birch suggests a boreal element. The association between sugar maple, American beech, yellow birch, and perhaps hemlock indicates a mesic hardwood element. This scheme places yellow birch in a dual role, but field observation does indicate that the species is a frequent associate with both groups although its affinity appears to be somewhat stronger towards the mesic hardwoods. The red spruce shows a strong affinity to dominants of the mesic-hardwood range. It occurs in 16 of the 28 sugar maple stands, in 9 of the 10 American beech stands, and in all 16 of the hemlock stands. The remaining stand dominants are northern red oak and the white pine and red pine stand types found typically in the lower elevations of the area. These constitute the dry oak hardwoods and the pine associations representative of more southerly latitudes.

Frequent associations are interesting and descriptive of vegetative composition. Equally interesting, however, are cases of vegetative dis-association. For instance, data in Table 4 show that neither American beech nor yellow birch were ever found to associate with red pine or white pine in any of the 45 stands that one or the other of these 4 species dominated. In fact, there is a very weak relationship of the pines to all hardwoods in the study area. More than elevational gradient is involved here, because several of the red pine stands are at altitudes well within the major dominance range of American beech and its common associate yellow birch. Variations in moisture may be responsible.

A final point of interest from Table 4 is the wide amplitudes of some of these species. Red maple and sugar maple, for example, occur with 11 of the other 13 stand dominant species, balsam fir occurs in 10 of the 13, and red spruce and yellow birch in 9 of the 13. Three of these are the leading stand dominants. One of these, red maple, is only a stand dominant once and is of relatively minor importance in all associations in which it occurs, yet it is a very wide ranging species. This would suggest that something more than site tolerance is involved in determining the abundance and dominance potential of a species.

Figure 5 shows the association relationships of the major species of the vegetative groupings identified above as boreal, mesic-hardwood and the oak and pine associations. Within the boreal element (Figure 5a) the weakest association is between cordate-leaved birch and spruce in spruce stands. This is best explained by the occurrence of several red spruce stands at altitudes below the lower limits of the birch. The constancy is 100% in the other direction indicating probable succession of the birch stands toward a balsam fir-red spruce climax.

All 3 of the species representing the mesic-hardwood grouping (Fig. 5b) show high degree of association with one another, for example, between sugar maple and yellow birch in American beech stands. There is 100%

association of these 2 species in the beech dominated stands. Associations in the other directions are nearly as strong.

From Figure 5c it can be seen that the northern red oak stands are primarily independent of white pine and red pine. The only northern red oak stand which contained the two pines was a gentle east-facing slope at 1180 feet. Oak, on the other hand, appears in about one third of the pine dominated stands showing a somewhat closer affinity to red pine. This agrees favorably with the site differences of the two pines. Red pine often is the dominant on the ridges capping the lower east facing slopes where northern red oak commonly occurs.

Figure 6 shows some of the association relationships of the various conifers. Using red spruce as the indicator it appears as though the boreal conifers associate commonly with the other 4 conifers of the area, while the pines show little affinity to hemlock and eastern white cedar. The relationship of hemlock to cedar is stronger than that of either species to the pines and about equal in both directions.

Figure 7 shows some hardwood-conifer association values. Some associations are high, yellow birch and sugar maple to hemlock; and some are low, sugar maple and yellow birch to white pine. The degree of relationship of hardwood to conifer is likely most closely tied to the soil moisture requirements of the species. Hemlock does well in the mesic environments of sugar maple and yellow birch, while these latter species do poorly in the dry soils on which white pine typically occurs. Balsam fir and red spruce are seen as very common associates in yellow birch stands, even when these occur at relatively low elevations.

Figure 8 is a comparison of the associative values of a somewhat boreal hardwood (yellow birch), a mesic-hardwood (sugar maple), and a lowland hardwood (northern red oak). There is no association between yellow birch and northern red oak in any of the 16 stands dominated by them. The association of sugar maple to both yellow birch and northern red oak is a strong one, as is the association of yellow birch in sugar maple stands. Affinity of northern red oak in sugar maple stands is much weaker. All 3 species only occurred together in 4 of the 44 stands dominated by any one of them. In all cases these were sugar maple dominated stands.

A closer evaluation of this relationship of the stand dominants to the altitudinal gradient is afforded by looking at the mean RIVs of the altitude groups. In Table 5, 10 altitude groups based on a 500 foot interval have been established and the mean RIVs of the 14 stand dominants for each of the altitude groups is presented, both for trees and for saplings.

This information reveals the characteristics of the distribution of the major tree species of the area. Balsam fir is the most important species of the higher elevations, but also has a considerable range of importance, and if the sapling data are reliable indicators, is likely to become even more important in the mid-range elevations. Sugar maple is the dominant tree of the mid-range elevations and, likewise, by sapling data seems to be increasing its importance and range.

Red pine appears to be about holding its position, but northern red oak and white pine seem to be decreasing in importance. In general, the trends of the rest of the species are evident from Table 5.

Table 5: Mean RIV of leading stand dominants (and number of stands) by altitude groups.

A. Trees

Altitude	Ab	Pr	Bpc	Ba	As	Fg	Tc	To	Pres	Qr	Pgr	Ta	Ar	Pst
250-749	--	--	--	--	--	--	--	--	34(1)	--	--	--	--	80(2)
750-1249	--	--	--	--	--	--	59(2)	--	68(3)	56(1)	--	--	--	73(5)
1250-1749	52(3)	42(6)	--	34(2)	42(13)	39(4)	59(11)	63(3)	57(3)	46(4)	47(1)	--	38(1)	33(2)
1750-2249	52(1)	48(5)	--	41(4)	46(8)	34(6)	51(3)	--	64(5)	29(1)	--	39(1)	--	41(2)
2250-2749	43(2)	56(8)	--	35(2)	61(7)	--	--	63(2)	83(3)	--	--	--	--	--
2750-3249	45(3)	51(8)	52(4)	32(1)	--	--	--	--	--	--	--	--	--	--
3250-3749	57(12)	52(3)	--	--	--	--	--	--	--	--	--	--	--	--
3750-4249	81(18)	--	--	--	--	--	--	--	--	--	--	--	--	--
4250-4749	88(6)	--	--	--	--	--	--	--	--	--	--	--	--	--
4750-4868	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mean all stands	70(45)	50(30)	52(4)	37(10)	48(28)	36(10)	58(16)	63(5)	65(15)	45(6)	47(1)	39(1)	38(1)	61(10)

B. Saplings*

Altitude	Ab	Pr	Bpc	Ba	As	Fg	Tc	To	Pres	Qr	Pgr	Ta	Ar	Pst	Bpap
250-749	--	--	--	--	--	--	--	--	--	--	--	14(1)	40(2)	--	--
750-1249	58(2)	--	--	--	23(2)	--	--	--	47(1)	23(2)	--	27(1)	33(2)	--	--
1250-1749	42(12)	50(4)	--	--	46(14)	51(10)	43(11)	33(2)	36(1)	--	--	--	--	--	--
1750-2249	54(3)	38(7)	--	--	52(12)	37(5)	40(1)	--	38(2)	25(1)	--	--	--	--	19(1)
2250-2749	44(6)	39(5)	--	--	56(7)	--	--	82(1)	40(2)	--	--	--	--	--	--
2750-3249	57(11)	58(2)	34(1)	--	27(2)	--	--	--	--	--	--	--	--	--	--
3250-3749	72(14)	43(1)	--	--	--	--	--	--	--	--	--	--	--	--	--
3750-4249	90(17)	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4250-4749	91(6)	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4750-4868	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mean all stands	66(71)	43(19)	34(1)	--(0)	48(37)	46(15)	43(12)	50(3)	40(6)	24(3)	--	20(2)	36(4)	--(0)	19(1)

*Values will tend to be low because of inclusion of *Acer spicatum*, *A. pensylvanicum*, *Pyrus decora*, *Ostrya virginiana*, and *Prunus pensylvanicum* as saplings in sample.

Slope-aspect Variation

The change to a more boreal vegetation with increase in altitude is a well-known feature of mountain vegetation, but the slope and slope-aspect variations are less obvious. To study the variation in vegetation composition with slope-aspect, only data from the stands on or near Whiteface Mountain are used and those below 1250 ft. are omitted. This sample contains 121 stands. This screening out of stands which are quite far from the Whiteface complex and those below 1250 ft. is thought necessary because many of the stands in these latter two categories are selected for the presence of a particular species (e.g. pines or hemlock). The selection procedure for stands on or near Whiteface conforms to a systematic procedure with rare exception (see METHODS section).

Mean RIVs of several key species is given in Table 6a for the four major slope-aspect ranges. The averages were obtained by equally weighting the mean species importance values of 500 foot intervals for seven altitude ranges from 1250 to 4749 ft. centered at (1250 to 1749 ft., etc.). This procedure of normalizing by altitude is necessary because of the high degree of compositional variation with altitude and because the number of stands in each of the seven altitude-aspect ranges is not constant. Weighting by the actual number of stands in the slope-aspect range overweights for species of high importance in altitude ranges with large numbers of stands.

Usually the most boreal composition is associated with north facing slopes, but this does not appear to be strictly the case on Whiteface Mountain. Inspection of the data in Table 6 shows that the east facing aspects have the highest proportion of northern hardwood species while the west as well as the north facing slopes have high RIVs for the boreal species. Sugar maple, for example, is much more important on east slopes with a mean RIV of 16.0% than on west slopes with a mean RIV of only 5.2%. Yellow birch, an intermediate between the boreal and northern hardwood forests is highest on north facing sites and lowest on east. The most boreal of the species in the sample, balsam fir, is highest on north sites followed by west and lowest on east slopes. Red spruce, also a boreal species, is very high in RIV on west slopes but low on north facing sites.

A summary of the mean importance of single species may lead to some inconsistencies due to some peculiar nature of a given species or because the sample size is too small. For this reason, the data are also summarized as "species groups" in Table 6b. The boreal group consists of balsam fir, red spruce, cordate-leaved birch, and mountain ash. The hemlock-northern hardwoods group consists of hemlock, sugar maple, American beech, and yellow birch. The dry hardwoods group contains northern red oak, basswood, and white ash, while the pines are red pine and white pine.

Only one important species, eastern white cedar, is omitted from the species groups because when it is found in a stand it is usually by far the most important species. These "cedar swamps" seem to be a special type and cannot be logically lumped into one of the four groups even though they have more boreal associates than others. Minor species containing less than 1% mean relative importance of the total sample are also omitted from the species in Table 6b.

Table 6: Mean RIV of eight major species (a) and groups of species (b) for the altitude range 1250 to 4749 feet for the four major quadrants of slope-aspect. Data are means of seven 500 foot ranges in altitude with each range weighted equally (see text).

(a) Species	East 45°-134°	South 135°-224°	West 225°-314°	North 315°-44°
Abies balsamea	26.1	35.0	38.3	41.5
Picea rubens	17.2	17.3	23.8	14.6
Betula alleghaniensis	3.3	4.4	6.1	9.2
Acer saccharum	16.0	13.9	5.2	9.4
Tsuga canadensis	2.3	0.6	3.8	2.7
Fagus grandifolia	6.9	2.7	4.7	5.8
Quercus rubra	4.2	0.2	--	--
Pinus resinosa	--	3.5	0.5	1.1
Number of stands	25	26	26	33
(b) Species Group				
Boreal	56.1	63.0	69.0	65.0
Hemlock-Northern Hardwoods	28.5	21.6	19.8	27.1
Dry Hardwoods	6.4	1.1	0.3	1.7
Pines	--	4.2	0.8	1.1

Table 7: Mean RIV of eight major species (a) and groups of species (b) for altitudes 1250 to 4749 feet grouped by 180 degree ranges in slope aspect. Data are means of seven 500 foot altitude ranges with each range weighted equally (see text).

	Relative Importance of 180° Slope-Aspect Groupings			
(a) Species	East vs. 1°-180°	West 181°-360°	North vs. 271°-90°	South 91°-270°
Abies balsamea	26.8	40.4	34.6	32.6
Picea rubens	13.8	19.8	14.2	19.4
Betula alleghaniensis	6.7	6.9	7.4	6.2
Acer saccharum	18.1	4.0	12.5	9.6
Tsuga canadensis	2.9	2.2	3.0	2.1
Fagus grandifolia	6.5	6.2	6.3	6.4
Quercus rubra	2.3	--	1.0	1.3
Pinus resinosa	1.0	4.2	2.2	3.0
Number of stands	54	58	54	58
(b) Species Group				
Boreal (WBC)	53.9	68.7	58.4	64.2
Hemlock-Northern Hardwoods	34.2	19.3	29.2	24.3
Dry Hardwoods	4.0	0.3	2.1	2.2
Pines	1.0	4.6	2.2	3.4

Table 8: Mean RIV of eight major species (a) and groups of species (b) for the altitude range 1250 to 2749 feet grouped by four quadrants of slope aspect plus level stands. Data are means of three 500 foot altitude ranges with each range weighted equally.

(a) Species	EAST 45°-134°	SOUTH 135°-224°	WEST 225°-314°	NORTH 315°-44°	LEVEL
Abies balsamea	0.3	2.8	3.3	8.1	13.0
Picea rubens	2.6	12.6	24.1	13.6	15.1
Betula alleghaniensis	4.4	8.4	13.7	17.8	9.9
Acer saccharum	37.4	32.5	12.2	21.9	22.1
Fagus grandifolia	16.1	6.3	11.1	13.5	4.6
Tsuga canadensis	5.4	1.5	9.0	6.4	1.8
Thuja occidentalis	-	0.7	0.4	6.6	36.7
Pinus resinosa	-	8.2	1.2	2.6	0.1
Number of stands	11	16	17	14	11
(b) Species Group					
Boreal (WBC)	2.9	15.8	27.4	23.5	28.1
Hemlock-Northern hardwoods	63.3	48.7	46.0	59.6	22.7
Dry hardwoods	15.0	2.9	0.6	4.0	1.0
Pines	-	9.8	1.9	2.6	0.8

The reason for the difference between presenting the data for 90^{o} slope-aspect ranges versus 180^{o} ranges for sugar maple and red spruce is clarified by looking at Table 10. Here the same data for 4 species are divided into 90^{o} slope-aspect ranges centered on NE, SE, NW, and SW. Sugar maple is high only on NE and SE slopes and red spruce only SW and NW.

Plotted data for species groups in Figure 10 again shows that the east slopes contain species which indicate a relatively mild environment compared to the west slopes. The contrast between north and south slopes is not nearly so great in these lower altitude northern hardwood forests.

Table 8 also indicates data for the level sites. Poorly-drained level sites contain spruce-fir and cedar stands and well-drained sites contain sugar maple and other hardwoods. The high relative importance of boreal species and eastern white cedar may be due to an oversampling of level wet sites which have not been logged compared to well-drained level sites which may have been logged for hardwood timber and thus not sampled when visited.

The forests on the lower slopes of Whiteface contain pines on south and southwest sites, but not on east facing sites (Tables 8-10). On the latter there are dry hardwoods including several stands of northern red oak (Figure 10). The dry hardwoods are not typically found on west-facing slopes.

Stands above 2750 feet rarely contain species which were not in the boreal group. Several stands between 2750 and 3500 feet contain significant amounts of yellow birch and small amounts of mountain maple and striped maple. One northeast facing site at 3100 feet contains 29% importance of sugar maple which is the highest altitude at which this species was found. An east facing stand at 3350 feet was dominated by large trees of yellow birch which occurred in scattered amounts up to about 3450 feet.

Figure 11 is a bar graph of the mean RIVs of boreal species for 4 quadrants and 2 altitude groups. The upper altitude (3750 to 4749 ft.) shown in Figure 11a contained mostly balsam fir. This species was highest on north sites followed by west and lowest on east slopes. Red spruce, cordate-leaved birch, and species listed as "others", including mostly yellow birch and mountain ash, were least important on west slopes again indicating the most severe environment is on west slopes.

In summarizing the slope-aspect compositional variation, a significant feature is that except in the very high altitude range the western slopes were the most boreal of all aspects indicating the most rigorous environment. The contrast between east and west sites was much larger than between north and south. The east facing slopes contained species which indicate that the mildest environment occurs on those slopes. South and southwest sites contained relatively high composition of "dry" indicating species while "mesic" hemlock-northern hardwoods were highest on east and north facing sites.

Table 9: Mean RIV of seven "indicator" species (a) and groups of species (b) for the altitude range 1250 to 2749 feet grouped by 180° ranges in slope aspect. Data are means of three 500 foot altitude ranges with each range weighted equally.

	EAST vs. WEST		NORTH vs. SOUTH	
(a) Species	1°-180°	181°-360°	271°-90°	91°-270°
Abies balsamea	2.9	6.2	6.1	3.0
Picea rubens	6.3	21.2	11.5	16.0
Betula alleghaniensis	10.1	14.4	12.5	12.0
Acer saccharum	36.7	9.3	23.6	22.4
Tsuga canadensis	6.4	5.3	6.6	5.1
Fagus grandifolia	14.1	14.5	13.6	15.0
Pinus resinosa	2.4	9.9	5.2	7.1
Number of stands	27	31	26	32
(b) Species Groups				
Boreal (WBC)	9.3	31.2	20.4	20.1
Hemlock-Northern Hardwoods	67.3	43.3	56.3	54.3
Dry hardwoods	8.8	0.9	4.3	5.4
Pines	2.5	11.1	5.5	8.1

Table 10: Mean RIV of four major species for the altitude range 1250 to 2749 feet grouped by four quadrants of slope aspect. Data are means of three 500 foot altitude ranges with each range weighted equally.

Species	NORTH-EAST 1°-90°	SOUTH-EAST 91°-180°	SOUTH-WEST 181°-270°	NORTH-WEST 271°-360°
Abies balsamea	4.1	1.8	4.3	8.2
Picea rubens	5.4	7.2	24.7	17.7
Acer saccharum	36.9	36.5	8.4	10.3
Fagus grandifolia	16.6	11.6	18.4	10.6
Number of stands	11	16	17	14

Table 11: Mean RIV of several species (a) and groups of species (b) for all altitudes grouped according to steepness of slope. Data are means of stands occurring in slope range regardless of altitude.

	Slope Aspect Range in Degrees				
(a) Species	Less than 1	1 to 10	11 to 20	20 to 30	30+
Abies balsamea	17.4	20.2	16.8	35.8	61.7
Picea rubens	16.3	10.6	17.0	23.6	23.1
Betula alleghaniensis	6.3	14.5	8.0	5.3	-*
Fagus grandifolia	7.8	11.0	8.1	2.3	-
Tsuga canadensis	0.3	9.9	3.2	0.8	-*
Acer saccharum	11.7	19.5	19.0	6.1	-
Quercus rubra	-	0.1	3.6	-	-
Pinus resinosa	0.1	3.2	2.9	4.9	-*
Number of stands	11	25	33	45	16
Boreal	33.7	31.3	34.6	60.6	85.6
Hemlock-Northern hardwoods	26.1	54.9	38.3	12.5	-*
Dry hardwoods	2.1	0.9	6.9	0.9	-
Pines	0.8	3.2	3.3	5.7	-*

*occurred in this range

Data from Table 6b are also plotted as bar graphs in Figure 9a. West slopes tend to be the most boreal followed by north aspects while east slopes have the highest importance values for the northern hardwood species indicating a relatively mild environment on the east aspects. Pines are most abundant on south facing slopes although they are of relatively low total importance in this sample because stands below 1250 ft. are omitted. Dry hardwoods are most important on east aspects.

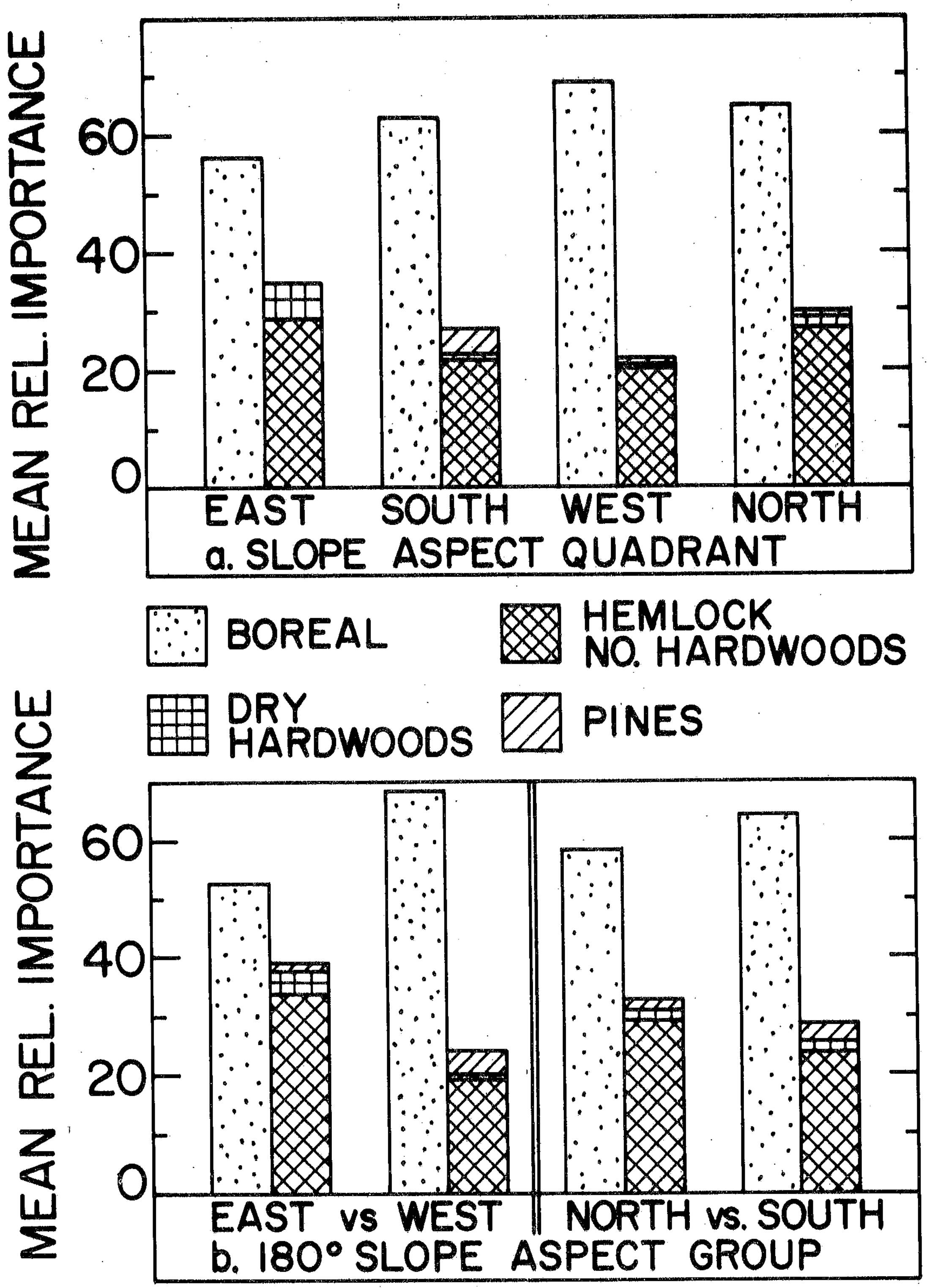
Because of the interesting result that the west to east contrast appears to be more pronounced than the north to south one, the data are examined in a different way in Table 7 and Figure 9b. In this case, the sample of stands on or near Whiteface proper is divided first into east and west aspects only and then into north and south only. Comparing the aspects in this way shows a greater contrast between east and west, but north slopes do not appear to be more boreal than south slopes. South slopes contain more red spruce but only slightly less balsam fir (Table 8a). North slopes have more hemlock-northern hardwoods species than the south, but lower amounts of pines.

The contrast between east and west facing slopes is shown by much higher importance of sugar maple and lower importance of balsam fir and red spruce on the east sites. Dry hardwoods are important on the east and pines on the west slopes. The high contrast between east and west and lower contrast between north and south sites is not easily explained. Subjective inspection of stand data shows that there are not only many protected northeast facing stands of sugar maple and American beech on Whiteface Mountain but also many stands (even at lower altitudes) on south-west sites with high amounts of red spruce and balsam fir.

Casual inspection of the stand data at high altitudes indicates that the high contrast between east and west sites may be due to variations at lower elevations. The sample of stands between 1250 and 2749 feet consisting mainly of hemlock-northern hardwood forests is treated in the same manner as in the previous section. Table 8 presents mean importance values for 7 major species and the 4 species groups for 4 90° slope-aspect groups plus level stands. Table 9 presents similar data, but they are divided into 180° groups to compare north versus south and east versus west. Figure 10 is a plot of the data for the species groups from Tables 8b and 9b.

The mean RIV of red spruce in Table 8 is much higher for the west slopes (24%) compared to the east (3%) while it is nearly the same on north and south slopes. However, in Table 9 when 180 degree slope-aspect ranges are examined instead of quadrants the south stands have higher mean RIVs for red spruce than north sites (16% vs 12%). The high difference between east and west is still evident (6% vs 21%) with west facing sites apparently more boreal.

The data for sugar maple in Table 8 shows the reverse effect. When the summary is by quadrants, the mean RIV of sugar maple is 33% for south slopes compared to 22% for north slopes, but in Table 9 (summarized by 180° ranges), they are nearly the same. Similarly for sugar maple the high variation between east and west was evident in both Tables 8 and 9 with eastern sites having much higher values for this hardwood species.


MEAN REL. IMPORTANCE
0
20
40
60
EAST
SOUTH
WEST
NORTH
a. SLOPE ASPECT QUADRANT
BOREAL
HEMLOCK NO. HARDWOODS
DRY HARDWOODS
PINES
MEAN REL. IMPORTANCE
0
20
40
60
EAST vs WEST
NORTH vs. SOUTH
b. 180° SLOPE ASPECT GROUP

Variation with Degree of Slope

The variation in composition with degree of slope for the entire sample is shown in Table 11. These data were not normalized by altitude and, therefore, the boreal species show high amounts for steep slopes because the upper altitudes are the most steeply sloping.

Species with maximum RIVs on "moderate" slopes (1 to 10°) are those in the hemlock-northern hardwoods group including sugar maple, American beech, and hemlock. Sugar maple occurs in relatively high importance on higher sloping terrain (1 to 20°), while hemlock is not found either on slopes greater than 10° or on level sites. Moderate slopes in the 1°-10° range are most favorable for hemlock.

The dry-hardwoods group including northern red oak obtains highest importance on relatively high slopes (11 to 20°). Red pine reaches maximum importance on steep slopes (above 20°), but also occurs on less steeply sloping sites.

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COMPARISON OF TOPOGRAPHIC AND VEGETATION GRADIENTS IN FORESTS OF WHITEFACE MOUNTAIN NEW YORK

by

Jon T. Scott and J. Gary Holway

Comparison of Topographic and Vegetation Gradients in Forests of Whiteface Mountain, New York

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ABSTRACT

Tree species data for 182 forested stands from on or near Whiteface Mountain in northern New York was used to obtain a vegetation gradient. The stand index value (STV) obtained by a modification of the method of leading dominants was found to be highly correlated with altitude. A regression analysis of STV versus altitude for three altitude ranges and plots of mean STV by 500 ft altitude intervals showed a non-linear relation. The regression lines and plots showed a region of steep slope between the upland spruce-fir (*Picea rubens*-*Abies balsamea*) and the lowland hardwood forests. If this "ecotone" between two "associations" is not caused by environment then there must be reasons for species to associate into types. If the slope of the curve is due to environmental variations along the altitude gradient then the continuum hypothesis is correct and association is due only to the chance that species overlap in their range of tolerance.

The STV was found to be higher on east facing than on west facing sites, but the north to south variation was small. A possible explanation is that heat balance differences between the east and west sites governed by wind exposure and diurnal variation in solar radiation input have greater impact than the north to south differences in solar radiation. East-west differences in wind damage are also larger than north to south differences.

INTRODUCTION

A phytosociologic index provides a framework upon which ecologists can perform a variety of fruitful investigations including studies of evolution, succession (Buell, et. al., 1966) vegetation structure (Goff and Zedler, 1968), consumer populations (Beals, 1960) and vegetation-environment relations. This paper deals with the last mentioned of these. Its purpose is to describe the use of an index based upon data from 182 forested stands located on or near Whiteface Mountain in the Adirondacks of northern New York. This index will be used to study the variation of vegetation along topographic gradients, that is, along changes in altitude, slope and slope aspect. This application to a region of widely divergent vegetation within a small area leads to some tentative conclusions concerning the nature of vegetation distribution along environmental gradients.

The application of a phytosociologic (or compositional) index to vegetation data produces an arrangement of stands or species which has been given various names such as "continuum" by Curtis and McIntosh (1951), and "ordination" by Goodall (1954) and Curtis (1959). The term "gradient analysis" was used by Whittaker (1956) in a study of the distribution of many species along topographic gradients. Goff and Cottam (1968) have also used this term to express the variation of vegetation across wide ranges in composition and it is retained here. The placement of stands along a gradient governed by the species compositional index will be termed the "vegetation gradient".

The term vegetation gradient lacks the ambivalence of the others which have been used. The word "continuum" implies that vegetation is a continuous variable in all cases whereas it is well known that abrupt spatial variations exist (i.e. at borders of swamps or lakes, etc.). Also, the word continuum implies that there are no reasons for species to associate except that they happen to overlap in their range of tolerance along an environmental gradient. This may be so but has not yet been proven. Although these may be trivial arguments, we believe that the use of the word continuum has led to some misunderstanding. The word "ordination" implies an ordering or ranking which may not necessarily be based upon measured distance along the order. For instance, we can rank the numbers 0, 3, 4, 9, 18, in the proper order, but not provide the useful information that the difference between the last two numbers is equal to that of the first four. The term "gradient analysis" implies that the variation or distances along the gradient have been determined.

The vegetation gradient is based upon a species sociologic index which we will term the species index number (SPN). This is derived from measurable properties of vegetation such as density, basal area, cover and frequency. Goff and Cottam (1968) compared six methods of obtaining species index numbers using the same vegetation sample of upland stands in southern Wisconsin. They found that all methods gave similar results. In our studies at Whiteface Mountain we have compared three methods and also found that they give essentially the same information on the first axis. Only the fairly simple method of Curtis and McIntosh (1951) will be discussed here.

STUDY AREA AND VEGETATION SAMPLE

The study area and properties of the vegetation sample have been described by Holway, et. al. (1969) and will be briefly summarized here. All of the 182 stands were located on or within seven miles of the 4867 foot summit of Whiteface Mountain (Figure 1). This mountain is the most isolated of all the Adirondack high peaks being about 15 miles north of the so-called "high peaks region".

The climate of the Adirondacks is cool and wet with precipitation exceeding evapotranspiration by from 25 to 40 in. The Whiteface region receives about 40 in. of precipitation with about 30 in. of runoff. July mean temperatures range from about 60° F in the lowlands to the low 50° F range on the peaks. Frosts and rime-ice occur during all months of the year near Whiteface summit.

Bedrock of the region consists mostly of anorthosite with smaller amounts of granite. The soils above 3500 ft. contain little fine mineral material and consist mostly of moss-covered boulders and peat. Glacial till occupies the level sites and drainage channels, but the till is usually very shallow. The lower slopes have deeper soils with podsols fairly well developed.

Witty (1968) classified the soils on Whiteface Mountain. On the basis of morphological and other properties, field descriptions and results of laboratory analysis he found the Spodosol and Histosol families to be common in the region. The cation exchange capacities were generally low and the soils strongly acid. The amount of exchangeable bases was low except in some soils under hardwoods.

The summit of Whiteface contains a small region of treeless vegetation with tundra species present. Below this region down to about 4000 ft. are nearly pure stands of balsam fir (*Abies balsamea*)[1]. Red spruce (*Picea rubens*) is mixed with the fir down to about 2700 ft. and on wet or exposed sites lower on the mountain. Below 2700 ft. northern hardwoods are the dominant type with maple (*Acer saccharum*), beech (*Fagus grandifolia*), and yellow birch (*Betula alleghaniensis*), the most common species. On well-drained sites at about 1500 ft. and below, red pine (*Pinus resinosa*) and white pine (*Pinus strobus*) are common. Small amounts of hemlock (*Tsuga canadensis*) are often mixed with the hardwoods but this species occurs more often at altitudes of 1200 to 1800 ft. in stands where it is by far the most common species.

There are several finger-like ridges pointing to the east on Whiteface Mountain and Stevenson range to the north (see Figure 1). On the south side of these ridges from about 1500 to 2400 ft. red pine dominated stands occur repeatedly.

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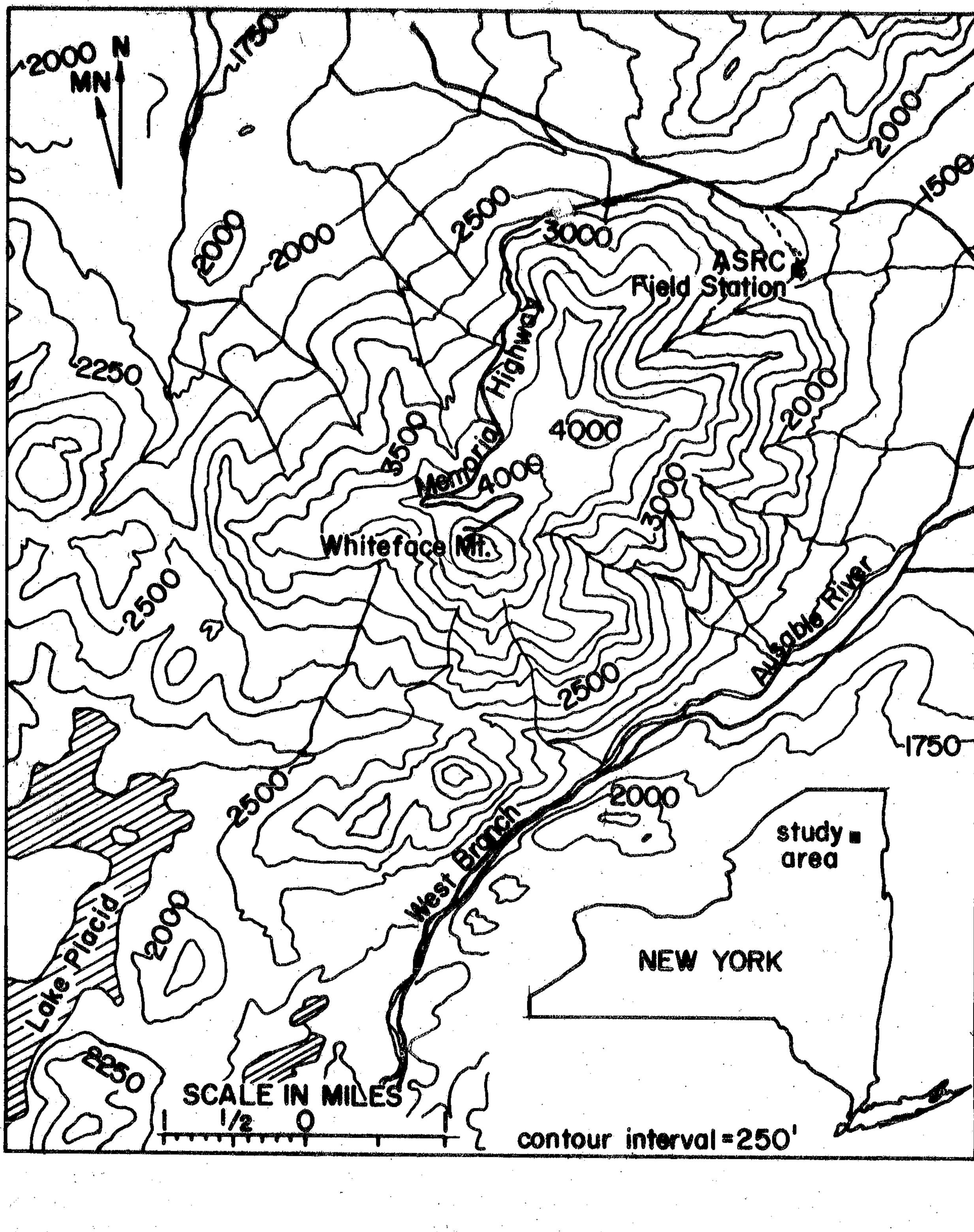
1 Classification is according to Fernald (1950).

Figure 1: Map showing the location of Whiteface Mountain and the region surrounding it. Of the 182 stands sampled, 132 were taken from the area shown with the remainder from nearby lowlands.


2000
N
MN
1750
2000
2000
2000
2500
3000
ASRC
Field Station
1500
2250
Memorial Highway
3500
4000
4000
2000
3000
Whiteface Mt.
2500
Ausable River
2500
1750
2500
2000
West Branch
study area
Lake Placid
2000
NEW YORK
2250
SCALE IN MILES
1 1/2 0 1
contour interval = 250'

On the east-facing slopes of these ridges from about 1000 to 2000 ft are stands containing northern red oak (Quercus rubra var. borealis) mixed with the northern hardwoods and small amounts of ironwood (Ostrya virginiana) and white ash (Fraxinus americana). These species also occur on other moderately well-drained sites of the Ausable River Valley to the east of Whiteface but not on the west side of the mountain.

Adirondack vegetation received many kinds of disturbances beginning with settlement in the early 1800's. Charcoal production for the local iron smelting industry began about 1815. This clear-cutting of lowland hardwoods continued until the late 19th century. Logging of the virgin spruce-fir forests took place in the late 1800's but ended in 1896 when the state legislature passed the "Forever Wild" bill to protect the Adirondacks.

Fires followed much of the logging. The more recent intensive fires are readily discerned from site inspection and many are well marked on aerial photographs by extensive areas of nearly pure paper birch (Betula papyrifera and its variety B. papyrifera var. cordifolia). The cordate-leaved variety may occur in nearly pure stands above 2800 ft but is also mixed with Picea rubens and Abies balsamea in the spruce-fir forests. The two varieties of birch may be intermixed at altitudes of about 1800 to 2800 ft but the cordate-leaved variety is rare below 2000 ft.

The 182 stands were selected primarily to obtain samples from a range of altitudes and slope aspects. It was arbitrarily decided first to obtain stands at 500 foot altitude intervals on the four major compass points. Aerial photographs and maps were studied to select promising sites. If these sites were judged to be "recently disturbed" then the nearest "undisturbed" site was sampled if one could be found. Preliminary analysis of the first two years of data showed that several common species were undersampled because undisturbed stands below 1500 ft were not easy to find. White pine (Pinus strobus) and hemlock (Tsuga canadensis) which occur on low-lying sites were much more rare in the sample than appeared to be the case from inspection of the area. Stands containing these species were sought and sampled.

When an "undisturbed" site was reached it was sampled for density, frequency and basal area. The quarter method (Cottam and Curtis, 1956) was used in 1964 but in 1965 and 1966 basal areas were determined with a Bitterlich prism (Grosenbaugh, 1952), circular plots were used for density and the quarter method for frequency. This latter method was deemed the most efficient from our studies and from Lindsey, et. al. (1958).

Trees were defined as stems of 4 in dbh or greater. Saplings were defined as stems from 1 to 3.9 in dbh. These were sampled for relative density and relative frequency by the quarter method. Ground flora frequency was obtained from one square meter plots at each sample point.

Table 1: Mean relative importance and constancy for the species contained in the vegetation sample of 182 stands at Whiteface Mountain. Species with less than 0.5 percent importance have been omitted. Common names and abbreviations used in Tables and Figures are also listed.

Species and Common Name	Abbreviations Tables	Abbreviations Figures	RIV %	Constancy %
Abies balsamea (L.) Mill. (balsam fir)...........................	Ab	F	21.0	66
Picea rubens Sarg. (red spruce)..................................	Pr	S	16.2	77
Acer saccharum Marsh. (sugar maple)..............................	As	M	11.7	43
Pinus resinosa Ait. (red pine)...................................	Pres	R	6.6	17
Betula alleghaniensis B and B Small (yellow birch)...............	Ba	Y	6.2	47
Tsuga canadensis (L.) Carr. (hemlock)............................	Tc	H	6.1	28
Betula papyrifera var. card. (Regel) Fern. (cordate-leaved birch.	Bc	C	5.7	36
Fagus grandifolia Ehrh. (beech)..................................	Fg	B	5.6	39
Pinus strobus L. (white pine)....................................	Ps	W	5.3	20
Betula papyrifera Marsh. (paper birch)...........................	B pap	P	2.8	41
Quercus rubra var. borealis (Michx. f) Farw. (red oak)...........	Qr	O	2.5	14
Acer rubrum L. (red maple).......................................	Ar	-	2.3	39
Thuja occidentalis L. (white cedar)..............................	To	N	2.3	16
Fraxinus americana (white ash)...................................	Fa	A	1.1	21
Tilia americana L. (basswood)....................................	Ta	T	1.0	13
Ostrya virginiana (Mill.) K. Koch. (ironwood)....................	Ov	I	0.8	18
Acer pensylvanicum L. (striped maple)............................	Apen	-	0.7	20
Populus grandidentata Michx. (large-toothed aspen)...............	Pg	-	0.6	8
Pyrus decora (Sarg.) Hyland (mountain ash).......................	Pd	-	0.6	15

Sample points in each stand were placed 20 normal paces apart along the slope. No change in course was made unless the slope aspect changed from the original point by at least 45 degrees (except for nearly level sites) or when an obviously disturbed area was encountered. When either of these events occurred, the pacing proceeded two points (40 paces) downhill and then in the reverse direction to the original course along the slope. No attempt was made to define a homogeneous stand in the field. That is, the stands were defined by altitude, slope aspect, and judgment of lack of recent disturbance.

The number of points in a given stand ranged from 10 to 40. The fewest number (usually 20) were used in the high altitude stands containing only a few species but 30 to 40 points were used in the mixed vegetation at lower altitudes.

The Chi-square test for homogeneity was applied to all 182 stands. The test described by Curtis and McIntosh (1951) was used which is essentially a test for heterogeneity. A stand was considered to be homogeneous if it did not pass the Chi-square test at the five percent level of confidence. There were 42 stands which proved to be "non-homogeneous". Inspection of the stand data showed that "heterogeneity" was caused by either clumping of the major species or by change in composition along the slope. In the following analysis all 182 stands will be used because the primary concern here is not to study only "homogeneous types" but to determine properties of the vegetation as it varies with topography. Analyses of vegetation gradients using only the homogeneous stands will be reported at a later date.

The relative importance value and constacy for all of the species in the Whiteface sample are given in Table 1. Balsam fir was the most important species followed by red spruce and sugar maple. Red spruce was the most commonly occurring species. Details regarding the composition of the samples and the ecologic relations of the major species were discussed by Holway, et. al. (1969).

THE VEGETATION GRADIENT

Leading Dominants

A method of determining a vegetation gradient was developed by Curtis and McIntosh (1951) whereby the relative placement of major species of a large number of stands could be obtained from their degree of association. Buell, et. al. (1966) used a similar procedure and the Whiteface data were also subjected to this "method of leading dominants".

The sample was first divided into groups based upon the leading dominant. The mean relative importance value (RIV) of all the species in each group was determined. The groups were then arranged in the "most symmetric" pattern as shown in Table 2 using both mean RIV and constancy. The same arrangement procedure was used for the data expressed as "normalized"

Table 2: Percent importance value and constancy (lower figures) for groups of stands based upon the species of leading importance value and arranged symmetrically. Abbreviations are given in Table 1.

No. of Stands Species	(44) Ab	(4) Bc	(29) Pr	(5) To	(10) Ba	(15) Tc	(10) Fg	(28) As	(6) Qr	(11) Ps	(15) Pres
Abies balsamea	67	21	16	7	8	3	2	2	--	4	1
	(100)	(100)	(93)	(100)	(90)	(60)	(40)	(25)	--	(27)	(40)
Betula pap. var. cord.	12	52	8	3	4	--	--	1	--	--	--
	(85)	(100)	(62)	(40)	(20)	(4)	--	--	--	--	--
Picea rubens	17	18	49	13	17	9	8	3	--	4	6
	(82)	(100)	(100)	(100)	(100)	(100)	(90)	(57)	--	(45)	(73)
Thuja occidentalis	--	--	1	63	1	1	--	--	--	1	3
	--	--	(28)	(100)	(30)	(33)	--	--	--	(27)	(33)
Betula alleghaniensis	1	8	6	2	37	9	16	6	--	--	--
	(14)	(75)	(55)	(60)	(100)	(93)	(100)	(72)	--	--	--
Tsuga canadensis	--	--	3	1	2	57	4	2	--	1	2
	(2)	--	(35)	(40)	(30)	(100)	(50)	(25)	--	(18)	(33)
Fagus grandifolia	--	--	1	--	10	6	36	14	1	--	--
	--	--	(17)	--	(70)	(93)	(100)	(100)	(67)	--	--
Acer saccharum	--	--	2	--	13	5	24	48	30	1	--
	--	--	(28)	--	(80)	(80)	(100)	(100)	(83)	(27)	(7)
Quercus rubra var. bor.	--	--	--	--	--	--	--	5	45	1	2
	--	--	--	--	--	(7)	(10)	(29)	(100)	(9)	(20)
Pinus strobus	--	--	2	--	--	--	--	--	2	61	14
	--	--	(28)	(20)	--	(20)	--	--	(17)	(100)	(80)
Pinus resinosa	--	--	1	--	--	1	--	--	3	15	65
	--	--	(10)	--	--	(7)	--	--	(17)	(9)	(100)

RIV in Table 3. In the latter case each RIV in Table 2 was multiplied by the ratio of the mean RIV of the most important species (balsam fir) divided by the mean RIV of the particular species. This procedure was an attempt to avoid overweighting the importance of common species in the sample but gave the same arrangement as Table 2.

The arrangements in Tables 2 and 3 give a species ordering with the high altitude spruce-fir (cool and wet) sites on one end and lowland pine (warm and dry) stands at the other with mesic hardwoods stands in the center. The wet to dry sequence is indicated but not proven. There is reason to believe from field evidence that white cedar (To) and hemlock (Tc) occur on drier sites than their position shown in Table 2.

Strip Method

To obtain a more precise positioning of the species along a vegetation gradient a method similar to that of Curtis and McIntosh (1951) was applied to the sample of 182 stands. The RIV of each species in each stand was plotted on a 100 cm long strip of graph paper. Each species was represented by a different colored dot. The 182 strips were then arranged so as to produce "solid normal curves" of the colored dots. In the first such arrangement the authors were guided by the order of the major species in Table 2. The only rule applied was to attempt to find the smoothest possible curve for each species. To obtain a value for ranking the species, the mid-points for each species in the order was found by adding the species RIV from left to right until the sum reached 50% of the total sample RIV of that species. The positions of the species mid-points were then normalized to a scale from 0.00 to 1.00 and rounded to the nearest 0.05 units. These numbers are here called SPN (species index number) and are analagous to the "climax adaptation values" of Curtis and McIntosh (1951). The final determination of these numbers is given in Table 4.

Obviously, this procedure is not without bias because the arrangement may have been affected by the personal judgment of the authors who had knowledge of the site characteristics. For example, if the strips were to be arranged according to a wet to dry sequence balsam fir stands would be placed at the opposite end from red pine stands, and the arrangement would no doubt be similar to the one based upon the order in Table 2. The question was asked as to how the strips would be arranged without knowledge of Tables 2 and 3 and without any field knowledge of the species involved. To answer this question, the strips were thoroughly mixed in bundles and given to students to arrange. The students were completely unaware as to what the symbols represented on the strips, and even if they had known, had no familiarity with the vegetation of of the region. The only instructions given were to arrange the strips so as to produce what seemed to them to be the most reasonable series of "solid normal distribution" curves.

Table 3: Adjusted mean RIV for groups of stands having one species of leading RIV. Values are those in Table 2 multiplied by the ratio of the mean RIV of <u>Abies balsamea</u> to that of the particular species. Abbreviations are given in Table 1.

	(44) Ab	(4) Bc	(29) Pr	(5) To	(10) Ba	(15) Tc	(10) Fg	(28) As	(6) Qr	(11) Ps	(15) Pres
Ab	67	21	16	7	8	3	2	2	--	4	1
Bc	46	189	28	12	13	--	--	3	--	--	--
Pd	49	40	40	--	23	--	--	--	--	--	--
Pr	21	24	64	17	22	11	11	4	--	5	8
To	--	--	13	572	6	5	--	--	--	6	24
Ba	4	28	20	9	124	30	55	20	--	--	--
Apen	3	--	40	9	74	62	57	9	3	--	3
Tc	--	--	9	2	7	197	14	7	--	5	6
Fg	--	--	2	--	40	23	136	52	4	--	--
Ar	4	--	23	41	25	38	38	16	8	40	17
As	--	--	3	--	23	9	44	86	54	2	--
Ta	--	--	--	--	--	4	--	87	69	--	--
Bpap	1	--	36	22	7	13	7	46	26	23	34
Fa	--	--	4	14	10	2	12	83	135	--	--
Ov	--	--	3	--	--	18	5	39	276	45	8
Qr	--	--	--	--	--	1	1	38	374	11	14
Ps	--	--	7	1	--	2	--	--	10	241	56
Pres	--	--	2	--	--	2	--	--	9	48	207

Table 4: Listing of the species index numbers (SPN) for the Whiteface Mountain vegetation sample and the "smoothed" SPN (see text for explanation).

Tree Species	SPN	"Smoothed" SPN
Abies balsamea........................	0.00	0.00
Betula papyrifera var. cord.	0.10	0.10
Pyrus decora..........................	0.10	0.10
Picea rubens..........................	0.25	0.25
Thuja occidentalis....................	0.40	0.35
Acer spicatum.........................	0.45	0.55
Acer pensylvanicum....................	0.45	0.45
Betula alleghaniensis.................	0.45	0.50
Tsuga canadensis......................	0.50	0.50
Acer rubrum...........................	0.55	0.60
Fagus grandifolia.....................	0.60	0.65
Acer saccharum........................	0.70	0.75
Betula papyrifera.....................	0.75	0.75
Fraxinus americana....................	0.75	0.80
Tilia americana.......................	0.75	0.85
Populus gradidentata..................	0.80	0.95
Ostrya virginiana.....................	0.85	0.90
Quercus rubra var. bor.	0.85	0.90
Pinus strobus.........................	0.90	1.00
Pinus resinosa........................	1.00	1.00

Three such independent arrangements by students were obtained. In all three cases balsam fir was placed at the extreme left and red pine at the extreme right. This is the same as the sequence arrived at based on field evidence and on Tables 2 and 3. Further, the order of other species between the two terminal ends was nearly the same, but the students found it difficult to place the stands dominated by hemlock and white cedar.

Because of the difficulty of placing the hemlock stands in the strip order, a student was asked to arrange the strips without the stands having hemlock leading in RIV. The SPN were then determined as before. In this case the stands containing hemlock (not as the leading species) were placed by the student according to the species with which hemlock associates. The SPN of hemlock turned out to be 0.50 by this method.

The stands with hemlock leading in RIV were then examined for the species associating with hemlock. The weighted mean SPN of all species in hemlock stands (not including hemlock) was found to be 0.52. Thus the SPN of hemlock was determined by three different methods. The first was an arrangement of the strips based upon the most symetric placement of the leading dominants. The second was based upon a determination of the species hemlock associates with and the third upon the species associating with hemlock when it is the most important species in a stand. All three methods produced essentially the same result.

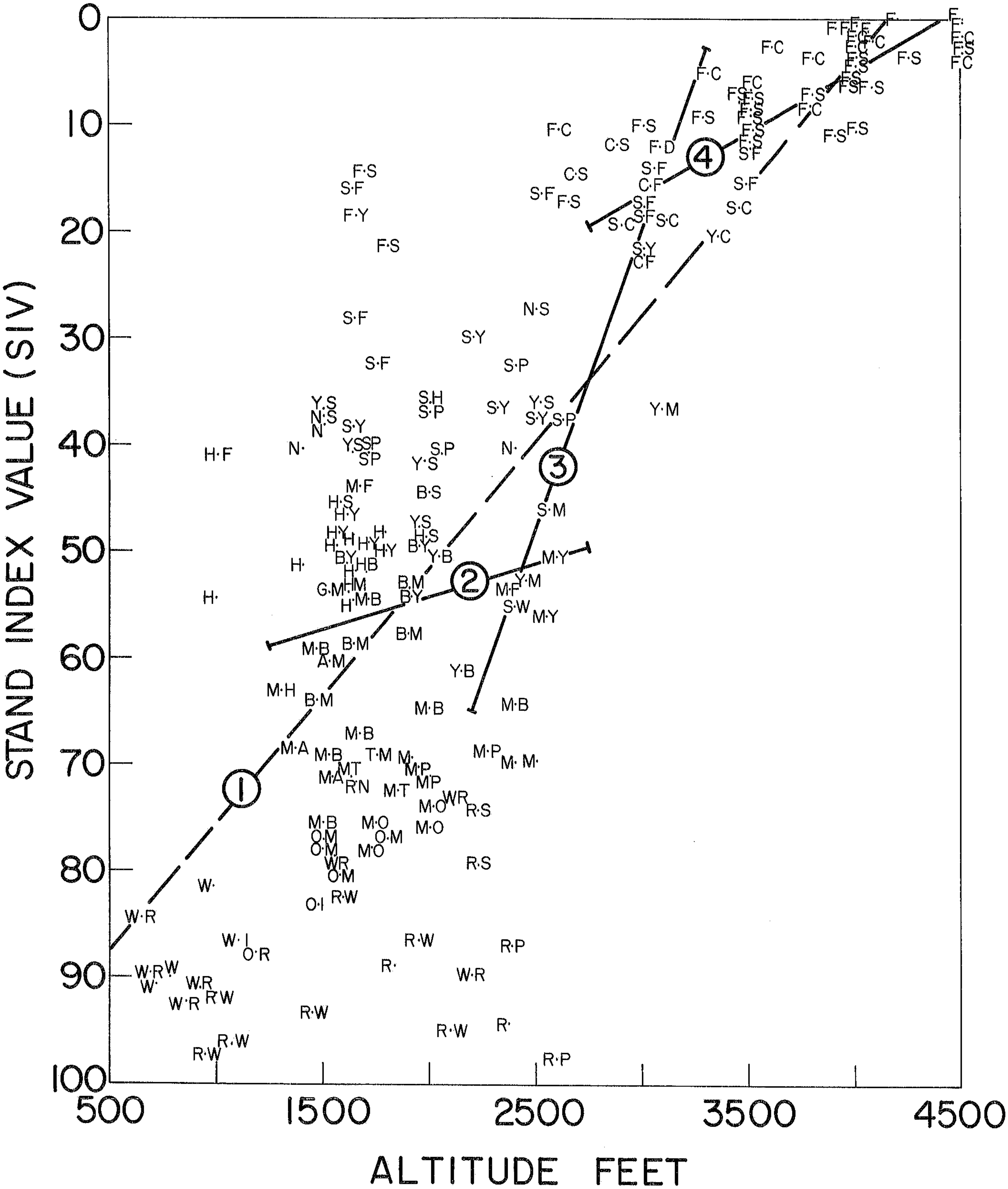
The above procedure was repeated for white cedar with similar agreement between methods. Such a procedure might also be recommended for obtaining the SPN for all species, but it is doubtful that the results would change the numbers given in Table 4.

The students with no knowledge of the meaning of the dots on the strips seemed to place strips predominantly according to the leading few species. This caused large variation in the SPN of the rare species for the several trials used. Rare species could be more reliably placed in the order by computing a "stand index value" (STV) and then ranking the stands by this value. The STV was obtained by multiplying the SPN (Table 4) by the RIV for all species in the stand and summing the products. The range of STV was therefore from 0 to 100.

After ranking the stands according to their STV the species mid-points were again computed to obtain the new "smoothed" SPN. These numbers are shown in the second column of Table 4.

The SPNs obtained here have no relevance to the vegetation in any other area except perhaps in relative placement of many of the species. The SPNs in fact are truly relevant only to the sample of 182 stands used in the analysis although nearly the same numbers would be obtained from a completely different sample taken in the Whiteface area. The relative

Figure 2: Scatter diagram of STV versus altitude and plots of regression lines. All stands are included. Numbers refer to the columns for the regression data in Table 6. Abbreviations are given in Table 1.


STAND INDEX VALUE (SIV)
ALTITUDE FEET
0
10
20
30
40
50
60
70
80
90
100
500
1500
2500
3500
4500
1
2
3
4

placement of the SPN from the present analysis is similar to those obtained by Curtis and McIntosh (1951), Brown and Curtis (1952) and Buell, et. al. (1966), but the earlier studies probably did not include as wide a range of site characteristics as in the Whiteface sample. If the stands from higher than 2500 ft were removed from the Whiteface sample then the SPN would perhaps be in closer agreement to those found in Wisconsin and northern New Jersey.

Although the SPNs have ecologic significance it is the STVs which are useful for relating the vegetation to environment. More rigorous techniques are available for placing stands along a vegetation gradient than the simple procedure followed here. In the present study the STV will be related only to simple measures of environment and therefore, only one "axis" of the vegetation gradient is desired. When more sophisticated environmental data is obtained techniques will be used which extract more information from the sample. Goff and Cottam (1968) have shown that all standard methods produce nearly the same results for the first axis.

VARIATION OF STV WITH TOPOGRAPHY

The major difficulty in a study of vegetation-environment relations is in measuring the environment. Paraphrasing the rigorous definition of Mason and Langenheim (1957), environment ideally consists of all phenomena which directly affect an organism sometime during its life cycle. They emphasize that environment acts at the organism level. Therefore, the concept of "stand environment" is nebulous at best. It consists of the integrated effects of all phenomena which affect individual plants and animals. However, many physical parameters may be measured at the stand level which are closely related to environmental phenomena and therefore influence the composition of vegetation. We can never hope to measure the "operational environment" as defined by Mason and Langenheim (1957), unless we have sensors which are organisms themselves. Approximations to the environment would consist of measurements of such things as energy, moisture, and nutrient balances and smaller elements of these. It is the goal of the study at Whiteface Mountain to obtain better measures of these quantities in order to relate them to the vegetation gradient. Because this work is not yet complete, only simple approximations of the environment can be used. In this paper the vegetation gradient (STV) will be related only to topographic variables.

The Topographic Groups

The STV can be related to topography by plotting it in scatter diagrams against each feature (altitude, slope-aspect, or slope) or the various topographic features can be broken into groups (or ranges) and mean STVs compared for each feature.

Both techniques will be used here, but problems arise with each method. Looking strictly at mean values does not consider the kind and amount of variance and looking only at plots of individual stands may influence the result by overweighting for sub-groups within the sample which may have been "oversampled".

The difficulties involved with "oversampling" of certain topographic ranges are illustrated by the data for all stands summarized in Table 5. Mean STV is given for topographic groups broken down first by 500 foot ranges of altitude (250 to 750 ft etc.) then by slope-aspect quadrants (e.g. east includes stands with slope-aspect ranging from 45^{o} to 134^{o}) and last by 10^{o} intervals of slope. The number of stands in each group is also given. Note that certain ranges may include several stands while others were not even sampled. Therefore, if a scatter plot and a correlation were made, for example, of STV versus slope-aspect the result may be strongly influenced by the fact that some altitude ranges contained either a high or low number of stands with certain slope-aspect ranges. For example, in the 2500 ft range there were eleven south facing stands but only three each facing east and west. The mean STV for this range will be influenced by the fact that the STV for south-facing stands was higher than other aspects if stands are weighted equally.

Other methods of weighting to compute mean STV can be used. For example, when computing means for altitude ranges one can first compute means for slope-aspect groups by weighting the slope ranges equally and then obtain altitude means by weighting the slope-aspect ranges equally. Many combinations of weighting exist and the resulting STV means may be quite different than those in Table 5. Some of these are discussed in the following sections.

Altitude Variation of STV

It is expected that many physical phenomena related to the environment of an organism are highly correlated with altitude. These include many constituents of the heat, moisture, and nutrient balances. Many authors have found that the mean value of measures of species importance form "bell-shaped" curves when plotted against altitude indicating that the species has a range of tolerance with some optimum at a particular altitude. This work is well represented by Whittaker (1956, 1960), and Whittaker and Niering (1965). (See also Figure 7.)

Plotting of the stand index value (STV) rather than a species importance value has the advantage that the STV may result from the integration of more environmental phenomena than the species value. It is, therefore, a method of relating the total vegetation with environment. The STV is plotted against altitude in Figure 2. For each plot the one or two species of leading importance value are shown by the appropriate letters.

Table 5: Mean stand index values (STV) and number of stands by various groupings of altitude, slope-aspect, and slope. Weighting is at stand level (all stands weighted equally).

Altitude Range	Slope Aspect Range	Level N	Level STV	3°to9° N	3°to9° STV	10°to19° N	10°to19° STV	20°to29° N	20°to29° STV	More than 30° N	More than 30° STV	Slope-aspect means N	Slope-aspect means STV	Altitude Range N	Altitude Range STV
	E	-	-	-	-	1	90.6	-	-	-	-	1	90.6	-	-
	S	-	-	1	89.5	-	-	-	-	-	-	1	89.5	-	-
500	W	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Means	1	84.4	1	89.5	1	90.6	-	-	-	-	2	90.0	3	88.2
	E	-	-	1	86.7	-	-	-	-	-	-	1	86.7	-	-
	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1000	W	-	-	5	70.1	1	97.3	-	-	-	-	6	74.6	-	-
	N	-	-	-	-	1	90.0	-	-	-	-	1	90.0	-	-
	Means	3	91.2	6	72.8	2	93.6	-	-	-	-	8	78.0	11	81.6
	E	-	-	8	61.9	5	65.1	1	77.4	-	-	14	64.1	-	-
	S	-	-	7	57.6	2	67.5	-	-	-	-	9	59.8	-	-
1500	W	-	-	4	59.3	6	49.3	2	74.0	-	-	12	56.7	-	-
	N	-	-	3	40.9	1	52.0	2	71.2	-	-	6	52.8	-	-
	Means	11	37.5	22	57.1	14	57.8	5	73.5	-	-	41	59.3	52	54.7
	E	-	-	4	63.3	5	65.7	-	-	-	-	9	64.6	-	-
	S	-	-	3	61.4	3	60.9	2	65.5	-	-	8	62.3	-	-
2000	W	-	-	5	65.4	3	50.6	1	41.1	-	-	9	57.8	-	-
	N	-	-	4	55.8	-	-	1	71.9	-	-	5	59.0	-	-
	Means	5	52.0	16	61.7	11	60.3	4	61.0	-	-	31	61.1	36	59.8
	E	-	-	-	-	-	29.0	2	66.8	-	-	3	54.2	-	-
	S	-	-	3	69.1	3	72.6	5	49.3	1	32.7	11	61.0	-	-
2500	W	-	-	1	56.1	-	-	1	36.5	-	-	3	41.8	-	-
	N	-	-	-	-	3	23.2	3	39.2	-	-	6	31.2	-	-
	Means	1	40.4	4	65.8	7	45.1	11	48.6	1	32.7	23	49.9	24	49.4

Table 5 (Continued)

Altitude Range	Slope Aspect Range	Slope Range: Level		3°to9°		10°to19°		20°to29°		More than 30°		Slope-aspect means		Altitude Range	
		N	STV	N	STV	N	STV	N	STV	N	STV	N	STV	N	STV
	E	-	-	-	-	-	-	2	17.0	-	-	2	17.0	-	-
	S	-	-	-	-	2	15.2	-	-	-	-	2	15.2	-	-
3000	W	-	-	-	-	-	-	4	13.8	-	-	4	13.8	-	-
	N	-	-	-	-	3	15.9	4	27.2	1	11.9	8	21.3	-	-
	Means	-	-	-	-	5	15.6	10	19.8	1	11.9	16	18.1	16	17.9
	E	-	-	-	-	1	5.1	2	18.0	2	12.8	5	13.5	-	-
	S	-	-	-	-	-	-	-	-	2	9.8	2	9.8	-	-
3500	W	-	-	-	-	2	8.8	3	10.0	-	-	5	9.5	-	-
	N	-	-	-	-	1	8.5	3	7.2	-	-	4	7.2	-	-
	Means	-	-	-	-	4	7.8	8	10.9	4	11.3	16	10.2	16	10.2
	E	-	-	2	3.3	-	-	2	10.0	2	11.9	6	6.8	-	-
	S	-	-	-	-	1	3.5	3	2.9	1	0.9	5	2.6	-	-
4000	W	-	-	-	-	-	-	1	5.1	-	-	1	5.1	-	-
	N	-	-	-	-	2	0.8	1	3.8	3	3.4	6	2.6	-	-
	Means	-	-	2	3.3	3	1.7	7	5.4	6	5.8	18	4.1	18	4.5
	E	-	-	-	-	-	-	1	3.6	1	5.1	2	4.4	-	-
	S	-	-	-	-	-	-	-	-	1	3.4	1	3.4	-	-
4500	W	-	-	-	-	-	-	-	-	2	0.8	2	0.8	-	-
	N	-	-	-	-	-	-	1	0.0	-	-	1	0.0	-	-
	Means	-	-	-	-	-	-	2	1.9	4	2.5	6	2.3	6	2.3
Means of slope groups		21	51.0	51	59.8	47	46.3	47	31.3	16	7.7				

The leading species in Figure 2 tend to "clump" in regions of the altitude- STV plot. For example, the fir and spruce stands are concentrated in the upper right corner, the hemlock in the left center, and pines on the lower left. This indicates that an STV-altitude "classification" system might be fruitful because the stand index expresses stand composition. When plotted on an STV axis, the dominant species would, therefore, tend to be found in regions close to the species index number of the particular species. For example, hemlock should "clump" near 50 STV and balsam fir near zero on the STV scale. Yellow birch and red spruce are more widely scattered in Figure 2 indicating that they have wide ranges of tolerance.

The scatter plot in Figure 2 shows that STV correlates with altitude. The linear regression coefficient is 0.79 with a standard error of 18.0 STV units (Table 6). The scatter is fairly small for high altitude stands and increases with decrease in altitude down to about 1200 ft. Below 1200 ft the sample contained only a few stands because of the small amount of area below this altitude. The scatter would presumably continue to increase if more low-lying stands were included.

Computing the regression coefficient for the entire range of altitude of Figure 2 may be misleading because upon inspection the slope of the plot seems to change at about 3000 ft. Regressions were performed on smaller altitude ranges and the results are given in Table 6. The slope and zero altitude intercepts are given by A_1 and A_0 respectively. The regression equations can be obtained from Table 6 and these are also drawn for the four cases in Figure 2.

The regression line for the entire sample falls below the stand plots for high altitudes and above at low altitudes. When the regression lines for the three smaller ranges are plotted, (columns 2, 3, and 4 in Table 6) the slopes of the lines change with altitude and the lines seem to fit the data more closely. The correlation is low for the 1250 to 2750 foot range ($r = -0.11$) and the scatter is great ($S = 20.2$) with significance only at the 10% level of confidence.

Breaking the scatter plot in Figure 2 into smaller groups indicates that there may be a real change in slope of STV with altitude. Perhaps it would be better to fit the data to a more complicated function (e.g. sigmoid curve) but this would not improve the correlation because the scatter in the middle altitude range is very great.

The changes in slope of the regression lines in Figure 2 may lead to the interpretation that the steeper portion of the plot between 2500 and 3000 ft represents an "ecotone" between the two more gradually sloping hardwoods and spruce-fir "associations". If a straight line results when vegetation is plotted against environment the assumptions would be that there is no tendency for association between species or that vegetation is a "continuum". Because environment is not necessarily a linear function of altitude the interpretation that "ecotones" and "associations" exist must be viewed

Table 6: Regression analysis data for STV versus altitude for several ranges in altitude. Data show the number of stands in the range (N), correlation coefficient (γ), standard error of the regression in STV units (S), the regression constant or zero altitude intercept (A_o) and the regression coefficient or slope of the regression (A_1). The three groups on the right marked with an asterisk (*) contain no level or pine-dominated stands.

Variable	1 250- 4750	2 1250- 2750	3 2250- 3250	4 2750- 4750	5 250- 4750*	6 1250- 2750*	7 2250- 3250*
N	182	112	40	56	139	83	36
γ	-0.79	-0.11	-0.67	-0.69	-0.86	-0.41	-0.70
S	18.0	20.2	18.5	6.2	13.0	15.0	14.1
A_o	99.8	66.3	193.5	52.5	97.6	86.8	164.3
A_1	-0.024	-0.006	-0.058	-0.012	-0.024	-0.017	-0.048
Signif. Level	1%	10%	1%	1%	1%	1%	1%

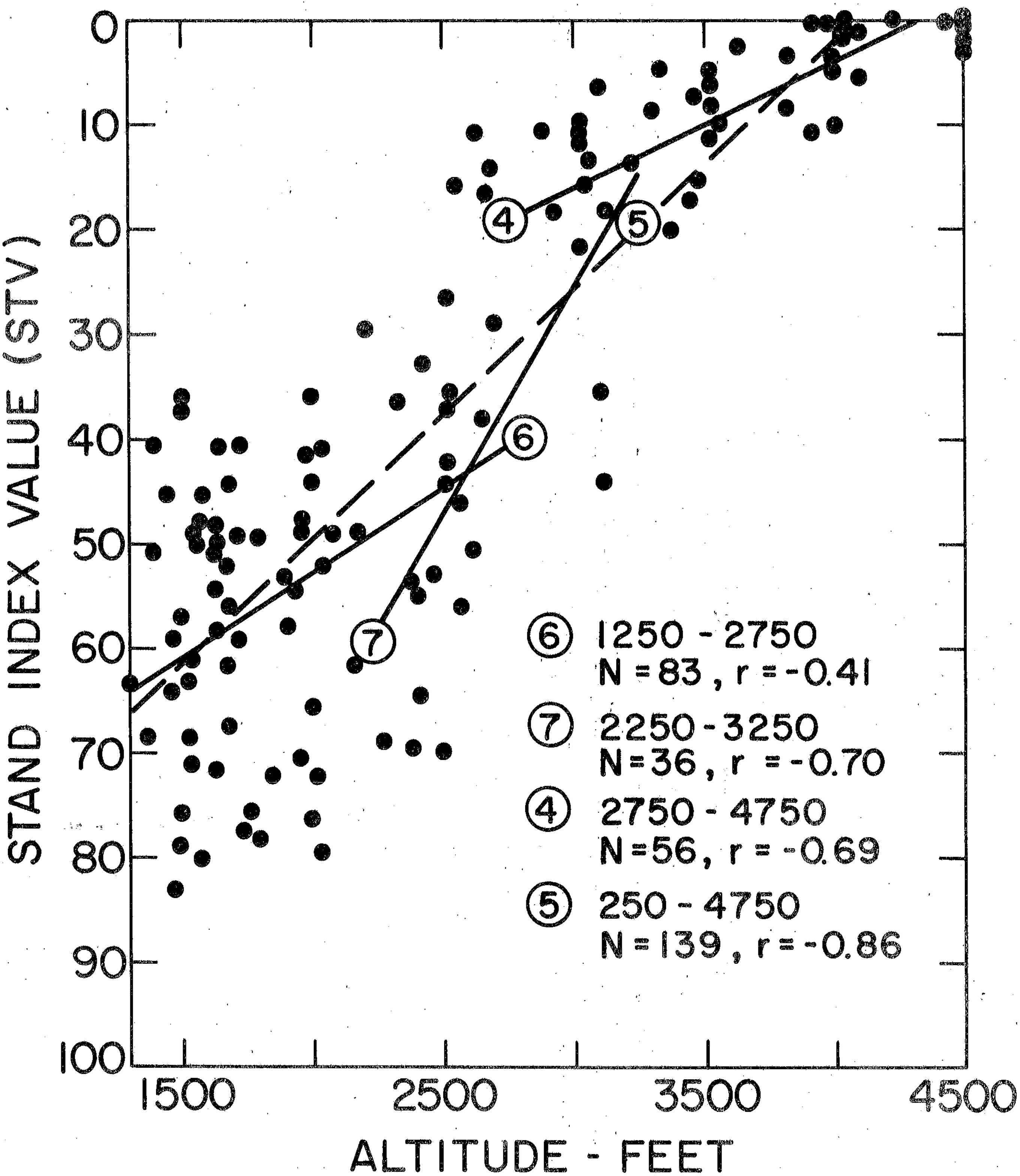
Table 7: Mean STV for altitude groups centered at 500 foot intervals with various weightings for slope-aspect and slope groups and certain stands selectively eliminated. In column (1) are means including the entire sample with each stand weighted equally. In column (2) stands are weighted equally but stands dominated by pine species and those on level sites have been removed. In column (3) pine and level stands have been removed but the means are obtained by weighting each slope-aspect group (E, S, W, N) equally. Column (4) is the same as (3) but each slope group is weighted equally to compute slope-aspect means before computing altitude means. Column (5) is the same as (4) except that stands not on Whiteface Mountain and adjacent peaks or ridges have been removed. Column labeled s is standard deviation.

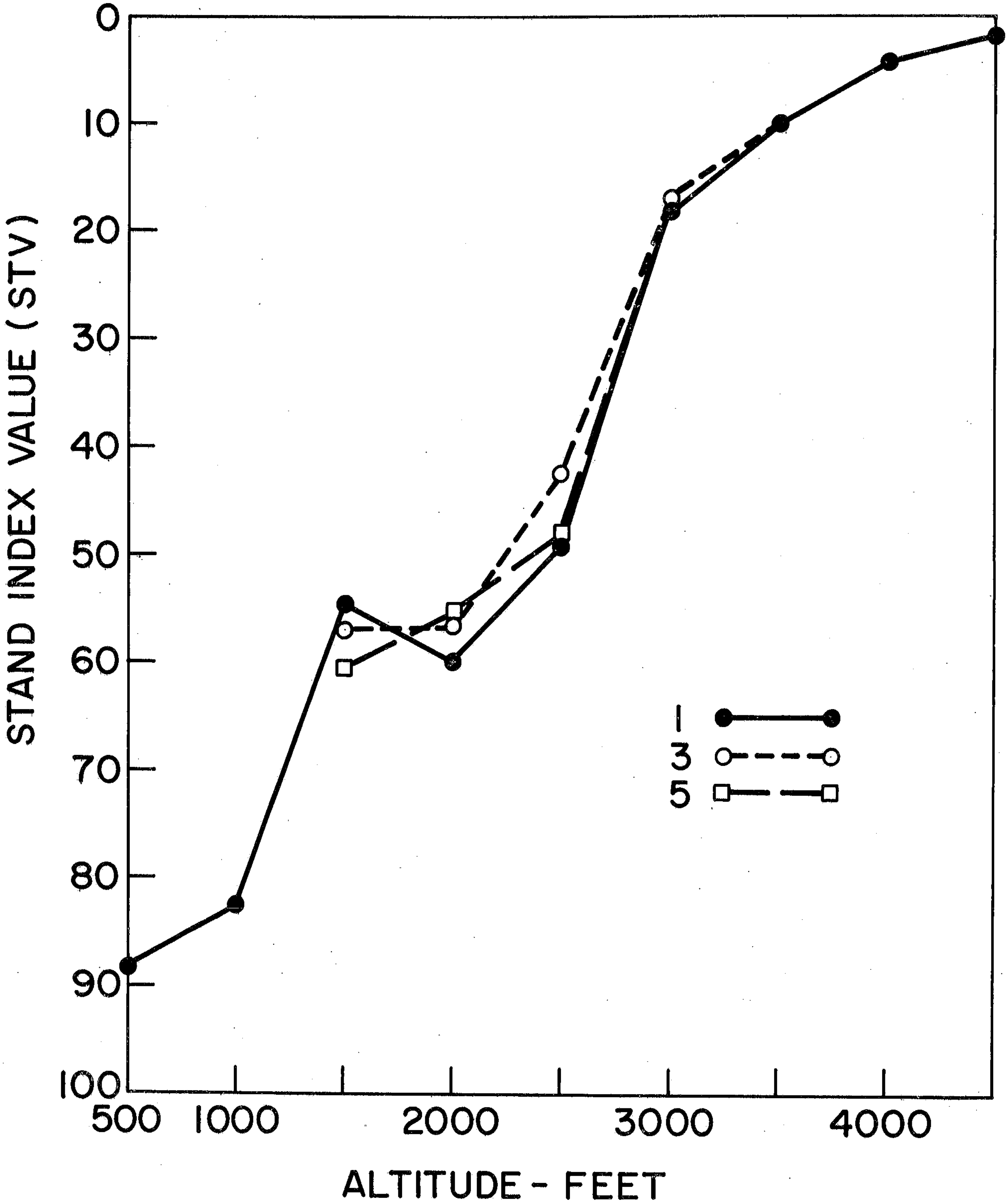
Center of Altitude Range	1			2			3		4		5	
	N	STV	s	N	STV	s	N	STV	N	STV	N	STV
500	3	88.2	-	-	-	-	-	-	-	-	-	-
1000	11	81.6	17.3	2	47.7	-	-	-	-	-	-	-
1500	52	54.7	18.5	37	57.0	14.1	4	56.6	4	58.5	3	60.3
2000	36	59.8	18.8	26	56.6	14.1	4	56.8	4	57.7	4	55.6
2500	24	49.4	23.1	20	42.4	17.7	4	42.5	4	43.4	4	48.2
3000	16	17.9	9.3	16	17.9	9.3	4	16.8	4	17.8	4	17.8
3500	16	10.2	4.4	16	10.2	4.4	4	10.0	4	9.8	4	9.8
4000	18	4.5	3.3	18	4.5	3.3	4	4.3	4	4.2	4	4.2
4500	6	2.3	2.6	6	2.3	2.6	4	2.2	4	2.2	4	2.2

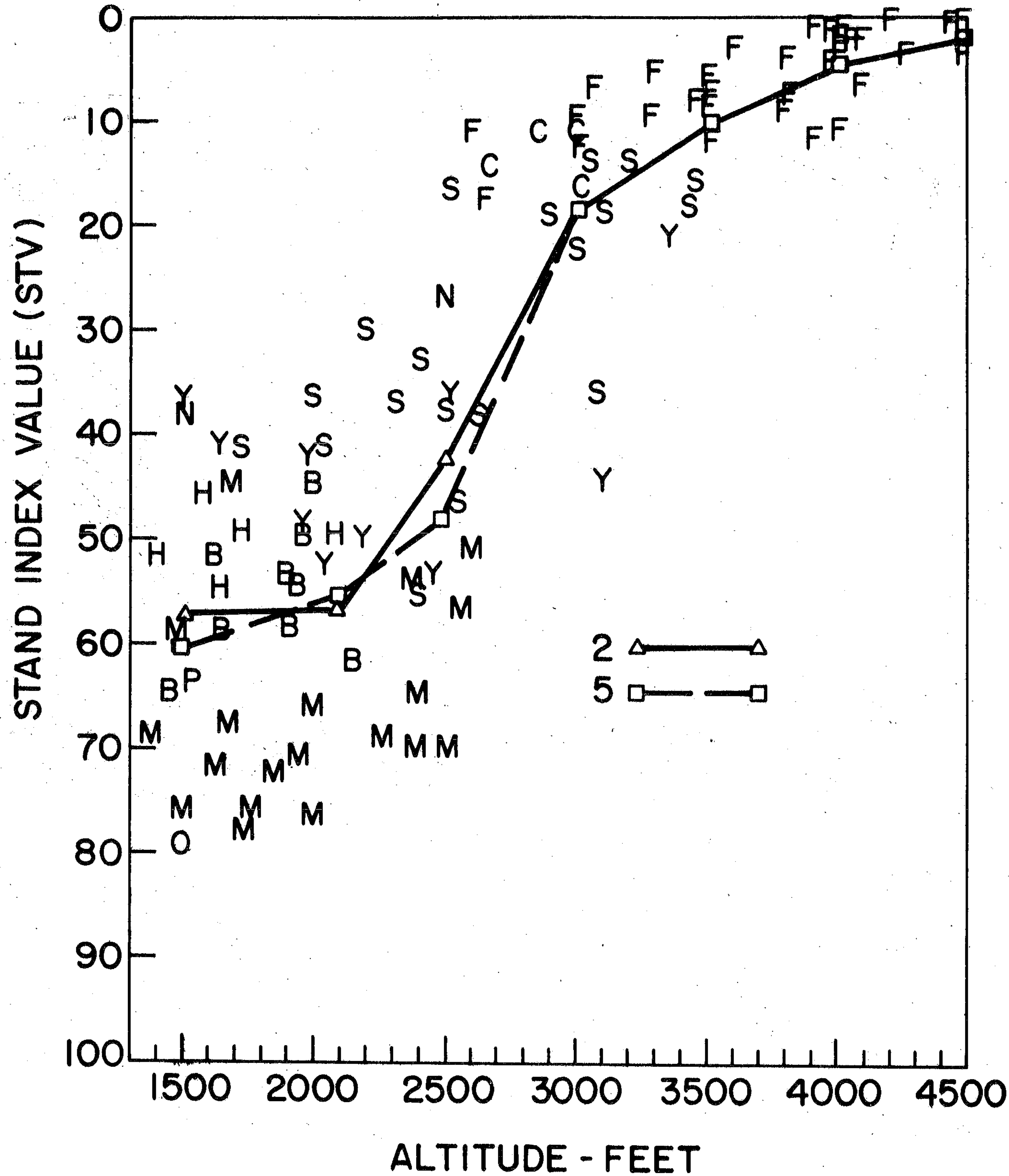
Figure 3: Scatter diagram of STV versus altitude and plots of regression lines. Sample does not include pine-dominated and level stands. Numbers refer to columns for regression data in Table 6. Abbreviations are given in Table 1 (page 67).

Figure 4: Plots of mean STV by 500 foot ranges of altitude. Numbers refer to columns of mean STV in Table 7 (page 68).

Figure 5: Scatter plot of STV versus altitude and plots of mean STV for 500 foot altitude ranges. Data do not include pine-dominated or level stands. Numbers refer to columns in Table 7 (page 69).


STAND INDEX VALUE (STV)
0
10
20
30
40
50
60
70
80
90
100
1500
2500
3500
4500
ALTITUDE - FEET
4
5
6
7
⑥ 1250 - 2750
N = 83 , r = -0.41
⑦ 2250 - 3250
N = 36 , r = -0.70
④ 2750 - 4750
N = 56, r = -0.69
⑤ 250 - 4750
N = 139 , r = -0.86


STAND INDEX VALUE (STV)
0
10
20
30
40
50
60
70
80
90
100
500
1000
2000
3000
4000
ALTITUDE - FEET
1
3
5


STAND INDEX VALUE (STV)
0
10
20
30
40
50
60
70
80
90
100
1500
2000
2500
3000
3500
4000
4500
ALTITUDE - FEET
2
5

with caution. In fact, there are reasons to believe that environment may also vary with altitude in the same manner as does the vegetation in Figure 2.

The scatter plot in Figure 2 could perhaps be changed by elimination of stands which are located on sites having special physiographic conditions. For example, there are several stands in the 1500 foot range which have low STV. These are lowland poorly-drained spruce-fir stands on level sites. Also in the range centered at 2000 ft there are several pine-dominated stands with high STV. These are located on south-facing sides of ridges or on the ridge tops and are very well-drained sites. Many of these could have received moderate burning. It seems likely that these special cases of topographic and physiographic conditions caused much of the wide scatter in Figure 2. Perhaps they could legitimately be removed from the sample.

The scatter plot with all pine-dominated and level stands removed is given in Figure 3 and the appropriate regression analysis data in the last three columns of Table 6. The scatter has been reduced compared to Figure 2. The regression for the 1250 to 2750 foot range now becomes significant at the 1% level. When the regression lines are drawn the interpretation from Figure 3 is the same as from Figure 2; the changing slopes may indicate an "ecotone" between two "associations".

Another method of examining the STV-altitude relationship is to plot the mean STV for altitude groups. This has been done in Table 7 and Figures 4 and 5. The danger of considering mean values lies with the large variance within groups and with the manner in which the means are computed.

The mean STV for 500 foot ranges of altitude (250 to 749 ft etc.) for all stands was first computed by giving equal weight to each stand regardless of its slope-aspect or slope. The result is column 1 of Table 7 and plot number 1 of Figure 4. For this case, the mean STV at 2000 ft is lower than at 1500 ft. The plot shows a fairly gradual change from 4500 ft down to 3000 ft, a rapid change between 3000 and 2500 ft, and then again a gradual slope from 2500 to 1500 ft. These slope changes are almost the same as those found by examining the scatter plots in Figures 2 and 3 and lead to the same tentative interpretation.

The question which should first be answered is whether or not the computation of mean STV for altitude groups is valid. A good simple answer cannot be obtained but several simplifications can be made. The first simplification is to remove the pine-dominated and level stands, as before, because these may represent anomalous physiographic conditions.

With the level and pine-dominated stands removed from the sample, the resulting mean STV is shown in column 2 of Table 7 and plotted in Figure 5. The curve for the mean STV still has a shape similar to the plot in Figure 4 but the values at 2000 and 1500 ft have changed significantly. Also given in Figure 5 is the scatter plot of stands above 1250 ft with level and pine stands removed.

A further simplification can be made by using a different method of weighting for the mean STV. In column 3 of Table 7 and plot 3 of Figure 4 the mean STV was obtained by first obtaining means for the four quadrants of slope-aspect (E, N, S, W) and then weighting these equally regardless of how many stands were contained in the slope-aspect groups. In this case, the pine and level stands have been removed. This same type of weighting before removing pine and level stands is not shown but is similar to column 1 of Table 7. In column 4 of Table 7 the mean STV for the four slope groups were weighted equally to obtain slope-aspect means before weighting these equally to obtain altitude means. Although the type of weighting did not always affect the result it is probably best to give equal weight to the groups rather than to individual stands because there was often large differences in the number of samples from one group to another (see Table 5 for the number of stands in each category).

The last column in Table 7 is weighted as in column 4 but only stands in the immediate vicinity of Whiteface Mountain have been included. These data are plotted in both Figures 4 and 5 for comparison. This last result shows the smoothest change of mean STV with altitude but the two gradually sloping regions at high and middle altitudes are still present with a region of rapid change between. It seems likely that this relation of STV with altitude is real for the particular sample. Interpretation must be made with full knowledge of many possible causes. Some of these may be physiographic, some ecologic, and some may involve flaws in the sampling or analysis. The many possibilities will be considered in the discussion section below.

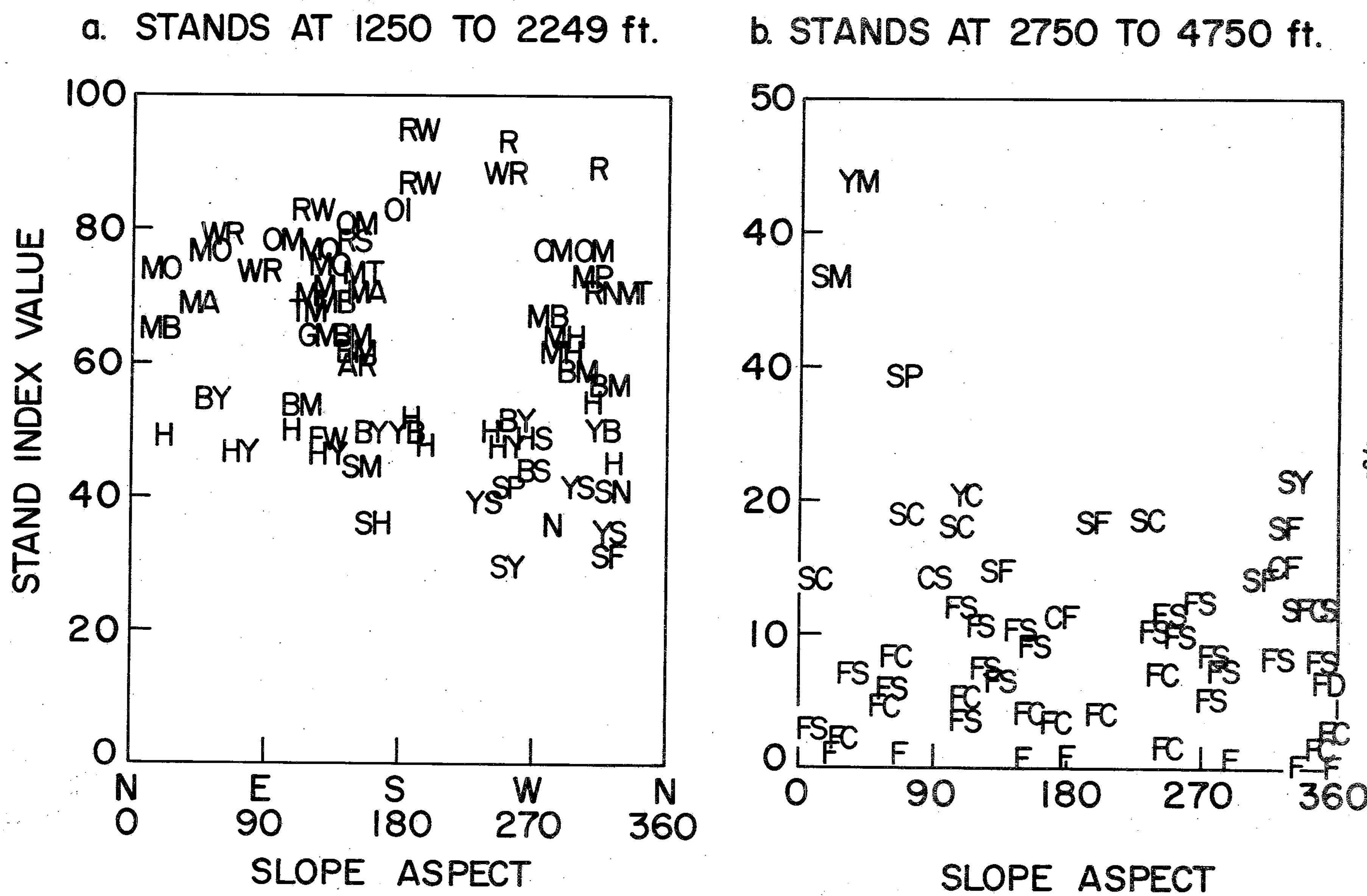
Slope-aspect Variation

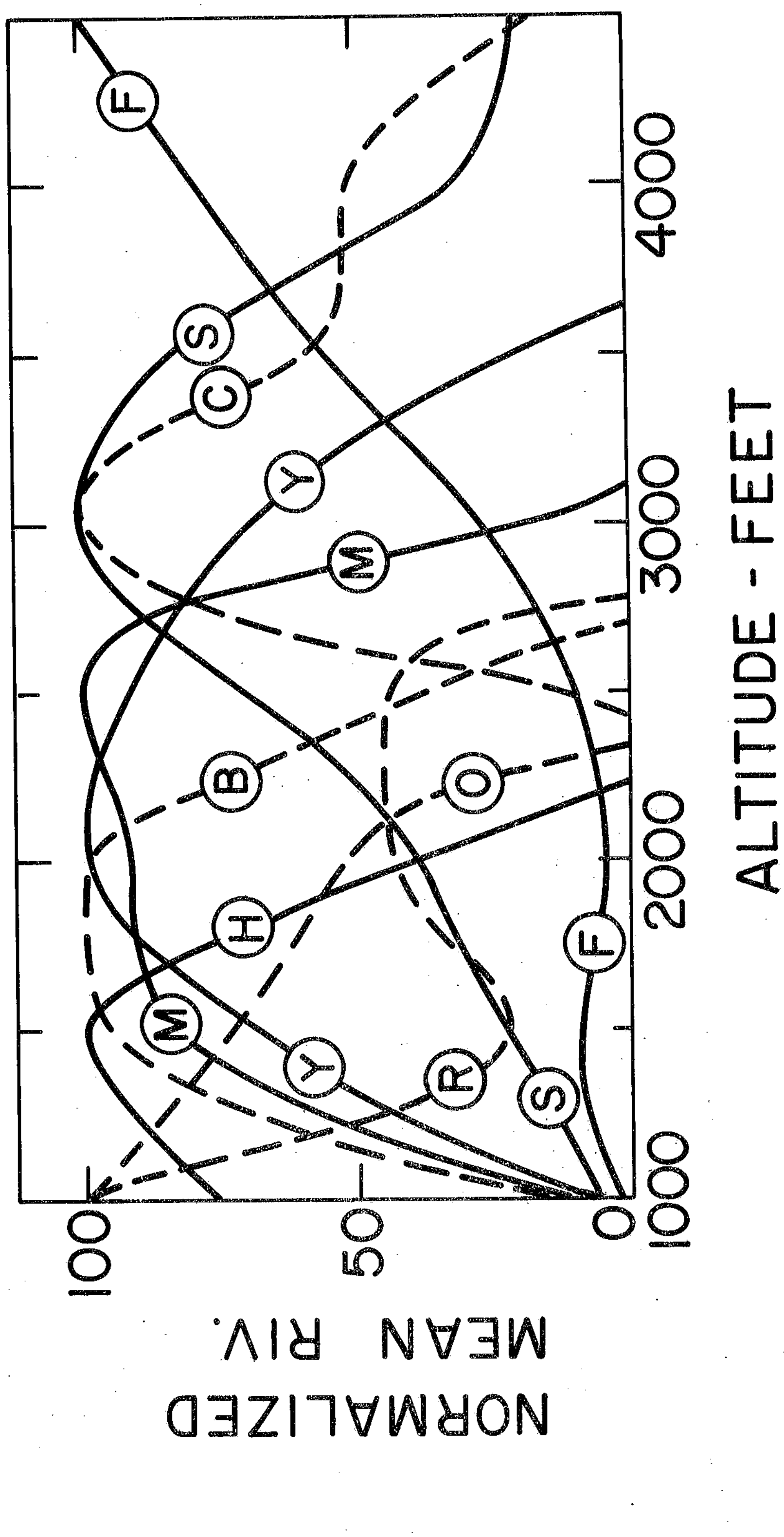
The slope-aspect variation of such quantities as solar radiation, wind speed and direction, rain catch and rime or fog drip collection should cause enough differences in environment on Whiteface Mountain to cause differences in vegetation. The slope-aspect variations in other regions have been well-documented in the literature, for example, by Whittaker (1956), Ayyad and Dix (1964), Whittaker and Niering (1965), Buell, et. al. (1966) and Mowbray and Oosting (1968).

The problem of determining slope-aspect variation of STV was similar to the case for altitude in that the various groupings of topographic features contained varying numbers of stands (Table 5). Data in Table 5 seem to show that there is a tendency for higher STV on east and south facing stands than on the north and west.

Figure 6: Scatter plots of STV versus slope-aspect for two different altitude ranges. Abbreviations are given in Table 1 (page 73).

Figure 7: Relative mean species importance value for 500 foot ranges of altitude for the dominant species on Whiteface Mountain. Each curve is normalized by expressing each mean RIV's for each altitude range as a percent of the range of maximum mean RIV (page 74).


a. STANDS AT 1250 TO 2249 ft.
STAND INDEX VALUE
100
80
60
40
20
0
N E S W N
0 90 180 270 360
SLOPE ASPECT
b. STANDS AT 2750 TO 4750 ft.
50
40
40
20
10
0
0 90 180 270 360
SLOPE ASPECT



NORMALIZED
MEAN RIV.
100
50
0
1000
2000
3000
4000
ALTITUDE - FEET
F
S
C
Y
M
B
O
H
R

The mean STV for the four major aspect quadrants and all altitude ranges was computed by various methods of weighting and restrictions on the sample. Four of these are given in Table 8. In the first column each stand is given equal weight. This is probably a poor method because both STV and the number of stands varied with altitude. In column 2 weighting is first by slope groupings and then by altitude. The results are quite different and show the highest mean STV for east slopes followed by south with west and north having the lowest values. Because all slope-aspects are not represented at altitudes below 1250 ft, these altitude ranges were removed in columns 3 and 4 of Table 8 with the weighting the same as column 2. Data in column 3 contain stands from the total sample but column 4 is restricted to the sample on Whiteface Mountain or its very close proximity. These latter two cases probably give the best representation of slope-aspect variation. The east side appears to contain more species with high index numbers while the west appears to have larger representation of species near the low end of the index scale. Holway, et. al. (1969) reported a similar species to slope-aspect relation for the same sample, but using species importance values. They found that contrast between north and south slopes was not as great as between east and west slopes which is also the case in Table 8.

The individual STV are plotted against slope-aspect in Figure 6 for two altitude ranges. The scatter plot for the lower altitude range (1250 to 2249 ft) shows a tendency for decrease in STV from the east or northeast quadrants through the south with lowest on the northwest. Because the mean value of STV for the same altitude range as Figure 6a also showed a maximum in the NE range with a minimum in the NW, a regression of STV versus slope-aspect was run. Using slope-aspect directly gave $r = 0.37$ significant at the 1% level but a large standard error of 13.4 due to the high degree of scatter. The regression was also run on STV versus slope-aspect by subtracting 45^o from each slope-aspect so that NE facing sites were given a value of 0 and NW sites a value of 360. This did not improve the results.

The same procedure was used for the high altitude range of Figure 5b. Before subtracting 45^o, the regression was only significant at the 10% level with $r = -0.14$ and standard error of 18.9. Adjustment of the slope-aspect value did not improve the result.

The mean STV for four major quadrants (E, N, S, W) and for the quadrants centered on 45^o from the major compass points (NE, SE, SW, NW) are given in Table 9 for the same altitude ranges as plotted in Figure 6. When all stands are weighted equally (column 1) the result is somewhat different than when weighting is first by four slope groups and then by altitude. The interpretation for these two altitude ranges is again that the "boreal" species are most common on west

Table 8: Mean STV for slope-aspect groups by various weightings. In column (1) are means for the entire sample with each stand weighted equally. In column (2) means for the entire sample are first computed by weighting each slope group equally to compute altitude means which are in turn weighted equally to compute the four slope-aspect means. Column (3) is the same as (2) except stands below 1250 feet have been removed. Column (4) are means computed in the same way as (2) but stands not on Whiteface Mountain or adjacent peaks and ridges have been removed.

Slope-Aspect Group	1		2		3		4	
	N	STV	N	STV	N	STV	N	STV
East	43	46.0	9	44.3	7	31.6	7	35.1
South	39	47.8	8	38.2	7	30.9	7	28.7
West	42	44.8	8	34.4	7	27.4	7	24.3
North	37	34.2	8	34.3	7	26.3	7	26.9

Table 9: Mean STV for the same two altitude ranges as in Figure 5. The breakdown of slope-aspect groups is either by four major quadrants (N, S, E, W) or by quadrants centered on the 45 degree compass points (NE, SE, SW, NW). In column (1) all stands are given equal weight. In column (2) the four slope means are first weighted equally to obtain altitude means which are then weighted equally to obtain the mean STV by slope-aspect groups.

Slope-aspect	1250 to 2249 feet (72 stands)		2750 to 4749 feet (79 stands)	
	1	2	1	2
NE	65.1	65.5	12.3(6.7)*	10.8(6.3)*
E	64.2	67.0	10.0	9.9
SE	62.6	59.4	9.0	6.2
S	60.9	62.5	6.6	7.8
SW	58.5	62.3	9.8	8.4
W	57.1	60.5	9.1	7.0
NW	56.8	61.6	8.3	9.1
N	55.6	58.5	11.3(7.8)*	8.9(6.1)*

*Omitting two stands (see text)

Table 10: Mean STV for slope groupings for various selections of stands and various weighting of altitude and slope-aspect groups. Column (1) contains means for the entire sample with each stand given equal weight. Column (2) is the same as (1) except that means of altitude groups are weighted equally. Column (3) is the same as (2) but stands not on Whiteface Mountain or nearby peaks and ridges have been removed. Column (4) contains means for the altitude range 2500 to 4000 feet for three slope ranges with altitude groups weighted equally. Column (5) contains means for the altitude range 1500 to 2500 feet for three slope ranges with altitude groups weighted equally.

Slope Range	1		2		3		4		5	
	N	STV	N	STV	N	STV	N	STV	N	STV
Level	21	51.0	5	61.1	3	39.2	-	-	-	-
3° to 9°	51	59.8	6	58.5	4	43.2	-	-	3	56.6
10° to 19°	47	46.3	8	46.4	6	30.0	4	16.8	3	51.3
20° to 29°	47	31.3	7	31.6	7	29.6	4	21.1	3	56.3
> 30°	16	7.7	5	12.4	5	12.5	4	14.8	-	-

and north sites and the hardwoods species with higher index numbers are more common on east and south facing slopes.

In Figure 6b there are two stands plotted which contained sugar maple, both on north-east facing sites. These were found at 3100 ft and were unusual sites for this altitude. Sugar maple was never found at a higher altitude. The high STV for these two stands greatly influenced the mean values in Table 9 which gives the mean for the appropriate slope-aspect group both with and without these maple stands.

The one or two leading species are indicated by the appropriate letters in the scatter plot in Figure 6. The tendency for "clumping" of species is not as obvious as in the altitude plots in Figures 2 and 5. Red oak and sugar maple tend to be more common in the range from northeast to south and hemlock and yellow birch more prominent on west and north sites, but this is not obvious.

Slope Variation

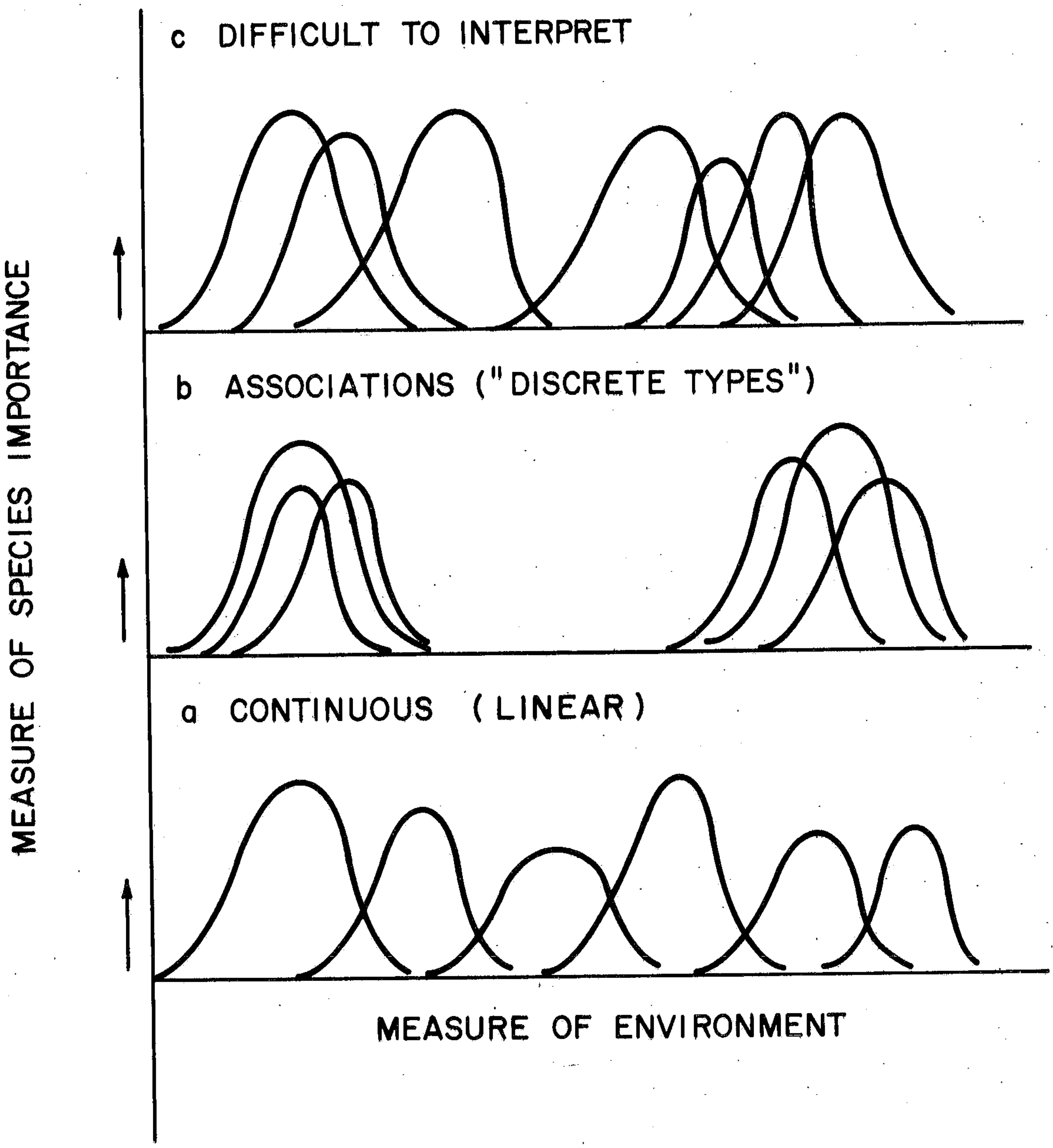
Changes in drainage caused by slope steepness differences should influence vegetation. The problem of detecting such variations in the Whiteface sample is difficult because the steepness of the slope is highly correlated with altitude (r = .67). Table 10 lists several methods of obtaining the mean STV by five slope ranges. Column 1 gives the data with no weighting. Data in Table 5 reveals that this procedure is not valid because high altitude ranges did not include many stands of low slope. Giving 500 foot altitude groups equal weight still does not resolve the problem (columns 2 and 3) for the same reason. In both cases STV decreases markedly with increase of slope, but only because of the high negative correlation of STV with altitude and positive correlation of altitude with slope steepness.

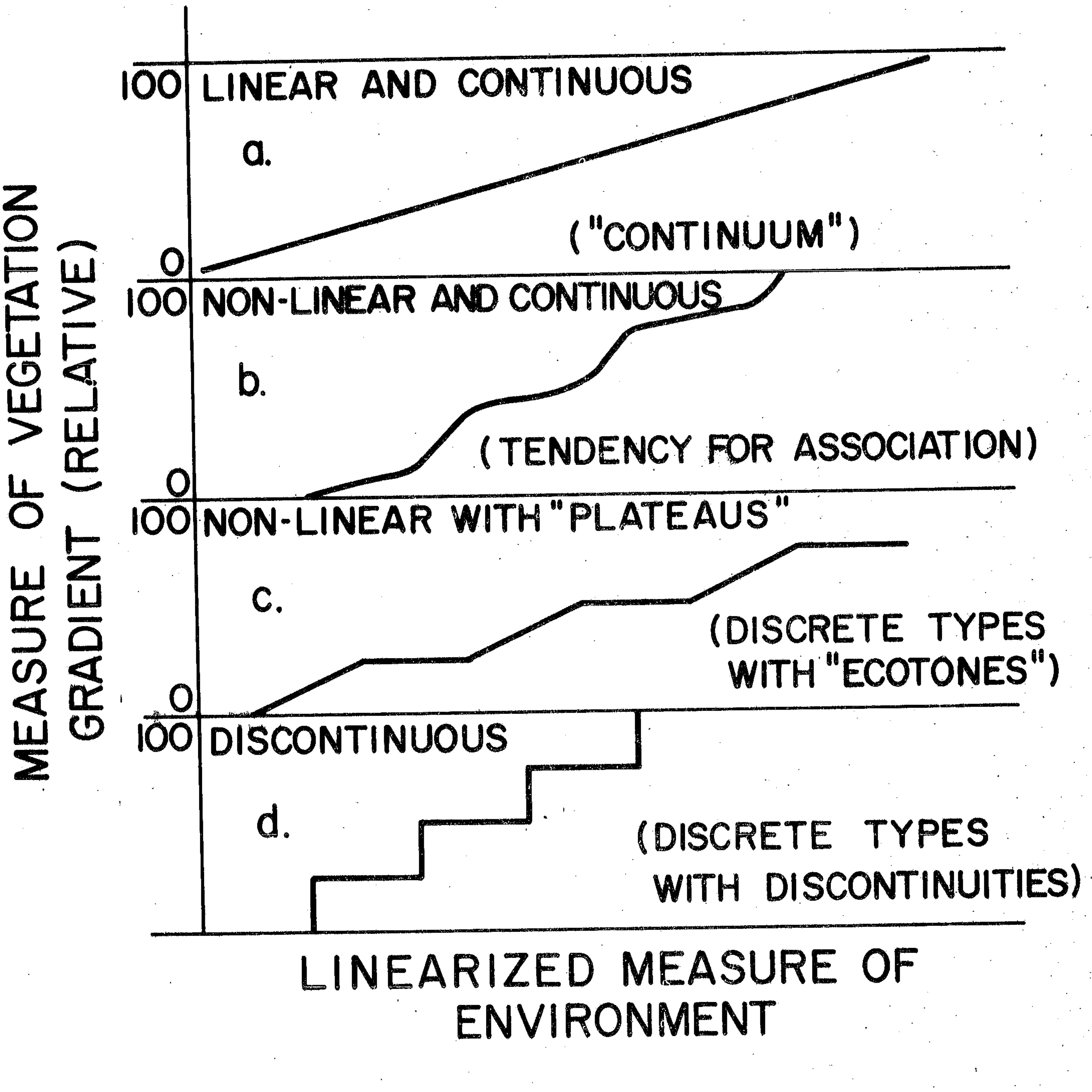
The last two columns in Table 10 give comparisons of mean STV for three slope-steepness ranges which were included in all of the altitude ranges for the particular column. For the 2500 to 4000 foot range in column 4 the interpretation is that the most "mesic" sites are on slopes ranging from 20^{o} to 29^{o} and the most boreal on slopes greater than 30^{o} but it is unlikely that the sample was large enough for this to be proven. In column 5 for the range of 1500 to 2500 ft the interpretation is that there is no variation with slope steepness but again the sample may be too small.

DISCUSSION

The Concepts of the Continuum and Association

The argument has not been settled as to whether natural vegetation is composed of discrete units or rather that it consists of a distribution of individuals based on chance and regulated only by environment. The argument is not whether


c DIFFICULT TO INTERPRET
b ASSOCIATIONS ("DISCRETE TYPES")
a CONTINUOUS (LINEAR)
MEASURE OF SPECIES IMPORTANCE
MEASURE OF ENVIRONMENT


100
LINEAR AND CONTINUOUS
a.
0
("CONTINUUM")
100
NON-LINEAR AND CONTINUOUS
b.
0
(TENDENCY FOR ASSOCIATION)
100
NON-LINEAR WITH "PLATEAUS"
c.
0
(DISCRETE TYPES WITH "ECOTONES")
100
DISCONTINUOUS
d.
(DISCRETE TYPES WITH DISCONTINUITIES)
MEASURE OF VEGETATION GRADIENT (RELATIVE)
LINEARIZED MEASURE OF ENVIRONMENT

it is most appropriate to use either classification or ordination techniques in vegetation studies because as Lambert and Dale (1964) point out both methods are useful when properly applied to the purpose for which they were designed.

The problem is whether or not species tend to clump into types (or "associations") along gradients of uniformly changing environment. Daubenmire (1966) has presented arguments in favor of the association point of view. This hypothesis implies that vegetation dynamics produced by such things as biologic competition or tendency of certain species to coexist to produce mutual benefit causes clumping along the gradient of environment.

The individualistic hypothesis originally proposed by Gleason (1926) views vegetation as a collection of species which associate merely because they have overlapping ranges of tolerance along environment gradients. The existence of classifiable types would therefore result from chance factors such as accidents of seed dispersal or similarities in genetic history. Vegetation is viewed as a linear function of environment or a continuum by Curtis and McIntosh (1951) and Curtis (1959). Evidence in favor of this hypothesis is reviewed by McIntosh (1963) and the subject is treated in detail by McIntosh (1967).

If these two concepts have been properly defined then it seems obvious that they cannot both be correct. The debate has been largely one of semantics due to differences in approach and data treatment. As Lambert and Dale (1964) point out, much of the argument has resulted from the use of inappropriate methods. For example, ecotones or discontinuities may appear when the environment has not been adequately measured or defined. Ecotones may be regions where the environment as well as the vegetation undergo rapid change. On the other hand, ecotones and regions of clumping may be rather subtle and could be masked by not specifically looking for the effect in the data analysis.

Most investigators who have interpreted vegetation as a "continuum" have examined measures of species importance along some measurable quantity such as space, time, temperature and moisture. McIntosh (1963) gives many examples of these and Figure 7 shows the result for the Whiteface Mountain sample. From this kind of analysis it would be difficult to tell whether or not ecotones and clumping exist. The problem is illustrated for three hypothetical cases in Figure 8. If the distributions appear as case (a) the interpretation would be that vegetation is a continuous linear function of environment although this cannot be proven by the method. Case (b) is one where there is obvious clumping of species curves along the environment gradient and the interpretation that types or associations exist would be proper. In case (c) there may be some tendency for clumping but it is difficult to prove this interpretation from the approach used.

A better approach than plotting measures of species importance is to relate a measure of the vegetation gradient such as the stand index value to the measure of environment. The hypothetical results of this kind of analysis are shown in Figure 9 for four cases.

This kind of study requires a stochastic model because the data from stand composition will give a large scatter when plotted (see Figures 2 and 3). However, the analogous analytic function can be used once the statistical relation is determined. Thus, case (a) would be a linear continuous function and would indicate that vegetation is a "continuum". In case (b) the function can be continuous but non-linear. Here the slope of the curve changes indicating ecotones and regions of clumping. This tendency for association could be due to "vegetation dynamics". If case (c) is the result the plateaus where the function is constant would represent definable types which would be easy to classify. Case (d) represents discontinuities of vegetation along a uniformly changing environment and classification is the best procedure.

Such a study as described in Figure 9 can only be accomplished by the techniques which obtain the vegetation gradient. Classification would be inappropriate for case (a) but would be proper in all of the others. It should not be assumed that vegetation is not a linear function of environment before it is proven. The methods described by Daubenmire (1966) provide only circumstantial evidence that "discontinuities" exist. The difficulty is in measuring the environment. To the knowledge of these authors the only published work which has attempted to resolve the problem described in Figure 9 is by Loucks (1962). He related a synthesized ordination of several environmental measurements to a vegetation ordination. His interpretation is that the vegetation in his study area is a linear function of environment (i.e. a continuum). Loucks did not find the subtle kind of variation which may have led to the interpretation that ecotones exist as in case (b) of Figure 9.

At first glance the results for the Whiteface vegetation sample could be interpreted as case (b) of Figure 9 (see Figures 2 through 5). There seems to be an "ecotone" in the altitude range of 2500 to 3000 ft between the hardwood stands and the high altitude spruce-fir communities. Unfortunately, it cannot be proven that environment is a linear function of altitude. There are reasons to believe that many environmentally related parameters also change rapidly between 2500 and 3000 ft. For example, the heat balance of the high altitudes may be affected by the fact that Whiteface protrudes above the lower peaks which are not generally higher than about 3000 ft. The soils above 3000 ft are thinner and more rocky than below where thick layers of glacial parent material are more common. A cloud cap covers Whiteface Mountain above 3000 ft on about 50% of the growing season days. The fog drip from this cloud influences the moisture balance of only the high altitude regions. The cloud cap causes higher absorption of solar radiation for the stands above 3000 ft compared to lower stands.

The proper approach to be used to prove whether or not the Whiteface sample can be interpreted as case (b) of Figure 9 would be to obtain independent measures of environment which are not arbitrary properties of the site such as altitude. The independent measures from a large number of stands can either be combined statistically or related to the vegetation separately. The problem of combining several environmental measures to obtain a "linear" result has been treated extensively by Loucks (1962). Because a large number of stands are required many of the environment measures may have to be obtained by using analytic techniques. Lettau (1952) has treated the problem of synthesizing many of the climatic variables. If a large sample is used, the errors in determining the stand environmental measures can be smoothed and subtle changes in the plot of vegetation versus environment may be revealed.

Possible Causes of Slope-Aspect Variations of STV

The interpretation of the slope-aspect variation of STV from Tables 8 and 9 and Figure 6 is that there is greater contrast between east and west facing sites than between north and south. The east sites are the most "mesic" for all altitude ranges. The west sites are apparently the most "boreal" followed by north and then south, but the small difference between the latter three quadrants of slope-aspect may not be significant at least from the Whiteface sample.

If the east-west contrast is indeed larger than the north-south contrast then certain interpretations about the environment can be made. Because the north to south contrast in solar radiation is large compared to any east to west contrast which may exist then the total input of solar radiation to a stand must be ruled out as an important cause of vegetation differences. It is rather the way in which the solar radiation input is divided which may be important. For example, the solar energy on south slopes may be used for evaporating available moisture so that the temperature does not rise much higher than on north and west sites. Because only the east-facing sites are protected from strong winds (prevailing direction SSW) then more of the solar input can be used to warm the stand compared to the other three aspects. The proper approach to an environmental analysis would be to examine the heat and moisture balances of a large number of stands.

Another contrasting feature of east versus west-facing sites involves the timing of maximum solar radiation input. For clear skies east sites receive their maximum input during the morning and west sites during the afternoon but the mountains cause cloudiness to vary diurnally. Measured solar radiation at the Whiteface Mountain Field Station over two summers was found to be 15% lower from local noon to sunset than from sunrise to noon. Thus west sites received less radiation. The afternoon radiation also contains more of the diffuse (non-directional) component which is absorbed eqully well by east and west sites. The contrast in solar input from west to east would, therefore, be more than 15%.

The diurnal variation of the wind speed may influence the manner in which solar radiation affects east and west sites. The maximum solar input on east sites occurs during the morning when the wind speed is relatively low. The radiation is, therefore, utilized in warming the stand. The wind speed is climatically higher in the afternoon when the west slopes receive their maximum input. The energy would, therefore, be rapidly lost by the stand as evaporation or sensible heat flux. This effect is qualitatively observable by the fact that it is more comfortable to work on the east side of the mountain on cool windy days.

Another contrast between east and west sites which is not so severe for the north-south case exists when rime icing occurs following major storms in the westerlies. These frost conditions are most common in late spring and late summer but occur in all growing season months. The rime icing is most severe on west sites followed by north and then south. On several occasions icing was observed to be serious on the west side of Whiteface down to altitudes as low as 2700 ft while there was no icing on the east. On these days, icing on northwest and southwest sites was not as severe as on the west but southeast and northeast sites were nearly free of riming.

Because the winds are far more severe on the west-facing 180^{o} of slope-aspect wind disturbance is also more obvious. Wind-throw patterns on high altitude west-facing sites seem to be a regularly occurring phenomenon while only scattered blow-down is found on east sites. The wind-throw may be a factor which selects for balsam fir and thus stands of low STV. The blow-down is followed by rapid reproduction of balsam fir. Thus, repeated blow-down at intervals of about 50 to 70 years would help to maintain nearly pure balsam fir stands.

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MULTI-DIMENSIONAL ORDINATION
OF BOREAL AND HARDWOOD FORESTS
ON WHITEFACE MOUNTAIN

By

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Richard A. Park and Paul C. Lemon

Altitudinal changes of almost 4000 ft within a distance of three miles, coupled with the rugged topography of a mountainous area make the environment and therefore the vegetation quite heterogeneous. The effects of logging and fire in lower elevations add greatly to the diversity of this region. The growing season for this general area is reported to be from 90 to 104 days (Ferree & Hagar, 1956). Heimburger (1934) considered the strong winds and low temperatures to be limiting in the upper elevations, while soil moisture is the major factor controlling distribution of species in the lower elevations.

The nomenclature of the vascular species in this report follows that of Gray's Manual of Botany, 8th ed. (Fernald, 1950) with the exception of yellow birch which is here referred to as Betula alleghaniensis. A complete list of species names, common names and symbols used in figures is given in Appendix I. The nomenclature of bryophytes follows Ketchledge (1957).

Heimburger (1934) describes three vegetational series in the Adirondacks - a high altitude series ("subalpine") and two low altitude series ("western" and "eastern"). These series are composed of twenty-two forest types, nine of which are considered in this study. The forest types are named for the most characteristic ground flora species in the associations. This is done to enable one to recognize successional stages before the characteristic shrubs and trees have become established.

The subalpine series is equivalent to the type designated as spruce-fir by Ferree and Hagar (1956). In addition to the dominants Abies balsamea and Picea rubens, Betula papyrifera var. cordifolia and Pyrus decora are common associates. In this forest type, bryophytes (especially the feathery mosses Ptilium crista-castrensis, Hylocomium splendens, and Pleurozium schreberi) often dominate the ground flora. Cornus canadensis, Oxalis montana, Dryopteris spinulosa, Maianthemum canadense, Clintonia borealis, Solidago macrophylla, and Aster acuminatus are the most abundant vascular species included in the ground flora.

The "western" and "eastern" series of Heimburger (1934) correspond **respectively** to the northern hardwood and mixed oak-northern hardwood types of Ferree and Hagar (1956). The dominant trees in the western series are Acer saccharum, A. rubrum, Fagus grandifolia, Betula alleghaniensis and B. papyrifera with an admixture of Abies and Picea. The eastern series contains Acer saccharum, Tilia americana, Fraxinus americana, Quercus rubra var. borealis and Ostrya virginiana. Bryophytes do not assume a dominant role in this series. Ferree and Hagar (1954) also mention a pioneer forest type composed of B. papyrifera or B. papyrifera var. cordifolia. Heimburger (1934) considers this as an early successional stage and classifies it according to the ground flora.

In addition to these forest types several vegetation associations exist on Whiteface which were not included in these studies. One such type is the alpine zone which lies above treeline. Another is the exposed ridges dominated by *Vaccinium* species.

Witty (1968) gave detailed descriptions of the soils on Whiteface Mountain. Two major groups have been described, spodosols (mineral soils) and histosols (organic soils). The spodosols are moderately deep to deep, well-drained soils that occur mainly at lower elevations on gently to steeply sloping terrain. The histosols are divided into two groups; (1) very shallow to moderately deep, moderately to well-drained on slightly to very steep slopes, and (2) moderately deep, poorly to moderately well-drained, on level to moderately sloping soils.

The spodosols were located mainly in northern hardwood areas but also included pine stands, open blueberry ridges, some above timberline areas and well-drained spruce-fir stands. These high elevation mineral soils were moderately high in organic content. The histosols occurred mostly in spruce-fir stands and at least in the poorly drained areas were usually associated with sphagnum moss, which is noted for its tremendous water-holding capacity and low pH (Grout, 1903).

The organic soils are found chiefly at the higher elevations of Whiteface Mountain and the surrounding associated peaks. Arms of these histosols extend along the major ridges from the summit. The boreal zone - *Picea*, *Abies* and associated ground flora species - occupies most of this area. In addition, on the east side of the mountain, which is composed of a series of east-west ridges separated by steep-walled cirques, the boreal zone extends to between 2500 and 4000 ft. This area has high organic content mineral soils.

The lower areas to the east side of Whiteface are characterized by mineral soils with relatively thin "O" horizons. This area is chiefly *Acer saccharum* with admixtures of *A. rubrum*, *Quercus* and *Tilia*. The stands with southern exposures in the low elevations are also on mineral soil but here the "O" horizon is generally much thicker. The slope is not as severe on this side where the dominants are sugar maple, beech and yellow birch.

FIELD METHODS AND DATA ANALYSIS

Criteria for stand selection

The stands used in this study were selected from 182 stands sampled from 1964 to 1966. A stand was defined as a sample of vegetation from an area of uniform slope, aspect, and altitude. Details of stand selection were reported by Holway and Scott (1969). The techniques used in any ordination model require only that a wide range in stand composition be sampled (Greig-Smith, 1964) and therefore no attempt was made to obtain a random sample.

In addition to the field criteria for stand selection in the field, stands were eliminated from further consideration if there were not at least twenty points sampled (with exception of two stands at 4500 ft where 15 points were used). Since the stands used in this report were originally sampled as part of a forest tree study (Scott & Holway, 1969; Holway & Scott, 1969) stands in which the ground flora data was scanty or missing were also not used. Since the major consideration of this study was an ordination from the subalpine spruce-fir zone to the lowland northern hardwood-sugar maple-beech forests, stands that were present as a result of primarily edaphic conditions (Tsuga, Thuja and Pinus) or remnants of earlier forests (Pinus) were eliminated.

The final criterion for accepting a stand was a test for homogeneity (Greig-Smith, 1964). The quadrats in each stand were combined into four groups and the data for the dominant trees in these groups were tested for homogeneity using the Chi-square test. A stand was judged as homogeneous if the variance among the groups was less than could be expected by chance alone. All heterogeneous stands were eliminated from the study.

Field methods

The field work for this study took place during the summers of 1964 to 1966 and has been described in detail by Holway and Scott (1969). The vegetation was recorded in three size classes. Trees were considered to be woody stems over 4" dbh; saplings from 1" to 4" dbh; and ground flora as all vascular plants under 1" dbh. Non-vascular plants were not included due to difficulty of identification. Figure 1 shows the location of most of the selected stands, the others are located outside of the mapped area.

Although the same information was derived for each stand the method was altered during the second summer of sampling to obtain more efficiency in the field without loss in accuracy of measurements (Holway & Scott, 1969). The ground flora was always sampled in a series of one meter square quadrats. All species rooted within the quadrat were recorded. In 1964 (Nicholson, 1965) the trees and saplings were sampled by the point-centered quarter method developed by Cottam and Curtis (1956). In 1965 a modified forester's prism method using a #30 prism was used to determine basal area. Density was recorded from a 1/80 hectare circular plot. The quarter method was still used to obtain frequency. Efficiencies and techniques of the quarter and prism methods are discussed by Lindsey, Barton and Miles (1958) and Lemon (1962). The quarter method should be used if dbh size class information is needed.

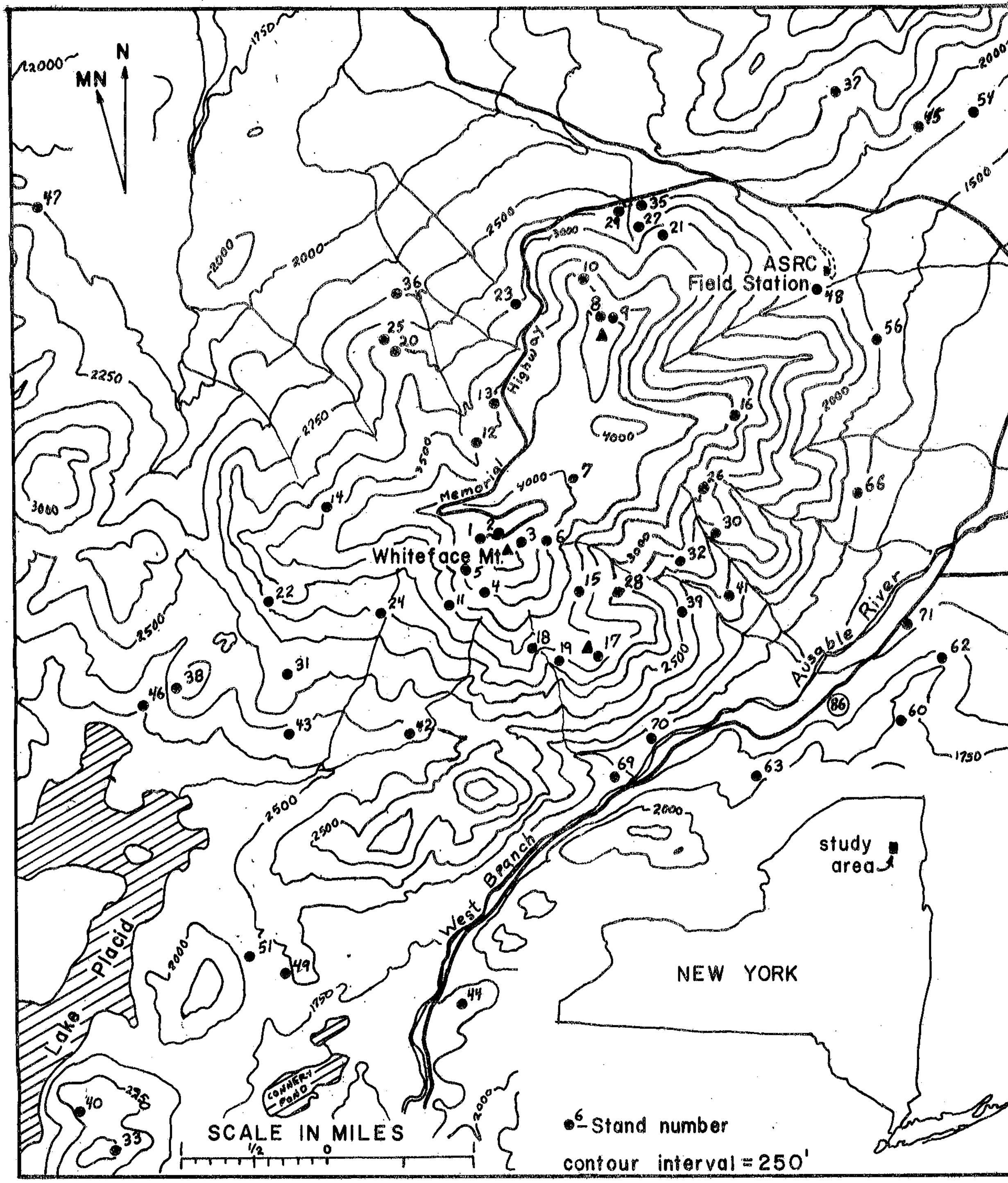


FIGURE 1. Map of study area showing location of stands.

However, the prism method is more efficient in the field and laboratory if only mean basal area is needed, as in computing importance value.

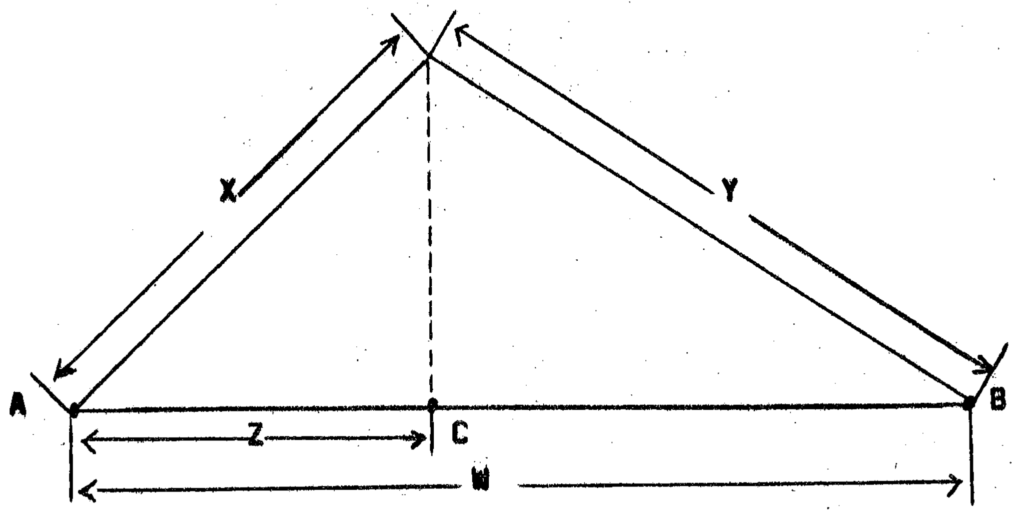
Analysis of stand data

From the stand data for trees, relative density, relative frequency, and relative dominance (basal area) were combined to give the importance value (IV). Formulas for calculating these parameters and a discussion of their relationship to each other can be found in Curtis and McIntosh (1950). Since basal area was not recorded for saplings, their importance value was based only on relative frequency and relative density. The importance values for both trees and saplings were converted to percentages to give the relative importance value (RIV). The only measurement recorded for the ground flora was frequency. As Goodall (1952) pointed out, frequency measurements alone are not a reliable measure of relative quantity, but frequency is useful in determining distributions of species. Bray and Curtis (1957) were able to construct meaningful gradients using only frequency measurements for both herb and shrub layers.

Seventy-one stands were used for the final analysis. The twenty-one most common tree species were included in the study. After eliminating all ground flora species of questionable identity (immature plants, seedlings, etc.) 82 species remained. Species that occurred in less than 10% of the stands or which contributed less than 0.5% to the total relative frequency were eliminated from the calculations. This was done for three reasons: (1) to eliminate the possibility of rare or accidental species from biasing the data, (2) frequency measurements tend to overestimate rare species (Goff & Cottam, 1967), (3) to simplify calculations and save computer time. Most of the species eliminated appeared in only one stand as a single record in a series of 20 to 40 square meter quadrats. The 27 species finally selected account for 81% of the total frequency. Of these, twelve are seedlings of tree species.

The ordination model

Ordination models are based on a variety of indices. Goff and Cottam (1967) compared six methods of gradient analysis and found that the results of the Index of Similarity method (Bray and Curtis, 1957) showed the highest degree of correlation ($r = .93$) with the other methods. This method is not only easy to visualize but is relatively simple to calculate. It is based on Sorenson's Index, $I = (2w/(a+b))$, where "a" and "b" are RIV values of a species in any two stands while "w" is the amount of the species RIV the two stands have in common, summed for all species in the stands. Since the sum of species RIV for each stand is equal to 100% this



Stand C is placed Z distance from stand A.

The distance Z is calculated by the formula:

$$Z = \frac{X^2 - Y^2 + W^2}{2W}$$

where W = dissimilarity between endpoints,

X = dissimilarity between endpoint A and stand C,

Y = dissimilarity between endpoint B and stand C.

Figure 2: Geometric method of determing position of stands along ordination axis.

formula reduces to $I = \Sigma w/100$, where "Σw" is the sum of the smaller RIV values for each species being considered. The index used in this study is the Index of Dissimilarity and is equal to $1.00 - (\Sigma w/100)$ expressed as a percent.

The assumptions of ordination are that the samples cover a range of values along a gradient and that each sample shows some degree of similarity with another sample. That is, no stand is totally dissimilar from every other stand. A series of samples which show no similarities would not show gradients and therefore would not fit in the ordination model of gradient analysis. Ideally, no stand should be completely dissimilar from any other stand, since a dissimilarity greater than 100% cannot be determined between two stands.

Another important consideration is that the ecological nature of a species is relatively constant throughout the area being considered (Goff & Cottam, 1967). This would eliminate areas in which the species exhibit obvious ecotypes or intraspecific clines that are not separable except in physiological terms (Goff & Cottam, 1967). The results would be bimodal species-abundance curves in the first case and platykurtic curves in the second example. A species or character that shows no difference along the gradient also adds nothing to interpretation.

The selection of end points for each axis in an ordination can be accomplished by a variety of methods. A subjective method is to select end points which represent extremes of the gradients in question, such as open canopy to dense shade, xeric to mesic, or early successional to late successional. Since two simultaneous ordinations were being performed on two separate groups of data for the same series of stands it was decided that an objective method in which the computer program selected end points for three axes would be preferable. This would remove any subjective bias permitting comparison on statistical criteria. The "standard deviation criterion" devised by F. G. Goff (Park, 1968) was applied. In this method the stand which differs most from the mean stand composition is selected for the first end point and the stand which differs most from it is selected as the opposite end point. The distance between the end points is equal to the dissimilarity between the two stands selected as end points. The placement of stands between the end points is determined by the amount of dissimilarity between the particular stand and the two stands chosen as end points. The method is shown schematically in Figure 2. Two stands which occur close together on this axis are not necessarily similar in composition or environmental requirements (Bray & Curtis, 1957). Their only factor in common may be that they have equal dissimilarities from the two end points. This difference becomes obvious when the second or third axes are used. In constructing additional axes the end points are selected so as to reduce as much of the remaining dissimilarity as possible and at the same time keep the axes orthogonal.

Cluster analysis

The second method used to obtain an understanding of the vegetation on Whiteface Mountain was cluster analysis. This method can be used to group associated species or stands. The grouping of species should be similar to those representing a vegetation type whereas the grouping of stands would be similar to combining the stands that represent a vegetation type.

According to Harman (1960) the grouping by cluster analysis is based on the theory that "the variables of a group identifying a factor have higher intercorrelations than with the other variables of the total set." As in ordination, similarity between the stands was determined for cluster analysis using Sorenson's Index of Similarity (I). Each stand is coupled to the stand most similar to itself. The stands are ordered in the dendrogram by the following procedure. The stand coupled to the stand which shows the least similarity to all other stands in the sample is used as the beginning point. The stand most similar to the first was clustered with it. The stand which had the highest sum of similarity indices with the first two stands was added to the cluster. Successive stands were added to the cluster based on the sum of the similarity indices a stand had with all other stands previously included in the cluster. The dendrograms for the clusters based on the tree and ground flora data are shown in Appendix II. The percent similarity used to separate the cluster was determined subjectively, but was not based on any prior knowledge of stands or species in the clusters. In nearly all samples of vegetation, a small number of stands do not seem to fit any cluster.

The relationship or distance between each cluster was not obvious from these calculations. By superimposing the results of the cluster analysis on the ordination model, these distances can be determined. The discreteness of the clusters or vegetation types can be inferred by the degree of separation of the clusters when plotted on the ordination axes. A cluster occupies a segment of a gradient, which may be overlapping another cluster when only one dimension is viewed. In this study, each cluster occupied a separate volume in the three-dimensional space defined by the first three axes of the ordination model.

RESULTS

Distribution of species along topographic gradients

The change in community composition from lowland northern hardwood forests to subalpine spruce-fir forests is obvious in all synusiae of the forests. The differences between the ridges and valleys and the variations related to slope aspect

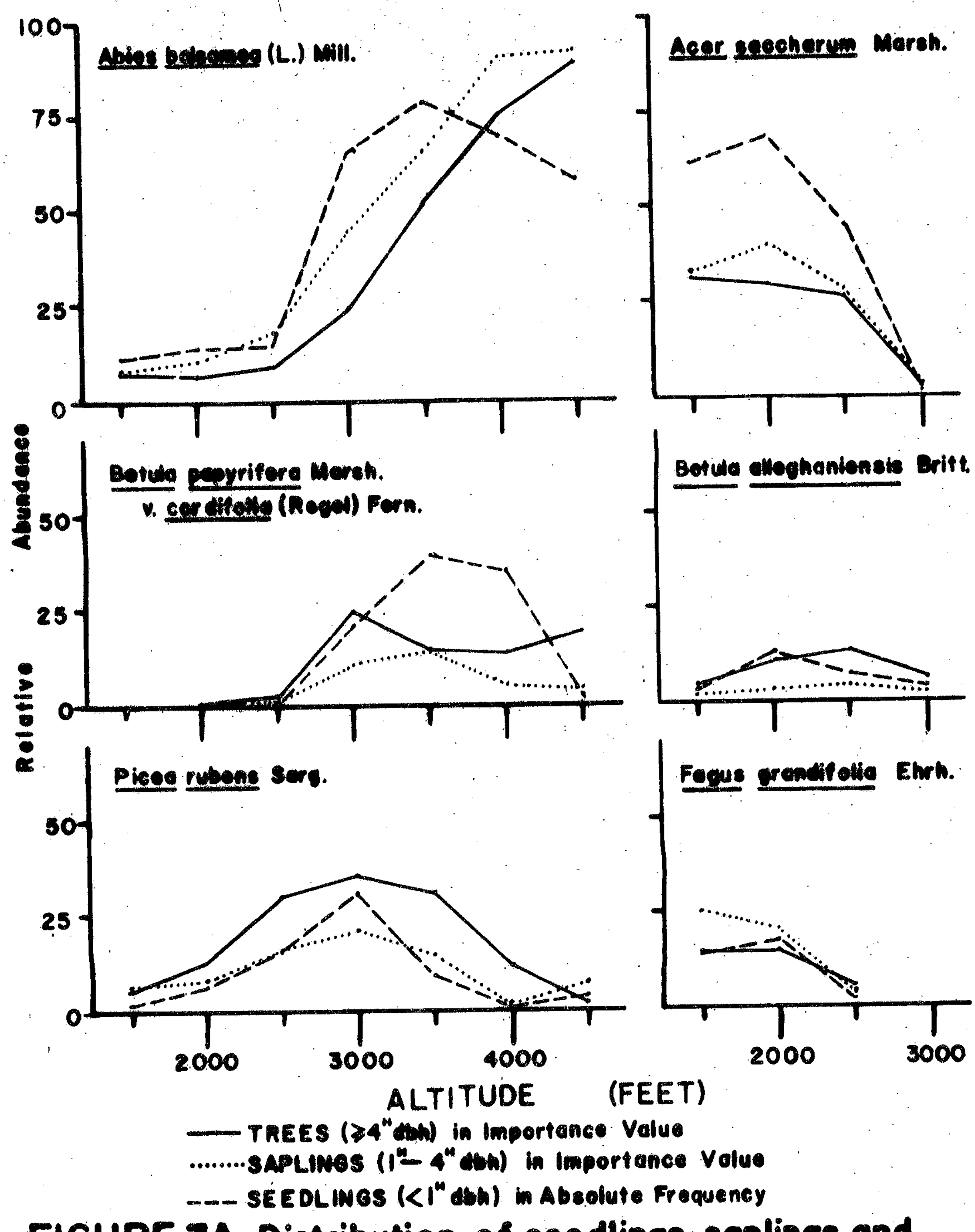


FIGURE 3A. Distribution of seedlings, saplings and trees for six major species against altitude.

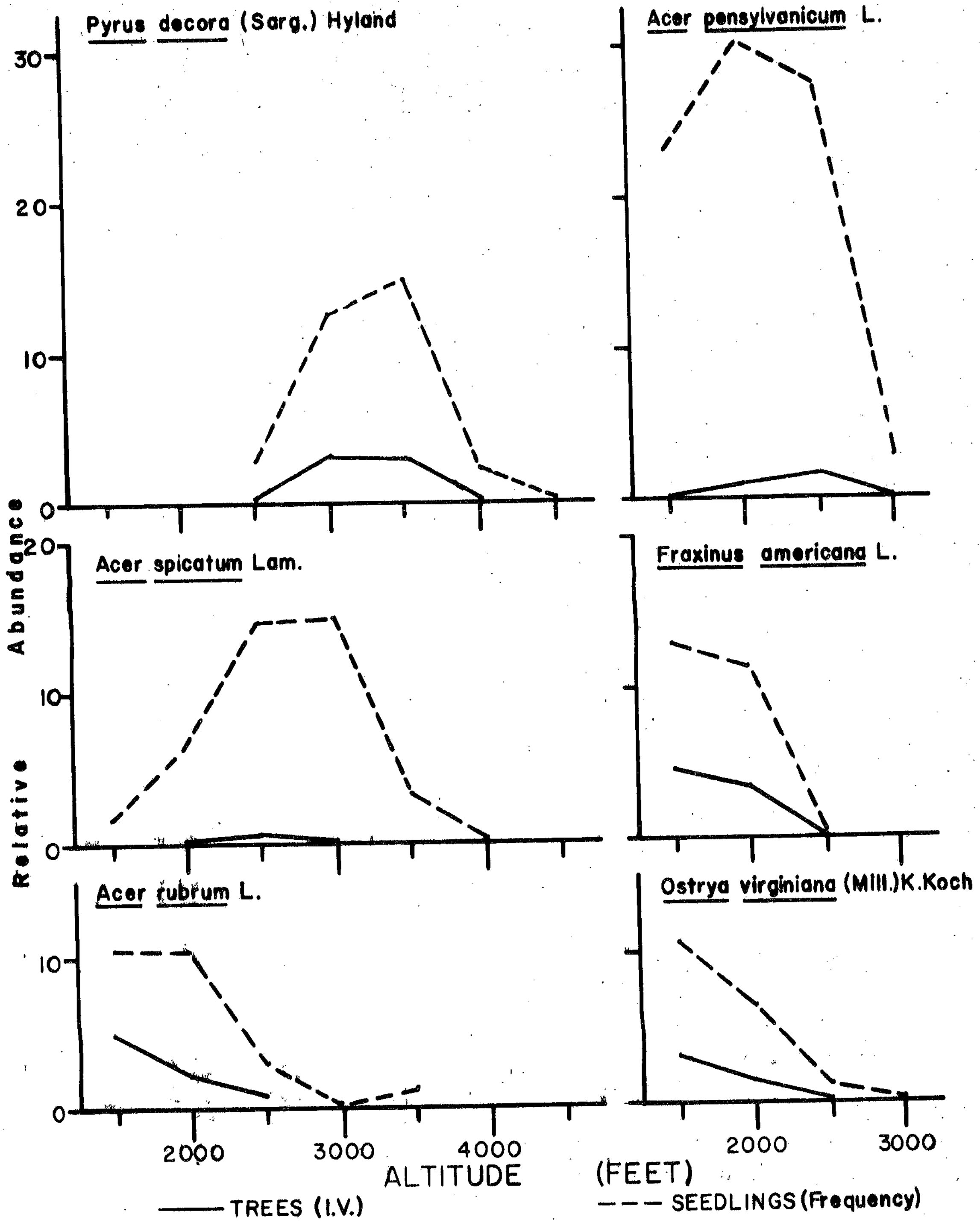
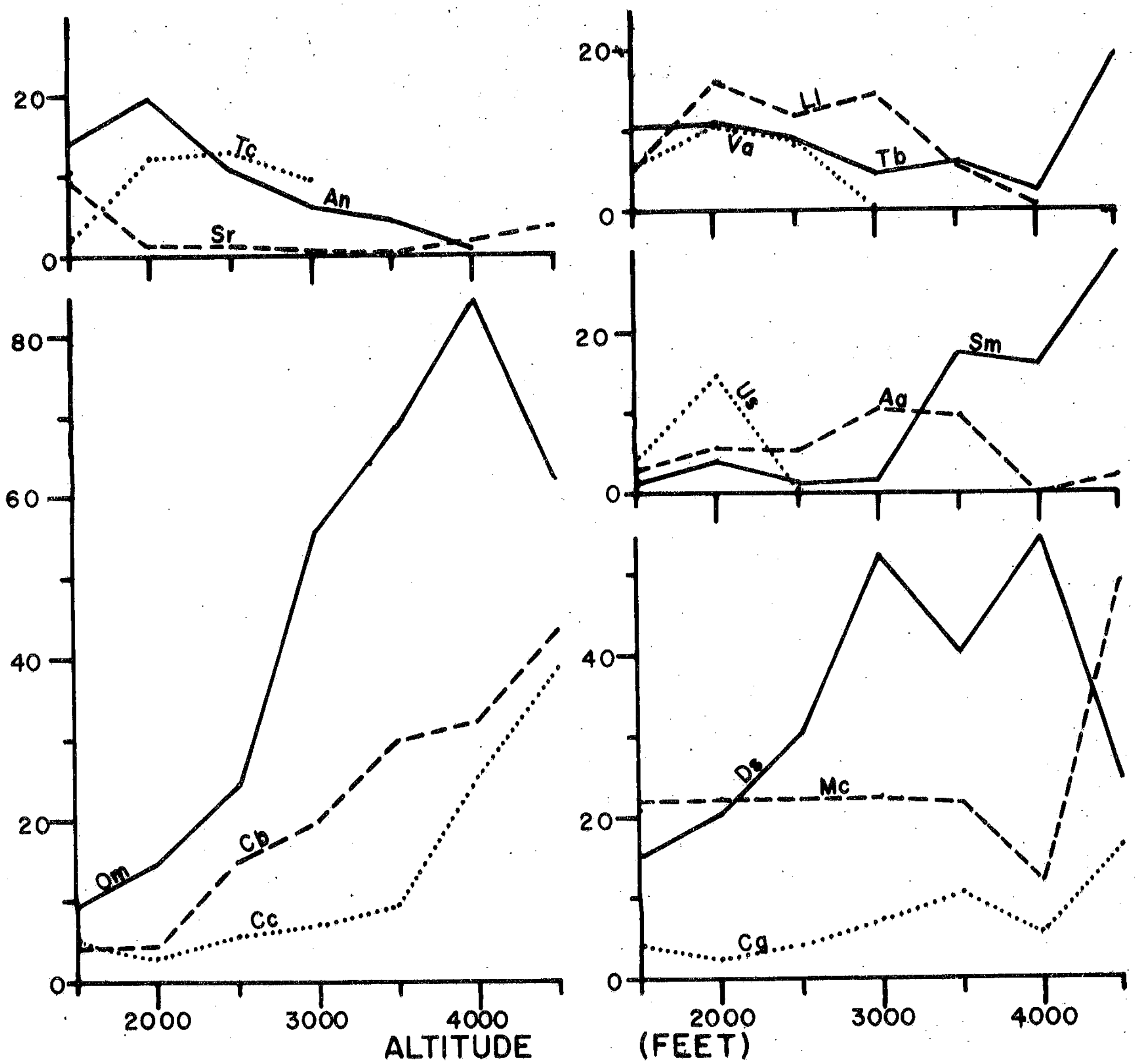


FIGURE 3B. Distribution of seedlings and trees for six minor species against altitude.



Aa — Aster acuminatus Michx.
An — Aralia nudicaulis L.
Cb — Clintonia borealis (Ait.) Raf.
Cc — Cornus canadensis L.
Cg — Coptis groenlandica (Oeder) Fern.
Ds — Dryopteris spinulosa (O.F. Muell.) Watt
Ll — Lycopodium lucidulum Michx.
Mc — Maianthemum canadense Desf.
Om — Oxalis montana Raf.
Sm — Solidago macrophylla Pursh
Sr — Streptopus roseus Michx.
Tb — Trientalis borealis Raf.
Tc — Tiarella cordifolia L.
Uv — Uvularia sessilifolia L.
Va — Viburnum alnifolium Marsh.

FIGURE 3C. Distribution of ground flora (percent frequency) against altitude.

are not quite so evident. A fairly detailed analysis of the distribution of trees, saplings and some of the ground flora species with respect to altitude and slope aspect can be found in the reports by Scott and Nicholson (1964) and Nicholson (1965), Scott and Holway (1969) and Holway and Scott (1969).

Altitude is closely correlated with changes in vegetation and is therefore the major gradient considered here. However, because climatic, edaphic, and biotic gradients such as temperature, biomass, soil characters and light are affected by altitude, it should be considered a "complex gradient" (Whittaker, 1956).

The abundance measurements are averaged for 500-foot altitude intervals and plotted in Figures 3A, 3B and 3C. Tree and sapling abundance is graphed according to RIV. The seedlings and ground flora are measured in frequency. In Figure 3A data for trees, saplings and seedlings of the six dominant tree species are plotted. In Figure 3B the data for trees and seedlings for six minor tree species that were included in both ordinations are plotted and in Figure 3C the frequency of the fourteen ground flora species included in the ordination and cluster analysis are plotted.

The curves for the trees, saplings and seedlings of each species are in agreement with each other except for Abies and Betula papyrifera var. cordifolia. For these species the seedlings reach a maximum at elevations different from the saplings and trees. In Abies the seedling maximum is at 3500 ft as opposed to 4500 ft for the other size classes. This could be because of recent unfavorable conditions at high altitudes which limit reproduction in this species or to low seedling success at all times in established sites at high elevation. B. papyrifera var. cordifolia seedlings have their maximum abundance at 3500 to 4000 ft which is higher than for the larger size classes. Since this is mainly an early successional or disturbance species, the high frequency of seedlings at the upper elevations may be the result of re-occurring recent disturbances caused by the severe weather conditions or may represent the general failure of seedlings to survive beyond this stage at these higher elevations. This species is also being replaced in some of the lower areas in which it had become established following the logging and fires in the latter part of the last century.

The curves of abundance along a gradient give the environment tolerance (i.e. ecological amplitude) of each species. Ecological amplitude implies that a species inhabits a sector of the gradient rather than just a point (Daubenmire, 1968). They approximate a normal distribution along the gradient but have three distinct shapes for the tree species. The species most closely approximating a normal distribution have their maxima somewhere toward the center of the altitudinal range dropping off to near zero at both ends. This type of curve is exemplified by Picea, Betula alleghaniensis, Acer spicatum and Pyrus. Abies is typical of the type which reaches its

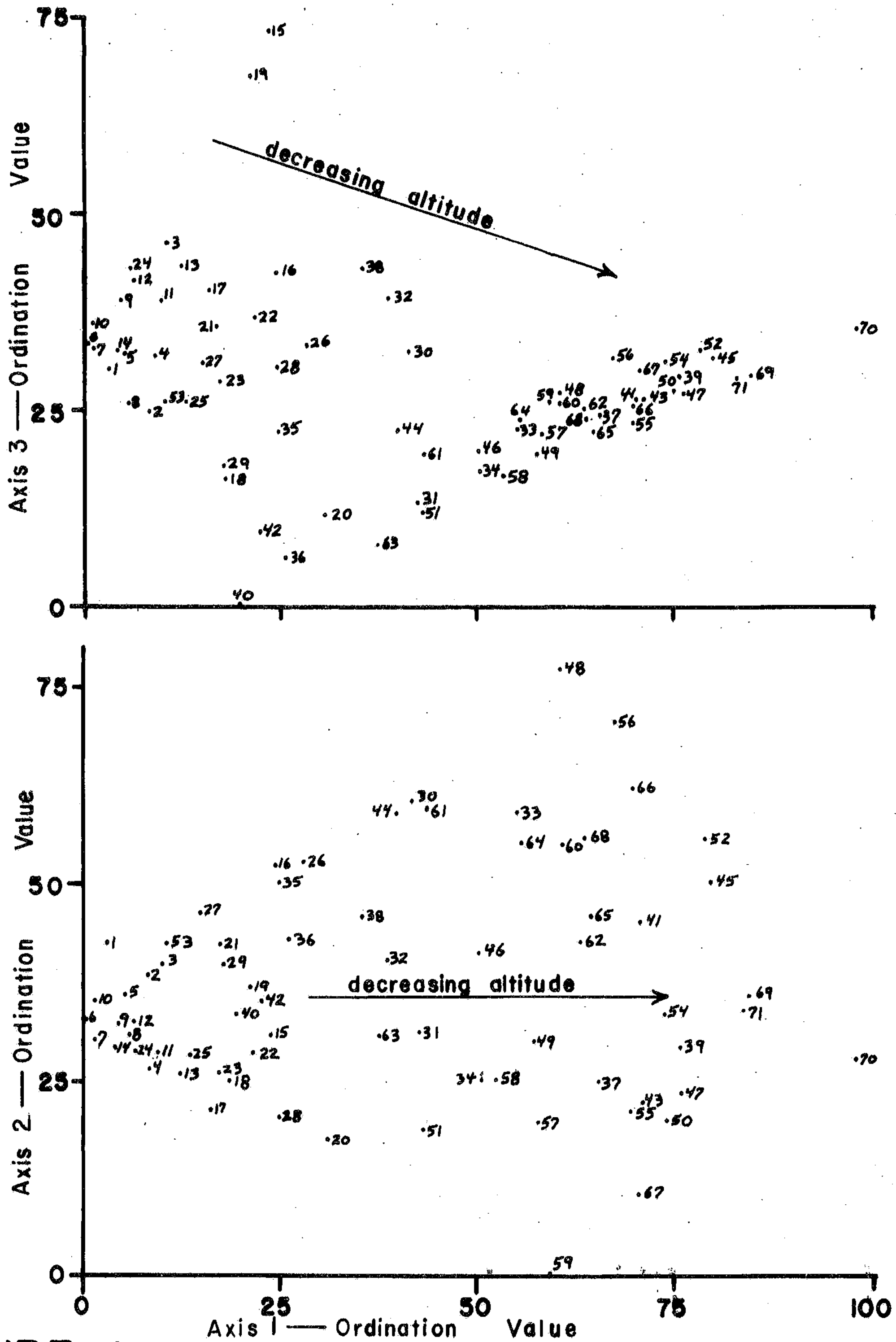


FIGURE 4. Distribution of stands in ground flora ordination.

maximum near the upper limit of altitude and thus appears as only the left-hand side of a normal distribution because the entire range of environmental tolerance for the species does not exist in the area. *Acer saccharum* and *Fraxinus* have their maximum RIV near the lower end of the gradient, thus appearing as the right-hand side of a bell-shaped curve. The other species exhibit varying degrees of truncated normal curves.

The shapes of most of the curves (species abundance versus altitude) for the ground flora species in Figure 3C are not as nearly expressed as are those for the tree species. The curves for *Tiarella cordifolia*, *Viburnum alnifolium* and *Uvularia sessilifolia* appear bell-shaped, but curves for the other species have quite irregular shapes. As a group, their altitudinal distribution is not as distinct as is that of the trees. The average frequency of *Maianthemum canadense* is almost constant for a range of 2000 ft. At 3500 ft it shows a sharp decline in frequency, then rises to twice its previous value. Several species show bi-modal distributions, including most notably *Dryopteris spinulosa*. For this species, bi-modality would be due to ecotypic variation along the altitude gradient, if the two ecotypes have different altitudinal tolerances.

Species diversity also varies with altitude. For saplings and trees there is a marked decrease of diversity with altitude (Nicholson, 1965). Table 1 shows that the ground flora layer has the same relationship of species as the trees; that is, the number of species decreases with increase of altitude for altitude classes from 1750 to 4250 ft. The average number of species per stand is considerably higher in the highest altitude class than in the one below it and also has the greatest number of species per quadrat of any altitude class. Since stands at upper elevations in general were sampled with fewer quadrats a correction factor is included to account for variation due to size of sample area. For this correction factor the species diversity index (SDI) is given by:

$$SDI_A - (\overline{N}_{sp}/stand_A) \times \frac{\overline{N}_q/stand_{max}}{\overline{N}_q/stand_A} \qquad (1)$$

where A = stands of a particular altitude class,
max = altitude class with maximum value (1750 to 2250 foot class),
$\overline{N}_{sp}$ = average number of species, and
$\overline{N}_q$ = average number of quadrats

The species diversity indices derived from this calculation show that the highest altitudes have potentially the most diverse ground flora for a given area, even though the lowest altitude class has the greatest number of different species. This could be due to more frequent open areas in the canopy, exposed boulders, or other phenomena that increase the variety of microhabitats. This may also be related to

Table 1: Diversity of ground flora species in 500-foot altitude classes.

Alt. Class (Feet)	No. of Stands	Total No. of Species in Alt. Class	Ave. No. Species Per Quadrat	Ave. No. Species Per Stand	Species Diversity Index (Eq. 1)
4500 4250	6	29	4.78	16.83	31.14
4250 3750	16	28	4.01	10.37	18.76
3750 3250	15	37	4.02	15.13	19.85
3250 2750	16	57	4.44	17.56	22.86
2750 2250	16	72	3.93	19.88	21.42
2250 1750	21	76	4.42	24.71	24.71
1750 1250	22	82	3.67	19.23	22.94

TABLE 2

Correlation coefficients between topographic variables and the first three axes of ground flora and tree ordinations.

	altitude	slope aspect	slope	tree axis 1	tree axis 2	tree axis 3	ground flora axis 1	ground flora axis 2	ground flora axis 3
altitude	**1.00**	.160	**.663**	**-.850**	-.023	**-.458**	**-.831**	-.158	**.398**
slope aspect		**1.00**	.152	-.219	-.211	-.029	-.273	.081	-.028
slope			**1.00**	**-.629**	.024	-.155	**-.505**	.120	**.394**
tree axis 1				**1.00**	-.030	**.344**	**.858**	.011	**-.549**
tree axis 2					**1.00**	.202	.292	.086	**.360**
tree axis 3						**1.00**	**.499**	**.403**	.103
ground flora 1							**1.00**	.113	-.208
ground flora 2								**1.00**	.025
ground flora 3									**1.00**

69 degrees of freedom

.111 — P > .05
.280 — P < .05
.350 — P < .01
.500 — P < .001

the change in percent of species in each life form with latitude and altitude. Raunkiaer (Kershaw, 1964) describes vegetational trends in which the ground flora layer becomes more predominant and the tree layer less pronounced at higher latitudes and altitudes.

Three-dimensional ordination

The location of the stands along the first three axes of the ordinations are plotted on Figure 4 for ground flora and Figures 5A and 5B for trees. The stands are numbered sequentially with respect to altitude, stand 1 is located at 4500 ft and stand 71 is located at 1370 ft. These two figures are similar in several respects and can be explained with an understanding of the diversity of the vegetation and the assumptions of ordination. The first axis should account for the greatest proportion of dissimilarity existing in the total sample. The amount of dissimilarity explained with each axis varies with the method used to select end points. Using the stand with the greatest variance (standard deviation criteria) does not account for the maximum dissimilarity possible. A subjective method, such as pre-selected end points, is the most efficient method of explaining the dissimilarity (Park, 1968). The second (third, fourth...nth) axis is picked to explain as much of the remaining dissimilarity as possible. According to Park, reduction of about 60 to 80 percent in dissimilarity is possible for three axes.

The interpretation of the first three axes for both the tree and ground flora ordinations is that they correspond to similar gradients. Axis 1 ordinates the stands along the major environmental gradient which is related to altitude. The low elevation stands are separated from each other along axis 2. This is because the greatest dissimilarity remaining after axis 1 is computed that can be explained with an axis orthogonal to the first is in the low elevation stands which have more species than the high altitude stands. This groups the high altitude stands near the center of axis 2 as shown in Figure 5A because they are equally dissimilar from both low altitude end points (Figure 2). For similar reasons the high altitude stands are separated in Figure 5B along axis 3 which groups the low altitude stands near its center. A plot of axis 2 versus axis 3 would therefore not be meaningful in this study.

Correlation coefficients were computed for all possible combinations of the first three axes of the ground flora and tree ordinations and the three topographic measurements - altitude, slope aspect, and slope. The significant correlations ($P < .05$) are listed in Table **2**.

Altitude is significantly correlated with axes 1 and 3 of both the ground flora and tree ordination. The approximate direction of the altitudinal gradient is drawn on Figures 4, 5A and 5B. The degree of slope is significantly correlated

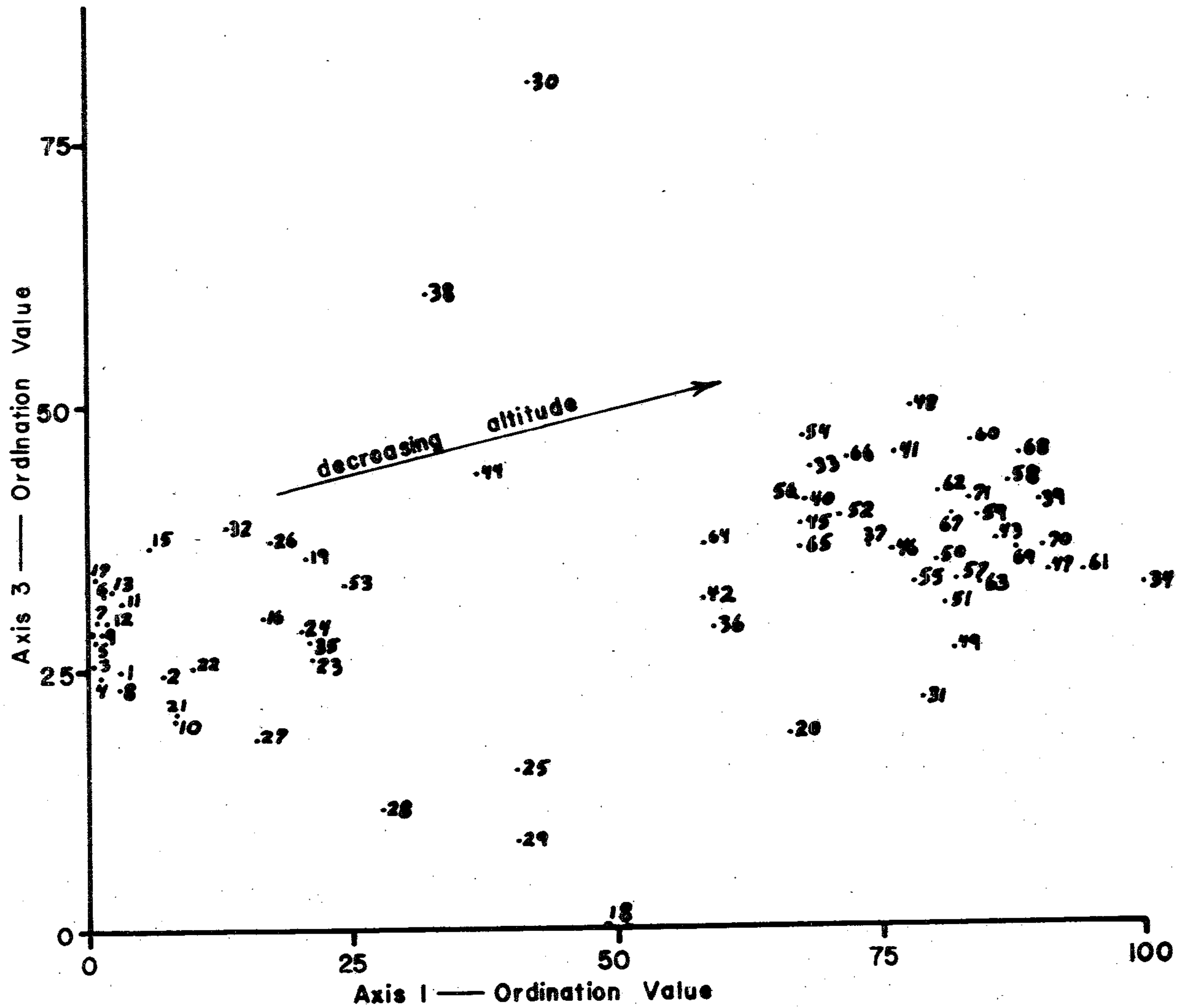


FIGURE 5B. Distribution of stands in tree ordination (axis 1 versus axis 2).

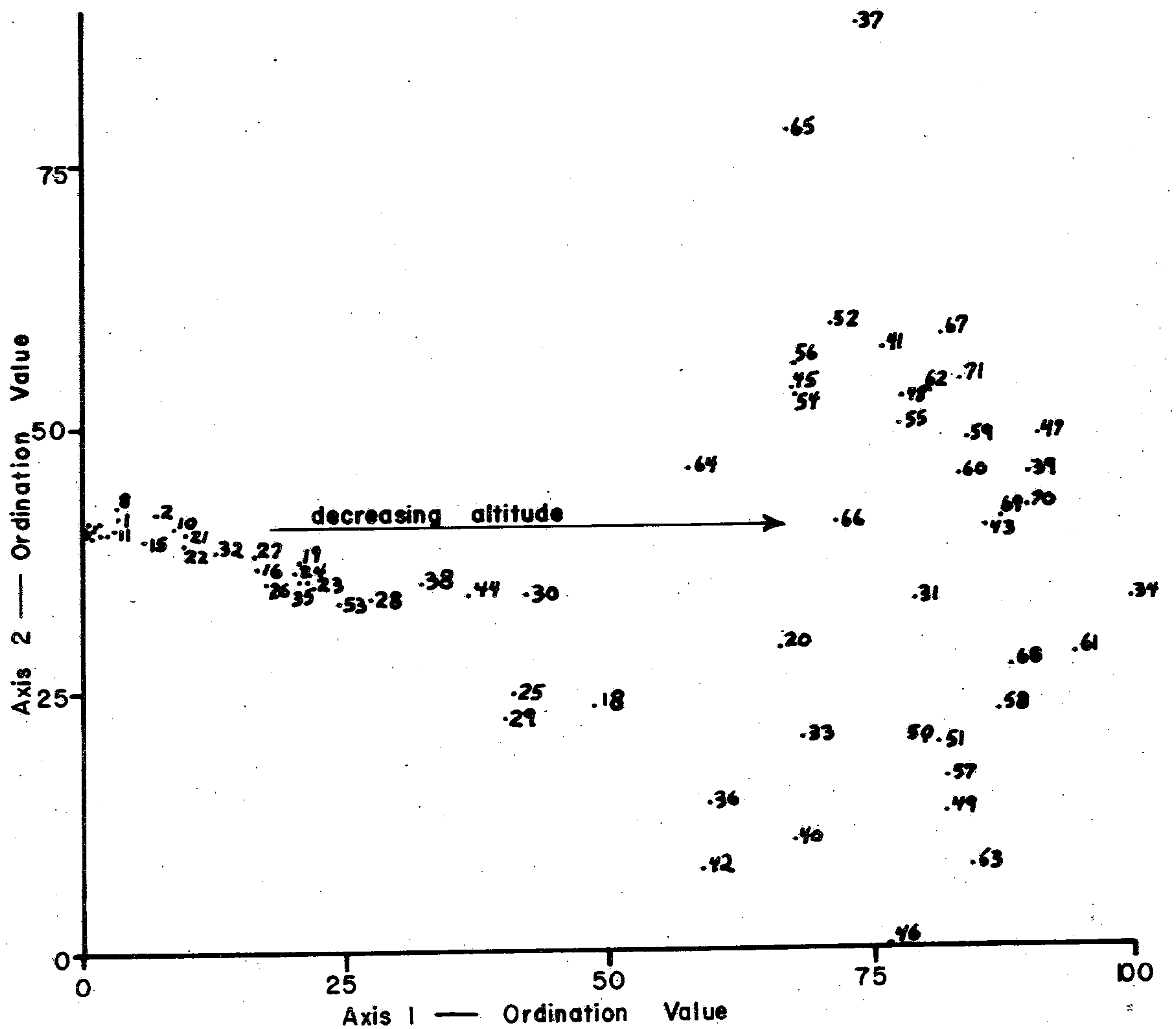


FIGURE 5A. Distribution of stands in tree ordination (axis I vs. axis 2).

to axis 1 of the tree ordination and axes 1 and 3 of the ground flora ordination. However, this may be a nonsense correlation because slope is significantly correlated to altitude, the higher elevations having steeper slopes.

The first axes of the two ordinations show a correlation with each other that is even higher than the correlations with altitude. This indicates that the similarity existing between the ground flora and trees is more than can be explained by an altitudinal gradient. The use of a subjective method of end-point selection in the ordination model may yield even greater similarities between tree and ground flora ordinations.

Even though the second axis defines a low altitude gradient and the third axis defines a high altitude gradient in both ordinations, the correlation coefficients comparing the second and third axes of one with the second and third axes of the other are not significant. Distinct similarities do exist and will be discussed later in relation to cluster analysis.

The great dissimilarity existing between the high and low elevation stands results in a clumping of dissimilar stands when axes 2 and 3 are considered. This is especially noticeable in Figure 5A where separation of the low altitude stands is good along axis 2. The result is that the high altitude stands on the left-hand side of the figure are very poorly separated. For this reason comparisons of axes other than the corresponding axes of the two ordinations may be ecologically insignificant even though the correlation coefficients are statistically significant. For the same reason the graphs depicting the distribution of clusters in Figure 9 and the leading dominants in Figures 11 and 13 on the tree ordination are composites of axis 1 versus 2 and axis 1 versus 3.

A scatter diagram comparing the ordination values of the stands using ground flora and tree data is shown in Figure 6. In Figure 7 the average ordination values for both ordinations are plotted for 500-foot interval altitude classes.

In Figure 6 the stands are chiefly distributed along a diagonal from the lower left-hand corner to the upper right-hand corner. This diagonal consists of two groupings, one at each end of the diagonal. The high altitude stands are located mainly in the lower left-hand corner while the low altitude stands are grouped in the upper right-hand corner. The diagonal therefore represents an altitudinal gradient. The relative lack of stands near the center of this diagonal indicates that even though enough similarity exists in these stands to construct a meaningful vegetational gradient from the lowland northern hardwoods to the higher altitude spruce-fir, these two groups have distinct characteristics.

The slope of the line representing average ordination value against altitude in Figure 7 is very steep between 2500

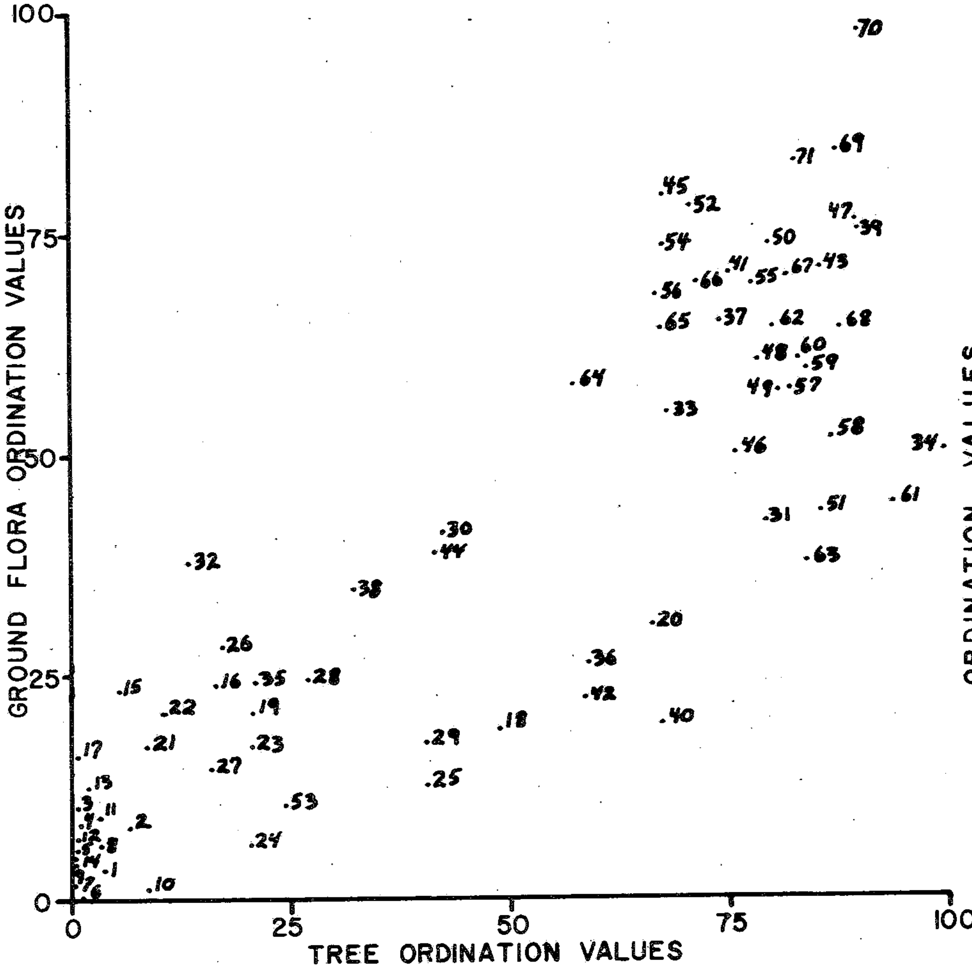


FIGURE 6. Comparison of first axis of ground flora and tree ordination.

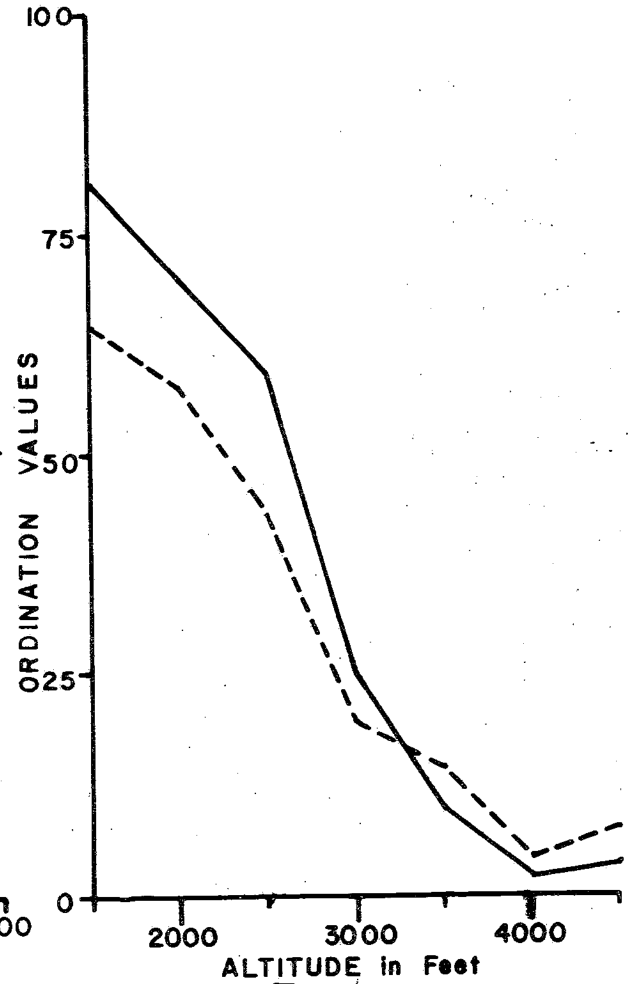


FIGURE 7. First axis of tree(——) and ground flora(---) ordination vs. altitude.

and 3500 ft indicating either that a rapidly changing environmental gradient with altitude exists or that an ecotone occurs along a uniformly-changing environmental gradient. Above and below these altitudes the slope of the line is not as steep indicating the existance of spruce-fir and northern hardwood groups, respectively. The need of two separate axes to separate the high (axis 3) and low (axis 2) altitude stands emphasizes this difference.

Relationship of clusters and leading dominants to the ordination axes

The distribution of clusters on the two ordinations are illustrated in Figures 8 and 9. Similarities exist between the ground flora and tree ordinations. They are both composed of three main clusters (see Appendix III for a list of stands in each cluster), one high altitude and two low altitude. The high and low altitude clusters can be thought of as representing the spruce-fir and northern hardwood types, respectively. The northern hardwood type contains two main clusters in both the ground flora and tree ordinations.

The clusters are formed in such a way so that stands with similar species are grouped together. In ordination, if appropriate axes are used, the stands are placed so that the ones close together are more similar to each other than to stands further away. The stands which occur in the two clusters near the center of the right-hand side of Figure 9 are more similar to each other than they are to stands within the same cluster near the end points. Even though the stands have to be considered as parts of separate vegetation types by the cluster analysis and therefore as "discrete" units, they represent two very similar segments of a vegetation gradient in the ordination model.

The similarity of dominant trees and ground flora in the corresponding clusters of the two analyses is represented in Table III. Index of Similarity (I) was calculated for the trees by summing the RIV for all species with a value greater than 20% for all stands in the cluster. For the ground flora, all species were included with a relative frequency greater than 15%. The clusters depicted on Figure 8 were formed by analysis of ground flora with the dominant trees being superimposed after the clusters were formed. The dominant tree and ground flora species for each stand were used as a method of comparison between the two cluster analyses. The similarities are due to the environmental gradients that control the distribution of the ground flora and associated trees.

Figures 10, 11, 12 and 13 show the distribution of leading dominants on the ordination axes (symbols for species listed in Appendix I). The distribution of species is similar for both ordinations, especially for the most common species. The one major exception is *Acer rubrum* which clusters with

Table 3: Comparison of species in tree and ground flora cluster analysis.

	Tree Analysis		Ground Flora Analysis		I[1]
	Major species[2]	Minor species[2]	Major species	Minor species	%
High Altitude					
Trees	Abies balsamea Betula papyrifera var. cordifolia Picea rubens	Betula papyrifera Betula alleghaniensis Pyrus decora	Abies Picea Betula papyrifera var. cordifolia	Pyrus Betula alleghaniensis	93
Ground Flora	Abies Oxalis Dryopteris Betula papyrifera var. cordifolia Maianthemum Clintonia Coptis Cornus Picea	Acer pensylvanicum Acer rubrum Aster Viburnum	Abies Dryopteris Oxalis Betula papyrifera var. cordifolia Maianthemum Clintonia Coptis Cornus Picea	Acer pensylvanicum Acer rubrum Aster Viburnum	95
Low Altitude I					
Trees	Acer saccharum Quercus Populus grandifolia Tilia	Betula papyrifera	Acer saccharum Quercus Populus grandifolia Betula papyrifera	Picea Tilia	77
Ground Flora	Acer saccharum Acer spicatum Aralia Fraxinus Ostrya Streptopus Uvularia	Maianthemum Aster Betula alleghaniensis Dryopteris Fagus Trientalis	Acer rubrum Acer saccharum Acer pensylvanicum Aralia Fraxinus Ostrya Streptopus Trientalis	Maianthemum Acer rubrum Picea Uvularia	73

[1] Per cent similarity of species composition based on Sorenson's Index.

[2] Major species - present most frequently or in high abundance
Minor species - present as a subordinate species or exclusive to one cluster

Table 3 (Continued)

	Tree Analysis		Ground Flora Analysis		I
	Major species	Minor species	Major species	Minor species	%
Low Altitude II Trees	Acer saccharum Fagus Betula alleghaniensis Acer rubrum	Picea	Acer saccharum Fagus Betula alleghaniensis	Quercus Tilia	78
Ground Flora	Acer saccharum Dryopteris Fagus Lycopodium	Acer pensylvanicum Acer rubrum Acer spicatum Maianthemum Oxalis Picea Solidago Streptopus Tiarella Trientalis	Acer saccharum Dryopteris Fagus Lycopodium	Acer pensylvanicum Viburnum Uvularia Betula alleghaniensis	71

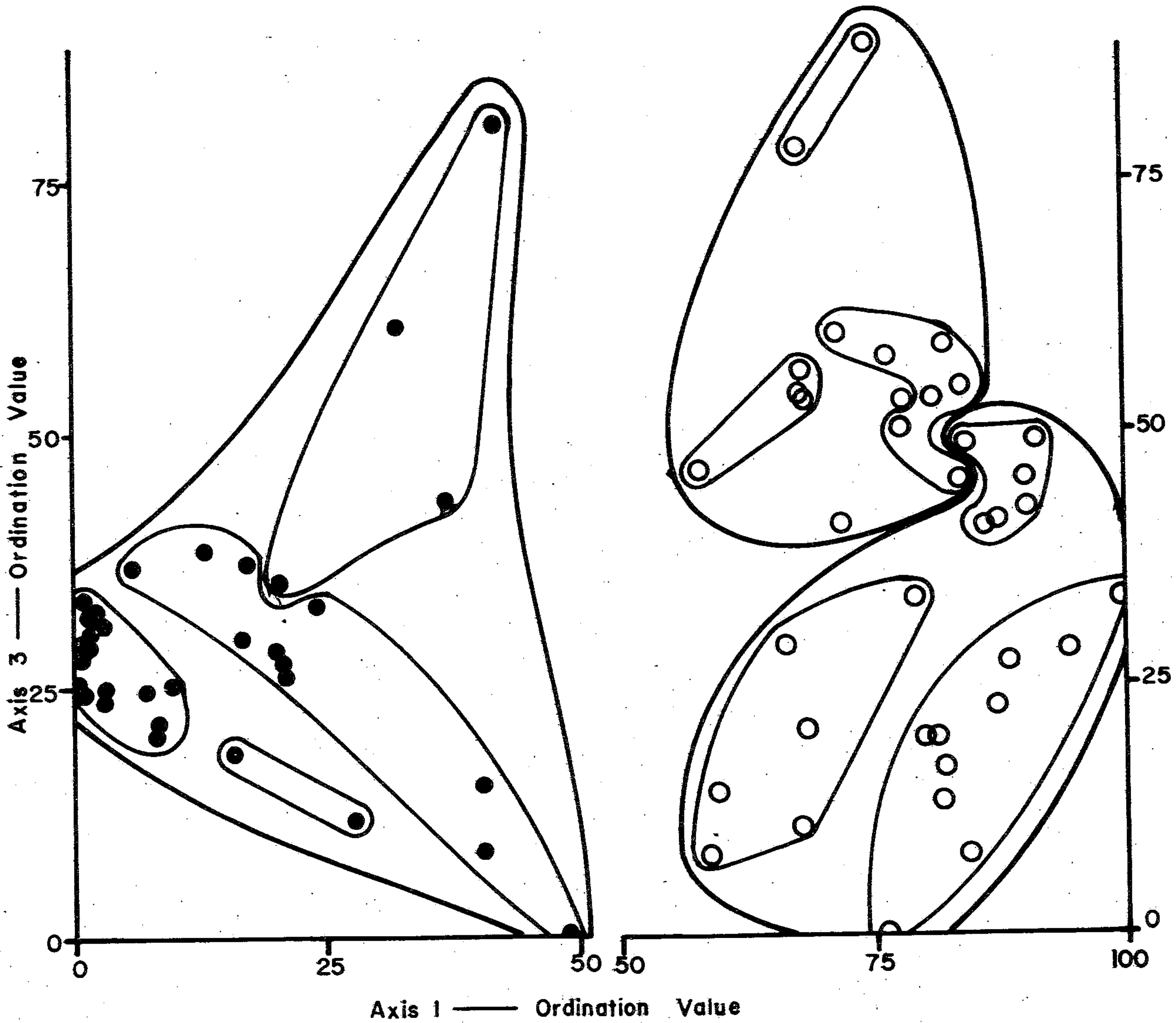


FIGURE 9. Distribution of clusters on tree ordination.

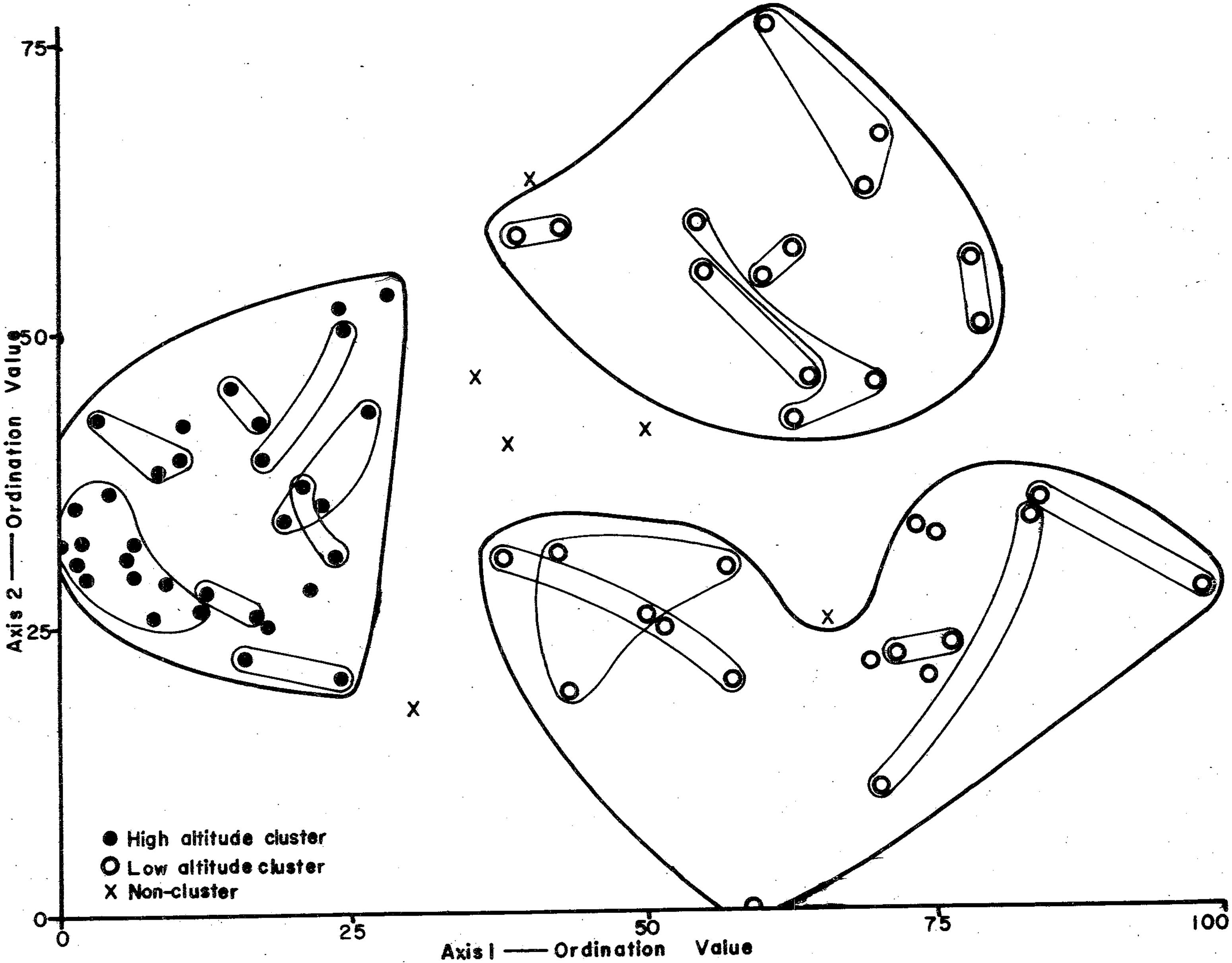


FIGURE 8. Distribution of clusters on ground flora ordination.

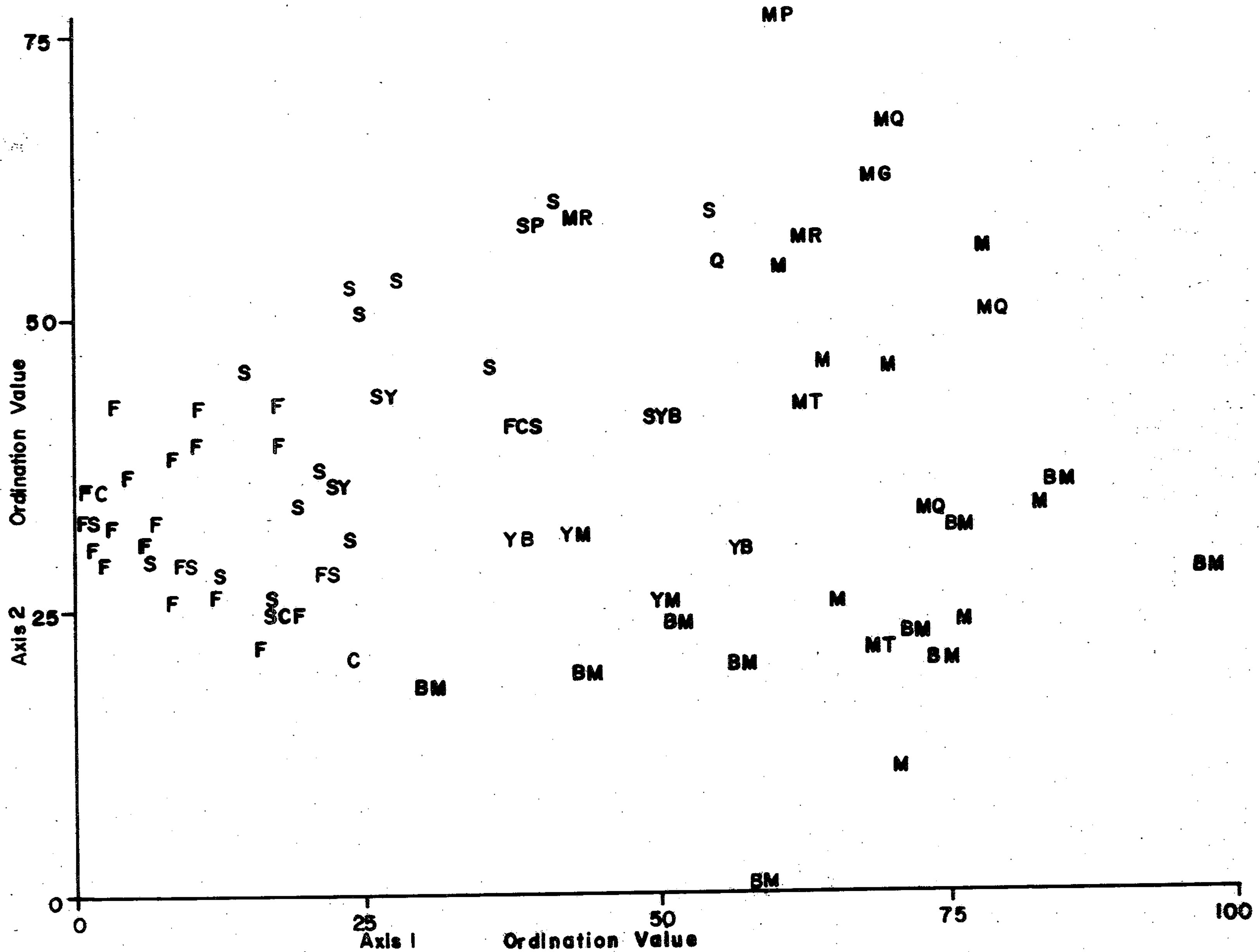


FIGURE 10. Distribution of leading dominants on ground flora ordination

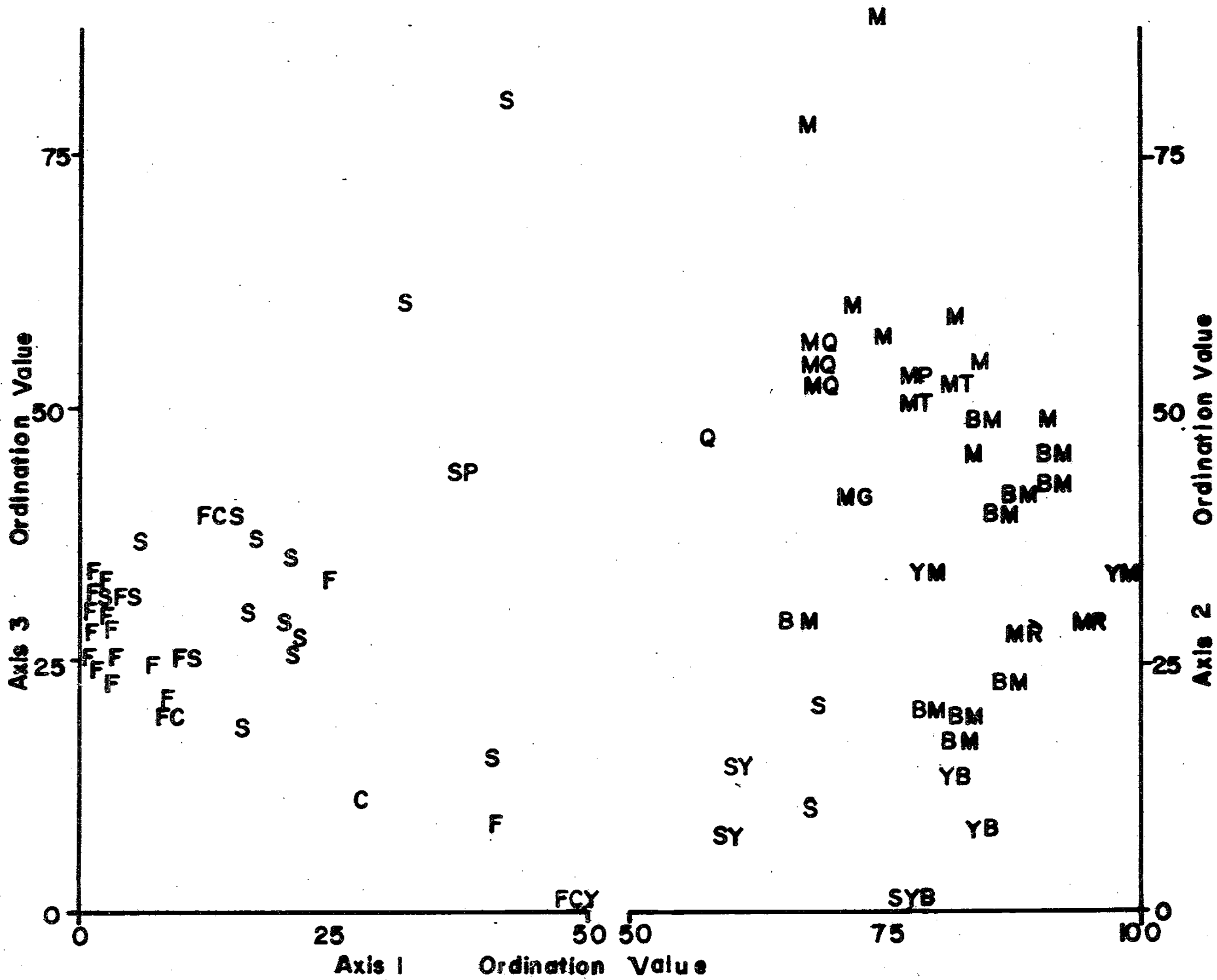


FIGURE II. Distribution of leading dominants on tree ordination.

Betula alleghaniensis and Fagus in the tree ordination (low altitude cluster II) and with Acer saccharum and Quercus in the ground flora ordination (low altitude cluster I).

Vegetation groups also exist for the ground flora (Table 3). These groups are not as distinct, mainly because of the wider distribution of individual species. However, the similarity of species between corresponding clusters of the two models is at least 70% (low altitude cluster II, ground flora) and is as high as 95% (high altitude cluster, ground flora).

The tree species in the three clusters are essentially the same as reported by Heimburger (1934) as belonging to three vegetational series (Table 4). The high altitude cluster corresponds to Heimburger's subalpine series. Low altitude cluster II, dominated by Fagus, Betula alleghaniensis, Acer saccharum and A. rubrum, is equivalent to his western series. Low altitude cluster I which contains the other northern hardwood species corresponds to the eastern series. The eastern series contains the drier habitat species, whereas the species of the western series are adapted to more mesic conditions requiring a better developed soil and are, in general, more shade tolerant.

If the stands are arranged by increasing ordination values for any axis, a distribution of species RIV results. The midpoint of occurrence of the RIV for each species along the ordination axis can be calculated. When the species midpoint values are ordered and placed on a scale of 0.0 to 10.0, a number results which is equivalent to the "climax adaptation number" of Curtis and McIntosh (1951). In this study, Acer rubrum was found to have a value of 10.0 and Abies a value of 0.0. The midpoints for the 14 most common tree species are plotted in Figure 14. The species composing the high altitude cluster are widely separated from the others. The species in low altitude cluster I have values from 7.8 to 8.9, while the species of low altitude cluster II have values from 8.8 to 10.0. The species midpoint value assigned a species has meaning only with regard to the gradient it was derived from - in this case altitude.

DISCUSSION

Gradients and the n-dimensional niche

No one can debate the existance of gradients of environmental factors both on a large and small scale. However, these gradients cannot be considered linear with respect to a measured topographic feature or with each other. As a result, a complex mosaic pattern develops which is far too complex to be described by a "discrete community" theory or even a one-dimension ordination model.

Table 4: Classification of Adirondack vegetation series* according to Heimburger (1934).

Trees	Ground Flora
Subalpine Series	
Picea rubens	Hylocomium splendens
Abies balsamea	Pleurozium schreberi
Betula papyrifera var. cordifolia	Ptilium crista-castrensis
Pyrus decora	Cornus canadensis
Betula alleghaniensis (stunted)	Oxalis montana
	Clintonia borealis
	Dryopteris spinulosa
	Maianthemum canadense
	Solidago macrophylla
	Aster acuminatus
Eastern Series	
Acer saccharum	Aralia nudicaulis
Tilia americana	Aster acuminatus
Fraxinus americana	Dryopteris spinulosa
Quercus rubra var. borealis	Clintonia borealis
Ostrya virginiana	Maianthemum canadense
	Oxalis montana
	Trientalis borealis
	Acer pensylvanicum
	Acer spicatum
Western Series	
Acer saccharum	Oxalis montana
Betula alleghaniensis	Cornus canadensis
Fagus grandifolia	Clintonia borealis
Acer rubrum	Dryopteris montana
Picea rubens	Viburnum alnifolium
Betula papyrifera	Acer pensylvanicum
Abies balsamea	Acer spicatum
Tsuga canadensis	Trientalis borealis
	Maianthemum canadense
	Lycopodium lucidulum
	Aralia nudicaulis
	Streptopus roseus
	Tiarella cordifolia
	Uvularia sessilifolia

*Types selected to correspond to types used in this study.

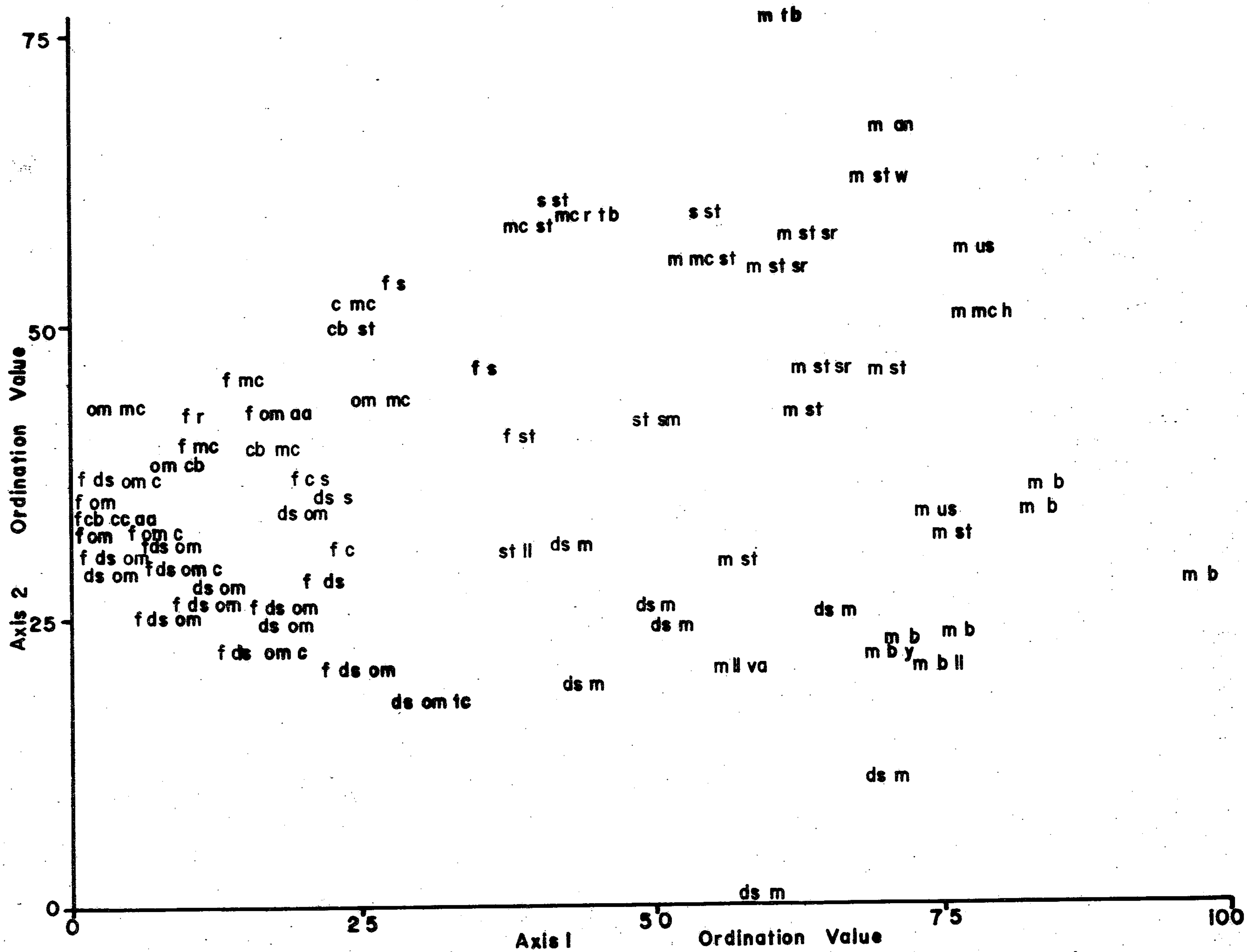


FIGURE 12. Distribution of ground flora species on ground flora ordination.

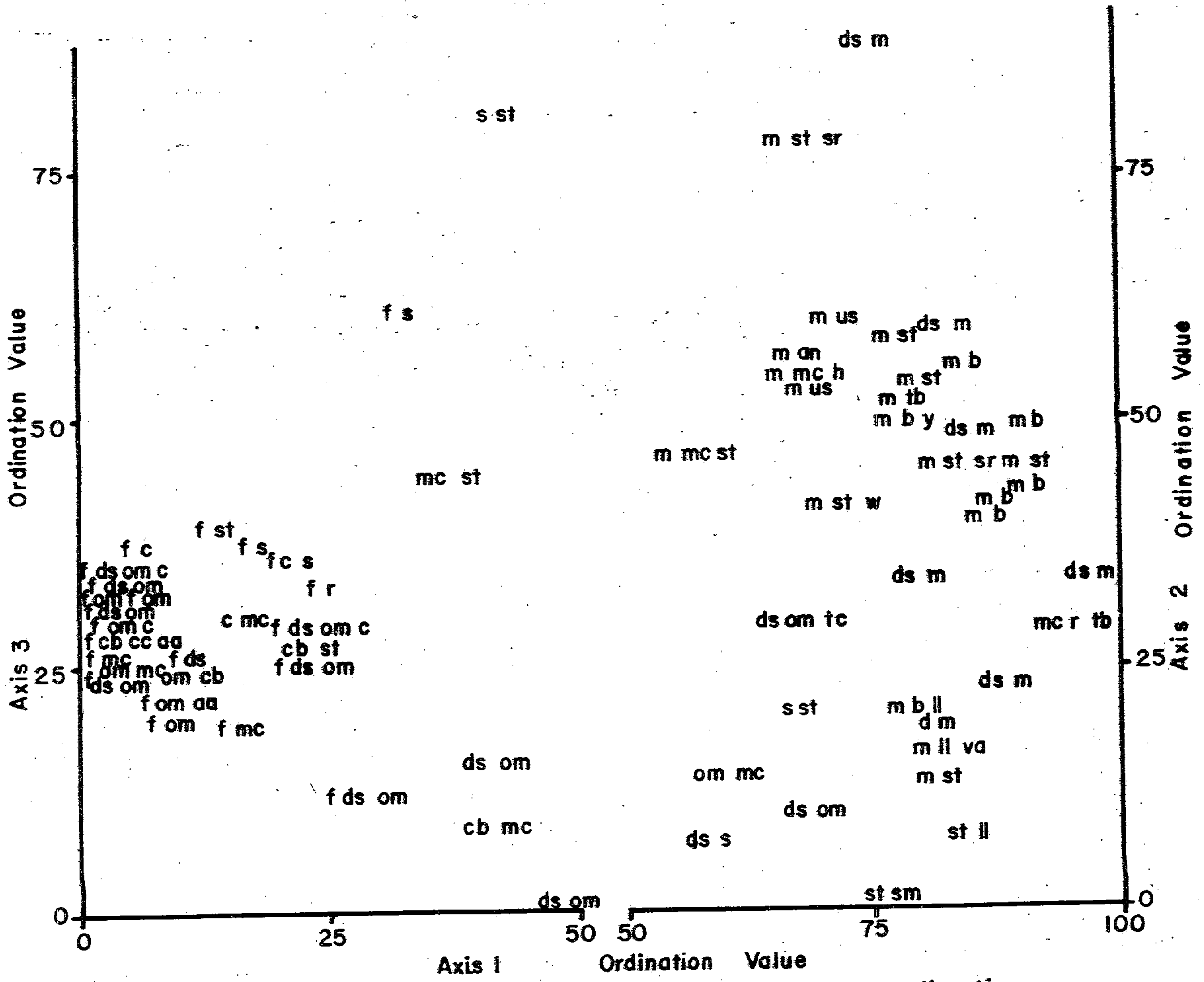


FIGURE 13. Distribution of ground flora on tree ordindtion.

synergistic effects of all these climatic factors during the past life history of each stand is an impossible problem. However, the responses of the vegetation and the development of the soil horizons have already integrated the effect of all environmental variables (Rowe, 1956).

The only gradient plotted on the ordination model is altitude (Figures 4, 5A and 5B). This, however, is a topographic gradient which is actually a composite of many environmental gradients, as are the changes related to slope and slope aspect which occur with altitude. The topography influences environmental gradients in three major categories - biotic, edaphic and climatic. The biotic gradient, which may be either successional or compositional, can be considered to be a produce of the other two.

Edaphic gradients have been analyzed by many workers. Most of these are soil moisture gradients (Loucks, 1962; Whittaker, 1956; Whittaker & Niering, 1965), but at least one worker has described a gradient related to calcium ion concentration (Monk, 1965).

The description of a soil moisture gradient for Whiteface Mountain is somewhat questionable at this stage because it would have to be based upon the location of each stand on the soil map compiled by John Witty (1968). Values for the soil characters would then have to be interpolated for each stand. About one-third of the stands used in this study are located outside of the area mapped by Witty. However, a moisture gradient does exist which approximates the altitudinal gradient. Another soil moisture gradient may exist for the low elevation stands (the right half of Figure 11) parallel to axis 2 with soil moisture increasing inversely with ordination number, so that the beech-birch-maple end is mesic while the paper birch-oak-basswood end is drier. This is based on less severe slope and greater depth of "O" horizon with an accompanying increase in water-holding capacity.

In such mountainous areas as Whiteface Mountain, where shallow soils and rock outcrops exist, the drainage patterns and soil development can vary considerably in distances which are quite small in comparison to the size of the average sampling unit. For this reason, vegetational and edaphic gradients will be difficult to measure on a small scale. Ground flora data which can be recorded on a smaller scale than tree data, may be better suited to describing such gradients. The flora which surrounds the slightly raised base of a tree or the downhill side of a rock outcrop is, in general, quite different from the typical vegetation associates. It seems that neither importance value in the case of trees nor frequency, in the case of ground flora, will be sufficient to measure the edaphic gradients which are being sought at the microhabitat level.

The differences which exist between the tree and ground flora ordinations may be due in part to the response time of these two layers. It could take from 30 to 70 years or more for a tree to obtain a diameter of 4". Any noticeable change in species composition with the exception of catastrophic destruction of existing trees would take a long time to occur. The ground flora respond to climatic changes much more quickly and are therefore indicative of the recent environmental history.

Interpretation of the ordination model

Ordination has been defined by Orloci (1966) as "a summarization of the information content of a matrix whose elements, distance, or angles define the spatial relationships between ecological entities." The methods of construction of matrices and their interpretation differ with investigators. Arguments have developed concerning the mathematical or statistical validity of various methods. Although Orloci states that the method of Bray and Curtis is not statistically sufficient to ordinate a group of samples, Goff and Cottam (1967) have shown that the results of the Bray and Curtis method closely correlated with the other methods used.

The results of the three-dimensional ordination model with superimposed clusters indicate a large degree of dissimilarity among the samples. In such a case, it would be possible to subdivide the original sample according to the results of the first axis and ordinate each part separately. A similar technique was used by Ream (1963) in the Wasatch Mountains where the gradient ran from semi-desert to alpine through four distinct vegetation types. The composite three-dimensional ordination would be more meaningful and easier to interpret. It could be viewed as a group of three-dimensional ordinations (hypervolumes) within a larger ordination (hyperspace). The clusters can be thought of as the hypervolume occupied by a community type or a group of closely related communities situated somewhere in a hyperspace.

The use of the standard deviation criterion as a method of end-point extraction can be questioned for several reasons. It was used in this study so that correlations could be computed between the two ordinations without biasing end-point selection. According to Austin and Orloci (1966), the standard deviation criterion which picks the extremes is not the most efficient method. Such a method emphasizes the unusual, accidental or rare sample. As a result, samples dissimilar from the unusual sample used as an end point but not necessarily similar to each other are clumped.

A compositional index based purely on relative values (i.e. RIV) results in a loss of information. Goodall (1952) points out that when all samples have the same total value (i.e. 100%) each one is given equal importance. The species in each stand are also given equal weight - an ubiquitous species being considered as important as a species with a very narrow ecological amplitude. It might be best to express each species in a stand by standard deviation or weighted standard deviation.

SUMMARY AND CONCLUSIONS

The purpose of this paper was to apply the techniques of ordination and cluster analysis to selected stand data in order to describe quantitatively environmental gradients controlling the distribution and associations of vegetation on Whiteface Mountain. A comparison of the three-dimensional ordination and cluster analysis constructed using frequency measurements for ground flora and IV for trees was made.

Seventy-one forest stands were included in this study. The stands were composed of vegetation that is typical of either the boreal spruce-fir or northern hardwood forests or any degree of combination of these two types.

From this study we can conclude that the measurement of frequency for ground flora can be used in an ordination of these forest stands to construct gradients with as much confidence as the more complex relative importance value which was used for the tree species. Some of the advantages of using ground flora frequency measurements are as follow: (1) it is easier to obtain in the field; (2) it is easier to calculate; (3) smaller areas can be sampled, making it a better indicator of local environment; (4) it is more indicative of recent environmental changes; (5) it is a better indicator of successional trends. The usefulness of the ground flora is due to their small size and rapid response time to environmental changes.

The first axis of the tree and ground flora ordinations was closely related to an altitudinal gradient. The first axis was also significantly correlated to slope and was indicative of a soil moisture gradient. A vegetational gradient from the high altitude spruce-fir forests to the low altitude northern hardwood forests was described by the placement of stands along axis 1.

The low altitude stands were separated from each other by the second axis in both ordinations. The vegetational gradient described was one from the xeric, subclimax species - *Quercus*, *Tilia* and *Fraxinus* - to the mesic, shade-tolerant climax northern hardwoods - *Fagus*, *Betula alleghaniensis* and *Acer saccharum*. The third axis was used to separate the high altitude stands from each other. The early successional *Betula papyrifera* var. *cordifolia* stands were at one end of the gradient and the *Picea-Abies* stands at the other.

The species composition of the clusters obtained from the analysis of the ground flora and trees were very similar and corresponded to the three vegetational series described by Heimburger (1934) for the Adirondacks. The high altitude cluster composed of *Abies*, *Picea*, *Pyrus* and *Betula papyrifera* var. *cordifolia* was equivalent to the "subalpine series". Low altitude cluster I with *Quercus*, *Tilia*, *Ostrya* and *Acer saccharum* as dominants was analogous to the "eastern series". Low altitude cluster II, which was dominated by *Fagus*, *Betula alleghaniensis*, *Acer saccharum* and *A. rubrum*, corresponded to Heimburger's "western series".

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APPENDIX I

List of Species

Tree Species:

symbol	scientific name	common name
F	*Abies balsamea* (L.) Mill.	*balsam fir
ST	*Acer pensylvanicum* L.	*striped maple
R	*Acer rubrum* L.	*red maple
M	*Acer saccharum* Marsh	*sugar maple
MT	*Acer spicatum* Lam.	*mountain maple
Y	*Betula alleghaniensis* Britt.	*yellow birch
P	*Betula papyrifera* Marsh.	paper birch
C	*Betula papyrifera* Marsh. var. *cordifolia* (Regel) Fern.	*cordate-leaved birch
B	*Fagus grandifolia* Ehrh.	*beech
W	*Fraxinus americana* L.	*white ash
H	*Ostrya virginia* (Mill.) K.Koch	*ironwood
S	*Picea rubens* Sarg.	*red spruce
	Pinus resinosa Ait.	red pine
	Pinus strobus L.	white pine
G	*Populus grandidentata* Michx.	big-toothed aspen
	Prunus serotina Ehrh.	black cherry
D	*Pyrus decora* (Sarg.) Hyland	*mountain-ash
Q	*Quercus rubra* L. var. *borealis* (Michx.f.)Farw.	northern red oak
	Thuja occidentalis L.	white cedar
T	*Tilia americana* L.	basswood
	Tsuga canadensis (L.) Carr.	hemlock

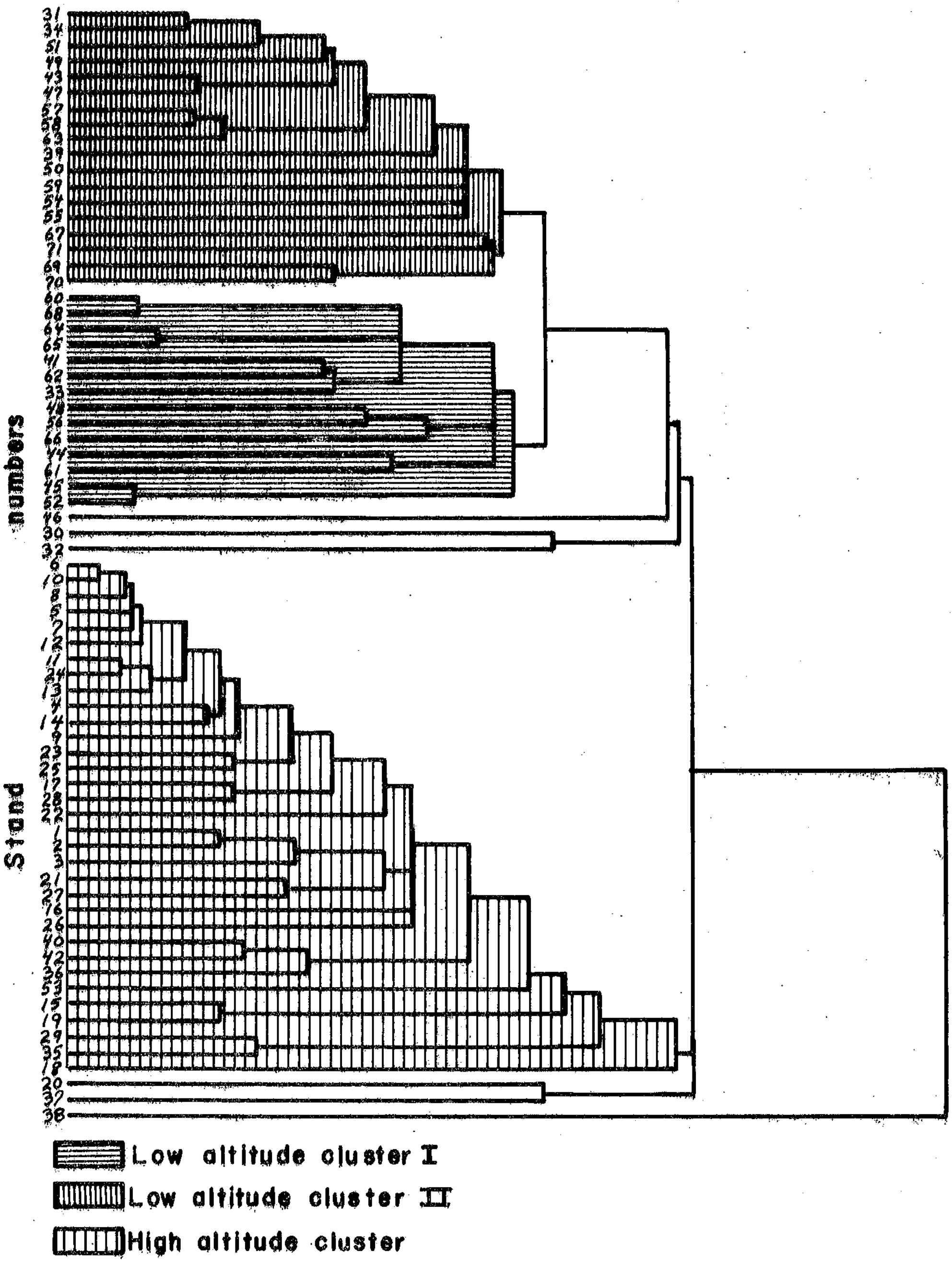
Ground Flora:

aa	*Aster acuminatus* Michx.
an	*Aralia nudicaulis* L.
cb	*Clintonia borealis* (Ait.) Raf.
cc	*Cornus canadensis* L.
cg	*Coptis groenlandica* (Oeder) Fern.
ds	*Dryopteris spinulosa* (O.F. Muell.) Watt.
ll	*Lycopodium lucidulum* Michx.
mc	*Maianthemum canadense* Desf.
om	*Oxalis montana* Raf.
sm	*Solidago macrophylla* Pursh
sr	*Streptopus roseus* Michx.
tc	*Tiarella cordifolia* L.
tb	*Trientalis borealis* Raf.
us	*Uvularia sessilifolia* L.
va	*Viburnum alnifolium* Marsh.

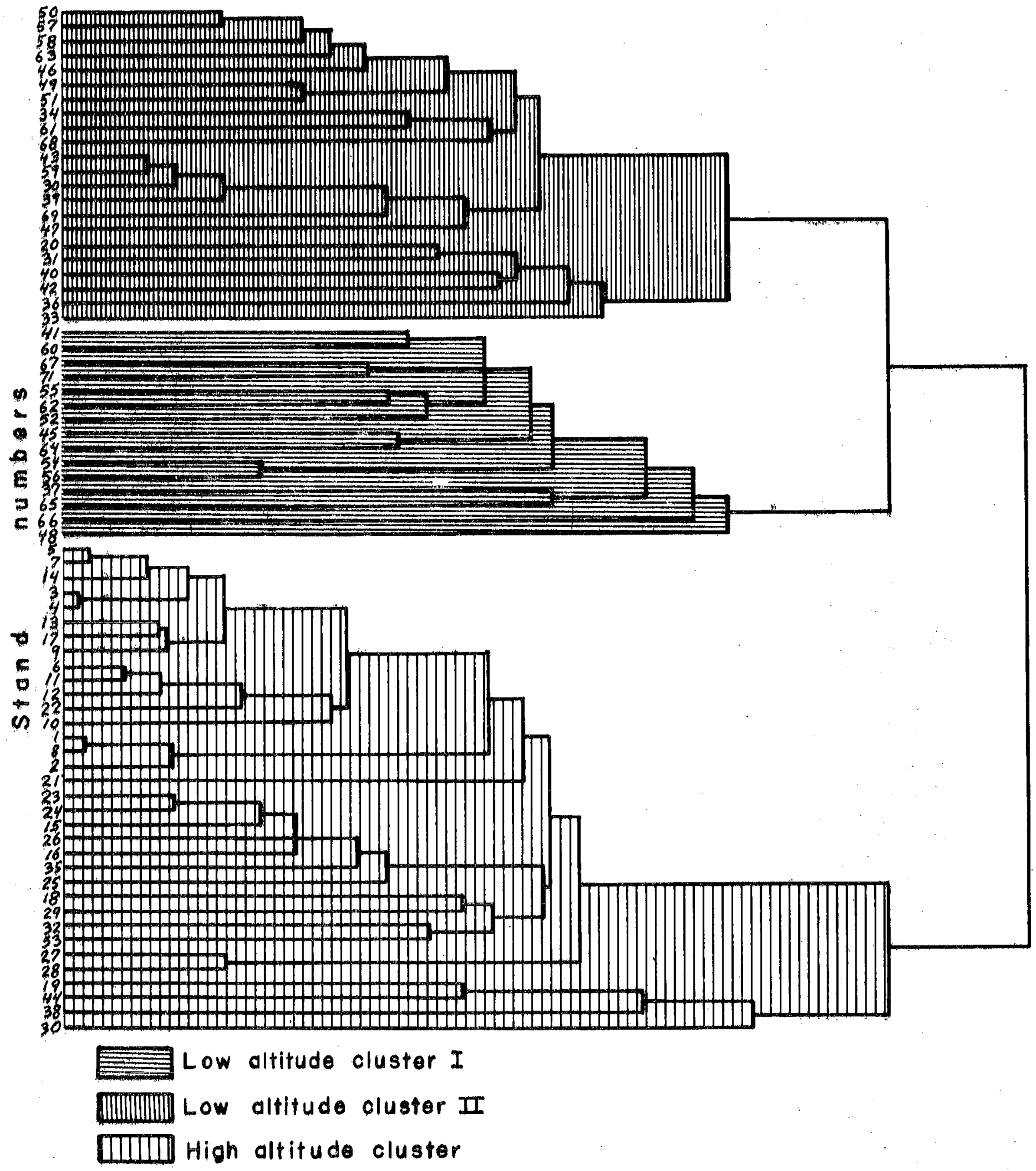
*Seedlings of this species also used in ground flora ordination. Symbol used for seedling is lower case letter.

APPENDIX II

Dendrogram of clusters based on ground flora data.



Dendrogram of clusters based on tree data.



APPENDIX III

Topographic and Vegetational Characteristics of Stands

Stand No.	Altitude (Feet)	Slope Aspect	Slope	Dominant Trees	Dominant Ground Flora	Cluster[1] I	II	III	N[2]
1	4500	239	32	F	om mc	t[3]g[4]			
2	4500	332	27	F	om cb	tg			
3	4500	108	36	F	f mc	tg			
4	4000	200	28	F	f ds om	tg			
5	4000	273	26	F	f ds om c	tg			
6	4000	120	34	F S	f om	tg			
7	3970	55	7	F	f ds om	tg			
8	3960	20	30	F	f ds om	tg			
9	3800	24	30	F	f cb cc aa	tg			
10	3780	59	28	F C	f om	tg			
11	3500	248	27	F S	f om	tg			
12	3500	320	17	F	f om c	tg			
13	3500	273	10	F	f ds om	tg			
14	3500	350	22	F	ds om	tg			
15	3480	113	24	S	f c	tg			
16	3450	104	37	S	c mc	tg			
17	3450	124	32	F	f ds om c	tg			
18	3350	107	26	F C Y	ds om	tg			
19	3110	229	28	S	f c s	tg			
20	3100	33	21	B M	ds om tc			t	g
21	3075	357	22	F	f om aa	tg			
22	3000	248	23	F S	f ds	tg			
23	3000	327	11	S	f ds om	tg			
24	3000	204	16	S	f ds om c	tg			
25	3000	339	23	S	ds om	tg			
26	2900	74	24	S	f s	tg			
27	2875	355	41	S	f mc	tg			
28	2860	99	24	C	f ds om	tg			
29	2650	29	16	F	cb mc	tg			
30	2625	189	27	S	s st	t			g
31	2600	153	5	Y M	ds m			tg	
32	2600	185	28	F C S	f st	t			g
33	2560	164	28	S	s st		g	t	
34	2550	243	7	Y M	d m			tg	
35	2525	353	17	S	cb st	tg			
36	2520	342	11	S Y	om mc	g		t	
37	2500	145	17	M	ds m		t		g
38	2410	264	32	S	f s	t			g
39	2400	84	21	B M	m st			tg	
40	2320	248	24	S	ds om	g		t	

Stand No.	Altitude (Feet)	Slope Aspect	Slope	Dominant Trees	Dominant Ground Flora	Cluster[1] I	II	III	N[2]
41	2275	77	24	M	m st		tg		
42	2200	240	17	S Y	ds s	g		t	
43	2150	152	13	B M	m b			tg	
44	2045	249	22	S P	mc st	t	g		
45	2000	125	15	M Q	m mc h		tg		
46	2000	268	15	S Y B	st sm			t	g
47	2000	4	12	M	m b			tg	
48	1950	126	6	M P	m tb		tg		
49	1950	161	5	Y B	m st			tg	
50	1900	310	8	B M	m b ll			tg	
51	1900	106	13	B M	ds m			tg	
52	1850	151	14	M	m us		tg		
53	1800		00	F	f r	tg			
54	1750	130	11	M Q	m us		t	g	
55	1750	121	8	M T	m b y		t	g	
56	1730	51	26	M Q	m an		tg		
57	1710	36	2	B M	m ll va			tg	
58	1710	181	8	B M	ds m			tg	
59	1680	56	5	B M	ds m			tg	
60	1670	281	4	M	m st sr		tg		
61	1660	131	6	M R	mc r tb		g	t	
62	1630	337	22	M T	m st		tg		
63	1620	248	11	Y B	st ll			tg	
64	1575	148	8	Q	m mc st		tg		
65	1550	152	6	M	m st sr		tg		
66	1530	120	14	M G	m st w		tg		
67	1530	131	5	M	ds m		t	g	
68	1525	143	6	M R	m st sr		g	t	
69	1500		10	B M	m b			tg	
70	1470	141	19	B M	m b			tg	
71	1370	37	14	M	m b		t	g	

[1]Cluster I -- High altitude cluster (spruce-fir)
Cluster II -- Low altitude cluster I (beech-birch-maple)
Cluster III -- Low altitude cluster II (oak-basswood)

[2]N -- non-cluster

[3]t -- tree analysis

[4]g -- ground flora analysis

A FLORISTIC COMPARISON OF UNDISTURBED SPRUCE-FIR FORESTS OF THE ADIRONDACKS WITH FOUR OTHER REGIONS

By

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ABSTRACT

The relationship of Adirondack boreal spruce-fir to the spruce-fir vegetation of other geographic regions reported in the literature is examined based on number of species shared in common. Two methods of evaluation are employed. One involves a simple determination of percentage of species shared in common. The second employs the standard 2w/a+b Index of Similarity using constancy values for values to represent a, b, and 2w.

The Adirondack sample is divided into two sub-samples, the Whiteface uplands (3000-3500 ft) and the Whiteface highlands (4000-4500 ft). Similarity decreases with geographic distance from Whiteface Mountain. The Smoky Mountain and Wisconsin forests are furthest and least similar to both types of Whiteface stands, the Catskill Mountain forests are closest and most similar.

INTRODUCTION

Extensive areas of undisturbed spruce-fir forests are found in the Adirondack Mountains of New York State. Much of this forest lies within the Adirondack Forest Preserve which provides a substantial measure of protection from human disturbance. There have been a few ecological studies in the Adirondacks and no comprehensive phytosociological study has been published to date. Oosting and Billings (1951) and McIntosh and Hurley (1964) have emphasized the need for quantitative ecological studies of the spruce-fir forests.

The floristic relationship fo the Adirondack spruce-fir to spruce-fir in other regions of eastern North America has been variously interpreted by different authors. Braun (1950) treats it as a variant of the eastern deciduous forest separate from the boreal forest to the north. Curtis (1959) stated that there was a close relationship between the Adirondack spruce-fir and the Wisconsin lake forest, as evidenced by the data of Heimburger (1934).

McIntosh and Hurley (1964) considered the spruce-fir of the Adirondacks, Catskills, and White Mountains to be similar. Crandall (1958) pointed out basic floristic and physiognomic similarities between spruce-fir of the Great Smoky Mountains and the Adirondacks. Oosting and Billings (1951) and McIntosh and Hurley (1964) suggested that the spruce-fir forest is essentially continuous from the Great Smoky Mountains to the northern Appalachians.

These references to Adirondack spruce-fir are based primarily on qualitative data. The prupose of this paper is to present a comparison of the Adirondack spruce-fir forest composition to the above mentioned regions based on quantitative stand data collected at Whiteface Mountain (Lat. 44° 20' N., Long. 77° 55' W.) in the northern Adirondacks.

METHODS

Data on the Adirondack spruce-fir forest were obtained from that being collected for a larger study concerning the relation of vegetation and environment at Whiteface Mountain. Stands with obvious signs of disturbance were excluded. Trees and saplings were recorded using the quarter method (Cottam and Curtis, 1956) and ground flora from square meter quadrants. Nomenclature follows Fernald (1950).

Of the 56 stands sampled during the summer of 1964, 17 were selected as being typical of well-developed, undisturbed spruce-fir forest. Of these 17, nine were at the 4000-4500 foot levels (Whiteface highland stands), and eight at 3000-3500 foot (Whiteface upland stands). All stands were within a mile of the summit of Whiteface Mountain and were dominated by either balsam fir (*Abies balsamea*) or red spruce (*Picea rubens*). Most stands below 4000 ft were logged during the 1890's, but none have been disturbed by man since their inclusion in the Adirondack Forest Preserve in the early 1900's.

In order to compare species found in different regions of the spruce-fir forest, constancy data taken from Curtis (1959) for the Wisconsin Lake forest, and ours for the Adirondacks were appended to a table comparing spruce-fir stands in the Appalachians presented by McIntosh and Hurley (1964). The comparisons made in the present paper are by two methods. The first is by the direct examination of the percent of species common between regions. The second method compares regions based on similarity using the common 2w/a+b Index of Similarity. The latter method involved a ranking of regions by trees only, shrubs only, ground flora only, all three components combined, and by rank values determined by order of position of each region by each of the four preceeding rankings.

RESULTS AND DISCUSSIONS

Constancies of vascular herbs, shrubs, and trees from representative regions of the spruce-fir forest are listed in Table 1. Within this sample the Great Smoky Mountain flora is most distinct in that it has the highest

Table 1: Percent presence of trees, shrubs, and herbs in spruce-fir stands from the Catskills, White Mountains, Great Smokies, Adirondacks, and Wisconsin.

Species	Great Smoky Mts[a]	Cat-skill Mts[b]	Wisc.[c]	White-face upland	White Mts[a]	White-face high
Trees:						
Picea rubens	100	100	-	100	100	100
Betula cordifolia .....[d]	0	75	-	100	0	100
Pyrus sp.	100	75	56	88	100	56
Acer spicatum	89	50	82	38	100	22
Abies fraseri	100	0	-	0	0	0
Prunus penslyvanicum ..	45	50	33	25	0	0
Ilex monticola	11	0	-	0	0	0
Abies balsamea	0	100	100	100	100	100
Fagus grandifolia......	11	25	-	0	0	0
Betula papyrifera......	0	0	87	0	100	0
Tsuga canadensis.......	0	25	41	0	25	0
Prunus serotina........	0	0	23	0[e]	25	0
Acer rubrum	0	25	77	25	0	0
Larix laricina.........	-	-	5	0	-	11
Acer saccharum.........	-	-	54	0[e]	-	0
Betula alleghaniensis..	100	75	41	50	75	0
Acer penslyvanicum.....	-	75	-	25	75	0
Shrubs:						
Viburnum alnifolium	100	50	-	0[e]	100	0
Viburnum cassinoides ...	11	0	-	0[e]	25	0
Vaccinium erythrocarpum	100	0	-	0	0	0
Rubus canadensis	100	0	-	13	0	0[e]
Sambueens pubens	89	25	-	25	0	0
Ribes rotundifolia	22	0	-	0	0	0
Rhododendron catawbiense	11	0	-	0	0	0
Vaccinium pallidium	11	0	-	0	0	0
Nemopanthus mucronata ..	0	25	-	0	50	22
Vaccinium angustifolium	0	0	44	25	25	22
Lonicera canadensis	0	25	97	0	0	0
Rubus sp.	0	50	(f)	25	25	0
Ribes sp.	0	25	(f)	25	0	67
Rhododendron roseum	0	25	-	0	0	0
Diervilla lonicera	-	-	80	13	-	0
Ledum groenlandicum	-	-	-	0	-	22
Alnus crispa	-	-	-	0	-	33
Vaccinium sp.	0	25	(f)	13	0	0[e]

[a]Data from Oosting and Billings (1951) summarized by McIntosh and Hurley (1964).
[b]Data from McIntosh and Hurley (1964).
[c]Data from Maycock (1956) in Curtis (1959).
[d]Designated in text as B. papyrifera var. cordifolia.
[e]Present in other stands.
[f]Present.

Table 1: (Continued)

Species (Herbs)	Great Smoky Mts	Cat-skill Mts	Wisc.	White-face upland	White Mts	White-face high
Aster acuminatus	100	100	-	38	100	44
Dryopteris dilatata	100	100	-	0[g]	100	0[g]
Oxalis montana	100	75	-	100	88	100
Clintonia borealis	100	100	95	75	100	100
Monotropa uniflora	66	0	-	38	50	11
Trillium undulatum	55	25	-	25	50	0
Carex flexuosa	55	50	-	-	50	-
Lycopodium lucidulum	33	25	-	63	75	0[e]
Cinna latifolia	33	0	-	25	25	0[e]
Viola rotundifolia	22	50	-	0	0	0
Dryopteris intermedia	11	25	100	0	(f)	0
Streptopus roseus	11	50	80	0[e]	0	38
Senecio rugelia	89	0	-	0	0	0
Houstonia serpyllifolia	44	0	-	0	0	0
Solidago glomerulata	44	0	-	0	0	0
Aster divarcatus	33	0	-	0	0	0
Impatiens pallida	33	0	-	0	0	0
Chelone lyoni	33	0	-	0	0	0
Arisaema quinatum	22	0	-	0	0	0
Circea alpina	22	0	36	13	0	0
Stachys clingmanii	11	0	-	0	0	0
Maianthemum canadense	0	100	100	63	100	100
Cornus canadensis	0	75	97	63	100	100
Aralia nudicaulis	100	50	95	75	0	22
Solidago macrophylla	0	0	-	75	100	89
Coptis trifolia	0	75	62	50	50	89
Trientalis americana	0	75	97	25	50	56
Dryopteris hexagonoptera	0	0	-	0	50	0
Chiogenes hispidula	0	0	-	0	25	44
Solidago sp.	0	25	(f)	0	0	0
Dennstaedtia punctiloba	0	25	-	0	0	0
Linnea borealis	-	-	74	0	-	44
Lycopodium annotinum	-	-	-	0	-	89
Pyrola sp.	-	-	(f)	13	-	0
Tiarella cordifloia	-	-	3	13	-	0
Smilacina racemosa	-	-	39	13	-	0
Athyrium filix-femina	-	-	59	0[e]	-	-
Cyperidium acuale	-	-	-	13	-	0
Pteridium aquilinum	-	-	77	13	-	0
Aster macrophyllus	-	-	90	25	-	0
Lycopodium obscurum	-	-	62	0[e]	-	0
Trillium crectum	-	-	-	13	-	0
Osmunda Claytonia	-	-	-	13	-	-
Polygonatum biflorum	-	-	-	25	-	22
Thelypteris phegopteris	-	-	36	38	-	67
Potentilla tridentata	-	-	-	0	-	11
Arenaria groenlandica	-	-	-	0	-	11
Veratrum viride	-	-	-	0	-	56

[g] Dropteris spinulosa had a percent occurrence of 100 in both Whiteface stand groups.

number of species (16) not listed for any of the other areas. The Whiteface combined list has only six species not contained on the species lists for the other regions.

Within the woody species group only mountain maple (Acer spicatum) is recorded for all six regions. Three additional genera (Abies, Pyrus and Betula) are found in all regions. At least one species of spruce and one of fir occurs in each region except Wisconsin where no Picea is listed. Several other tree species were found in at least half the areas considered. These are Betula alleganiensis, B. papyrifera var cordifolia, Prunus pensylvanicum, Acer rubrum and Tsuga canadensis. Regions which include the latter species are envisioned as being of a different type of spruce-fir association than on Whiteface. Spruce, fir, and hemlock do occur in stands together in the Whiteface region, but these are low altitude stands of a distinct non-boreal character.

No shrub occurred in more than four of the six regions. Species present in at least three regions were: Vaccinium angustifolium, Nemopanthus mucronata, Sambucus pubens, and Viburnum alnifolium. Genera such as Vaccinium, Ribes, and Rubus were present in most regions, but are difficult to interpret because each contains many species.

Only one (Clintonia borealis) of the 46 herbaceous species listed was reported for all six regions, although several species were found in five of the six (e.g. Maianthemum canadense, Cornus canadensis, Coptis trifolia, Tiarella americana, Aster acuminatus, Dryopteris dilatata, and Oxalis montana). Several other species were confined to only one region. Most of these fall into one of three classes: (1) those native to the undisturbed spruce-fir forest of the Great Smokies (e.g. Aster divaricatus, Senecio rugelia, and Solidago glomerulata), (2) species characteristic of alpine tundra which invaded Whiteface high altitude spruce-fir stands (e.g. Potentilla tridentata and Arenaria groenlandica), and (3) species more characteristic of deciduous or conifer-hardwood forests which may indicate ecotonal conditions in some spruce-fir stands (e.g. Trillium erectum, Athyrium filix-femina, and Osmunda claytonia).

To obtain more generalized comparisons than cursory inspection of Table 1 allows, a summary of region relationships based on percentages of common occurrence of species is presented in Table 2. In the table the row values following a region designation are species that the region has in common with those regions indicated in the column headings. For example, 59% of the Great Smoky species occur in the Catskills, 52% in the White Mountains, etc., while only 50% of the Catskill species occur in the Great Smokies and 69% occur in the White Mountains.

From this table we see that the stands from Wisconsin and the Great Smokies share the lowest percentages of common species. The data further imply that the two most similar regions are the Catskills and the White Mountains. This is because the region having the greatest percent of species occurring in the White Mountains is the Catskills (63%) and the one having the greatest percent of Catskill species was the White Mountains

(69%). This degree of similarity exceeds even that for the two Whiteface stands which are separated by less than a mile as compared to the 150 mi. or more that separate the Catskills and the White Mountains. This can be largely explained by the general paucity of flora that is typically encountered as habitat extremes are approached such as they are when you approach timberline.

Data in Table 2 fail to provide a distinct indication of the relationship of the Adirondack stands to the other regions. The Whiteface Mountain upland stands are least similar to the Great Smoky Mountain stands (42% upland species in Smokies and 43% Smokies species in upland), but are similarly related to the other regions (63-65% upland species found in other four regions). Highland stands were also least similar to the Great Smoky region (24% highland species in Smokies and 31% Smokies species in highland). Values for highland species in the other regions range from 45-55%.

An additional way to evaluate the degree of similarity or dissimilarity of the Whiteface upland and highland stand types with other regions is by comparison of similarity index values. Table 3 shows the relationship of each region to every other region using the percent constance values from Table 1 to determine the a, b and 2w values for computation of the Index of Similarity.

Examination of the degree of similarity of each region on the basis of trees only, shrubs only, and ground flora only, as well as the relationship based on combined values further clarifies the position of the Whiteface spruce-fir in relation to other regions. However, before looking at specific relationships, some general comments about the general relationships seem in order. For example, tree association values run consistantly higher than either shrub or ground flora values with one exception, the White Mountain-Whiteface highland types. In this case the ground flora value was slightly higher, but the shrub value is still considerably lower. In fact, the shrub association values consistantly have the lowest similarity values throughout. The maximum value is .45 (1.00 denotes absolute similarity) in the Catskill-Whiteface upland shrubs, while the Great Smokies-Wisconsin, and Great Smokies-Whiteface highland stands had no shrubs listed in common.

The ordering of the region pairs in Table 3 is probably most indicative of the overall relationship of the spruce-fir forests of the various regions to each other. The idea that the Catskills and White Mountains are most similar floristically as implied in Table 2 is further supported by Table 3. The Catskill-White Mountain regions show the highest value of .67 based on total composition. Once again, this relationship is even closer than that between the Whiteface upland and highland stand types. The value of similarity between these is .62. Only on the basis of trees alone do the Whiteface stands show more similarity to each other than the Catskill-White Mountain ones do, although even in this regard the Catskills and Whiteface uplands show a closer similarity than do the two Whiteface types.

In general the Whiteface Mountain stands show closest relationships to the Catskills, White Mountains, Wisconsin and Great Smoky spruce-fir forests in that order. In all cases the upland stands show a closer affinity to each of the other regions than do the highland stands.

The Wisconsin stands, in general, displayed a weak relationship to each of the other regions. The highest value based on total stand composition was .48 between Wisconsin and Great Smoky stands. By the rank total method the Wisconsin-Catskill association ranks highest of the Wisconsin associations but is still among the weaker relationships in the table. Data from both Table 2 and Table 3 seem to contradict the strong floristic similarity claimed by Curtis (1959) to exist between Wisconsin and Adirondack spruce-fir forests.

In summary it would seem that while all of these regions may well be spoken of as having spruce-fir forests, each is distinct. The distinct character is attributed to the differences in understory species, particularly the shrub layer, although in a few cases even the tree species composition is greatly dissimilar. While it has not been statistically analyzed at this point, there appears to be a general correlation between distances separating regions and values of similarity. For example, Whiteface stands were least similar to those furthest from them, and most similar to those closest.

Only two species were found in all six areas, but ecological equivalents of many species are present. For example, balsam fir is a dominant in the five northern regions and Fraser fir replaces it as a tree dominant in the southern Appalachians. It is likely that the presence of these ecological equivalents, as well as the species shared in common, accounts for the concept of a basic similarity in spruce-fir forests in the eastern United States as reported by Crandall (1958) and Curtis (1959).

In the final analysis it may turn out that the upland and highland spruce-fir forests of the Adirondacks are most closely related to those of the boreal forest of southeastern Canada. Both Cape Breton Island (Collins, 1951) and higher elevations in the Adirondacks are dominated by the same three tree types (balsam fir, paper birch and spruce), and lack northern hardwoods characteristic of ecotonal areas such as the Adirondack lowlands, Catskills, White Mountains, and Wisconsin lake forest.

Table 2: Percentages of species in common between representative areas of spruce-fir forests.

Region and Tot. No. of Spp.		Great Smokies	Catskill Mts.	White Mts.	Whiteface Upland	Whiteface Highland	Wisc.
Gt. Smokies	(38)	-	59	52	43	31	29
Catskills	(33)	50	-	69	54	52	52
White Mts.	(26)	40	63	-	51	57	42
Wf. Upland	(35)	42	63	66	-	66	65
Wf. High A.	(28)	24	47	55	49	-	45
Wisconsin	(30)	24	50	45	54	48	-

Table 3: Comparisons of Spruce-Fir Stands from Whiteface Mountain, the Catskills, the White Mountains, Wisconsin, and the Great Smokies Based on the 2w/a+b Index of Similarity. The order was determined by combining the rank numbers obtained when ordering the areas on values obtained from tree data only, shrub data only, ground flora data only, and from a combination of the tree, shrub and ground flora data.

Areas	Trees		Shrubs		Ground Flora		Total (T,S,GF)		Rank
	Ind. Val.	Rank	Ind. Val.	Rank	Ind. Val.	Rank	Ind. Val.	Rank	Total
Catskills - White Mountains	.73	3	.42	4	.69	1	.67	1	7
Whiteface Upland - Whiteface Highlands	.80	2	.31	4	.58	3	.62	2	11
Catskills - Whiteface Uplands	.84	1	.45	1	.51	8	.61	3	13
Catskills - Whiteface Highlands	.66	4	.23	5	.55	5	.55	5	19
Whiteface Uplands - White Mountains	.64	5	.03	13	.61	2	.59	4	24
Great Smokies - White Mountains	.58	8	.33	3	.52	7	.51	7	25
Catskills - Great Smokies	.58	7	.22	6	.53	6	.49	8	27
White Mountains - Whiteface Highlands	.51	11	.22	7	.58	4	.52	6	28
Catskills - Wisconsin	.52	10	.11	11	.48	9	.45	10	40
Wisconsin - Whiteface Uplands	.50	12	.21	8	.43	10	.43	11	41
Great Smokies - Whiteface Uplands	.54	9	.13	9	.42	11	.41	12	41
Wisconsin - White Mountains	.64	6	.11	10	.33	12	.40	14	42
Great Smokies - Wisconsin	.37	14	.00	15	.20	15	.48	9	53
Wisconsin - Whiteface Highlands	.37	15	.11	12	.22	14	.41	13	54
Great Smokies - Whiteface Highlands	.38	13	.00	14	.26	13	.25	15	55

ACKNOWLEGEMENTS

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SLOPE ASPECT VARIATION IN THE VASCULAR PLANT SPECIES COMPOSITION IN THE TREELESS COMMUNITY NEAR THE SUMMIT OF WHITEFACE MOUNTAIN, N. Y.

By

Stuart Nicholson and Jon T. Scott

Slope Aspect Variation in the Vascular Plant Species Composition in the Treeless Community Near the Summit of Whiteface Mountain, N. Y.

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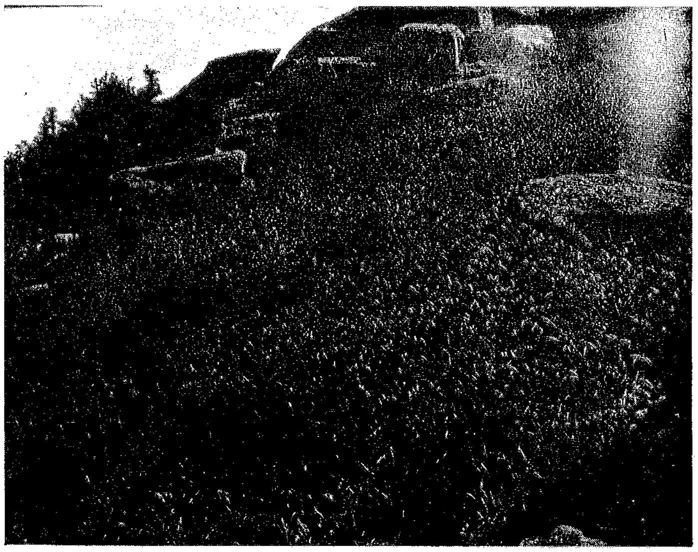
INTRODUCTION

The treeless community near the summit of the 4867 foot high Whiteface Mountain, N.Y. (Lat. 44° 20') endures a rigorous physical environment as well as considerable human disturbance. It has been interpreted as being true alpine tundra by Smith (1964) and as spruce-fir-tundra ecotone by France and Lemon (1963).

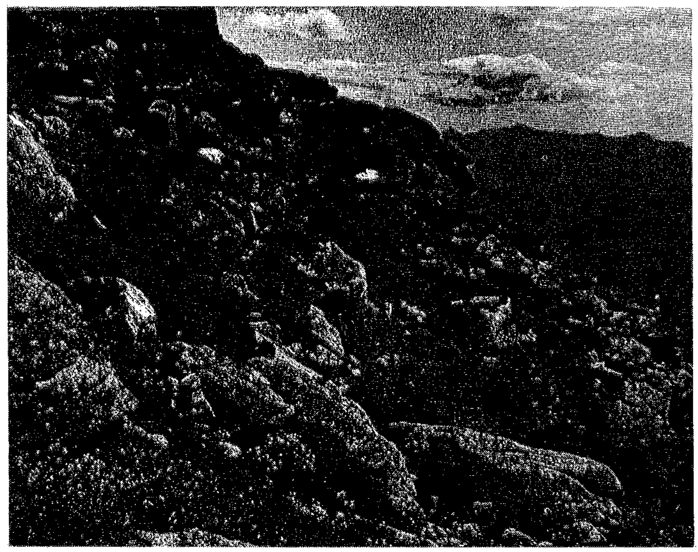
The microclimate at the summit is one of the coldest in the eastern U.S. Only a few higher, or more northerly peaks such as Mt. Washington, N.H. (6288 ft., Lat. 44° 16') or Mt. Katahdin, Me. (5268 ft., Lat. 45° 55') may have colder temperature regimes. Mean monthly temperatures at the summit during the summer range from 48 to 58° F. Mean January temperature is about 8° F.

Mean annual precipitation at Lake Placid (4 mi. S.W. at 1860 ft.) is approximately 39 inches. Total precipitation at the summit exceeds this by about 10 inches due to orographic lifting, but long term records are lacking. Average relative humidity is high, exceeding 70% three-fourths of the days in the normal year (Falconer, 1963, 1964). Condensation on trees during the presence of a cap cloud could yield several inches of precipitation each year. The cool temperatures, abundant precipitation, and high relative humidity result in a high precipitation to evaporation ratio. The summit is capped by clouds on about 40% of summer days and 50 to 70% of days in fall and spring adding to the cool-moist nature of the climate. Strong winds at the summit average 17 to 20 m.p.h. in summer and nearly double this in winter. Frost or rime icing can occur in all months of the year which would indicate a tundra climate but from the temperature data available the summit area is classified as a Dfd type (called humid continental) in the Koppen system. Growing season length near the summit may average about 50 to 70 days compared to 80 to 105 days for the Northeastern Adirondacks reported by Stout (1956) and Feuer et. al. (1963).

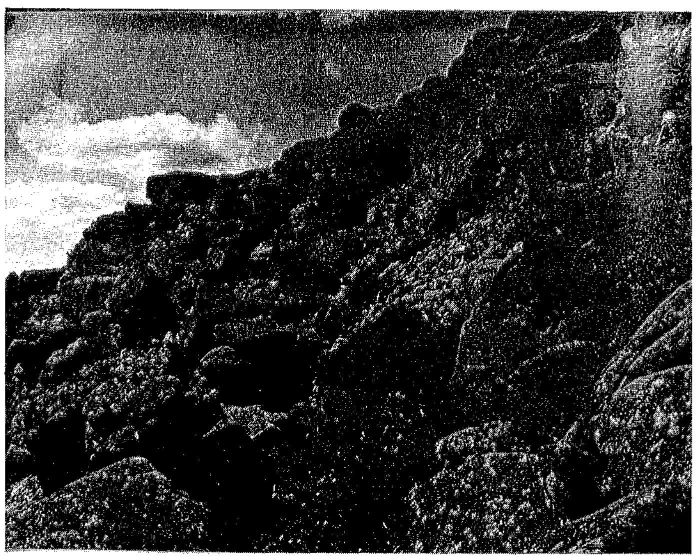
Soils in the Whiteface area were classified by Witty (1968). For the treeless summit he found two units for mapping purposes. One unit included most of the north and east and part of the west-facing slopes of the treeless area. This unit was composed mainly of organic material and was classified as Histosols of either the frigid Sysleptist or frigid Dyssaprist Humodic types. On the south and part of the west slopes of



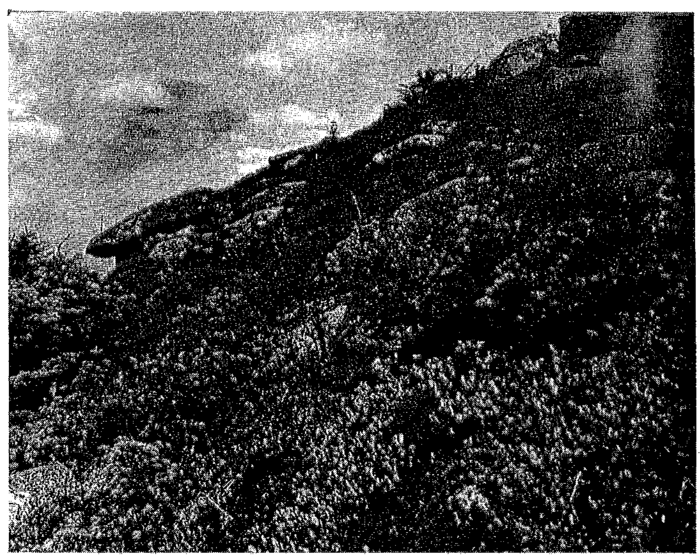
a. East



b. South



c. West



d. North

Figure 1: Pictures of the typical vegetation on the four aspects of the treeless area near the summit of Whiteface Mountain.

the treeless area Witty found a mineral soil which he classified as a Spodosol. He called it a frigid Typic Haplorthod. These soils were found on benches between nearly vertical rock exposures. Most of this south and west area is rock outcrop while the north facing unit was nearly completely covered with vegetation. Pictures of the typical vegetation of the four aspects are shown in Figure 1.

Disturbance by man in the treeless community was probably negligible until the summit became a popular hiking spot in the 1870's (Wallace, 1896), but Watson (1869) mentions a fire of undetermined origin which consumed virtually all the organic matter around the summit during the summer of 1867. Logging operations may have extended up the east side and to near the summit during the 1890's (Rogers, 1964), but the effect of this activity on the treeless community is unknown. Disturbance from visitors increased markedly after 1938 when the paved highway which extends nearly to the summit was completed. Hiking trails, an observation building, and other human impact have resulted in a removal of much of the treeless community. Distribution of exotics such as dandelion, milfoil, plantain, and various introduced grasses appears to closely coincide with the location of regularly disturbed areas, most of which are above 4640 ft.

The purpose of this paper is to report the present vascular plant composition of the Whiteface Mountain treeless community as it is represented on the four major slope-aspects. Further, an attempt will be made to explain the ecological basis of the compositional variations evident on the different aspects.

METHODS

Frequencies of vascular plants were recorded from 40 systematically located 1 m^2 quadrats on each of the four major slope-aspects (N,E,S,W) during the summer of 1964. Many of the specimens were verified by Stanley Smith of the New York State Museum. Nomenclature follows Fernald (1950).

Areas regularly disturbed by man were not included in the sampling. These were recognized from trampling, growth habit of plants, presence of exotics, and observations on the movements of tourists. On the east face, where tree cover extends nearly to the summit, sampling was restricted to treeless areas.

Descriptive data such as slope, slope-aspect, altitude, substrate characteristics, ground cover, and general comments were noted and are filed with the vegetation data.

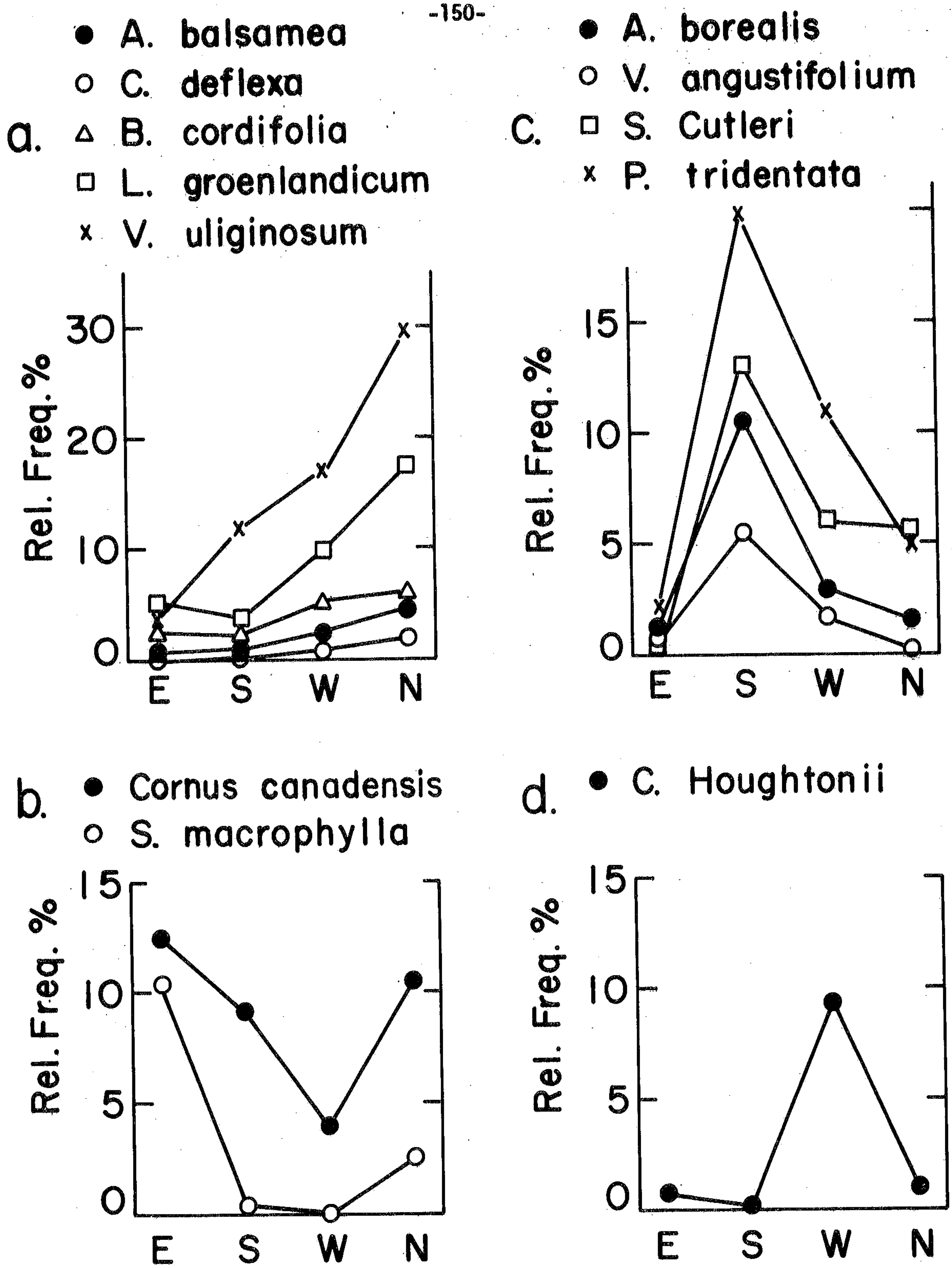


Figure 2: Relative frequency plotted against aspect for the most frequent species on the (a) north (b) east (c) south and (d) west facing aspects of the treeless area near the summit of Whiteface Mountain.

RESULTS

Relative frequencies of vascular plant species at each aspect and for all aspects summarized are given in Table 1. The alpine bilberry (Vaccinium uliginosum) was the most prevalent species overall and was the most frequent species on the north and west aspects. Three-toothed cinquefoil (Potentilla tridentata) was second in overall frequency and was the most frequent species on the south aspect. Next in overall frequencies were bunchberry (Cornus canadensis), Labrador tea (Ledum groenlandicum), and an alpine goldenrod (Solidago Cutleri). All these species are considered to be true tundra species (Woodin, 1959). Bunchberry and blue-joint grass (Calamagrostis canadensis) were co-dominants on the east aspect. Other important species were balsam fir seedlings (Abies balsamea), a goldenrod (Solidago macrophylla) common in nearby spruce-fir forests, a northern bentgrass (Agrostis borealis), and mountain sandwort (Arenaria groenlandica).

Although all species occurring in the treeless community are not tundra species per se, many may be represented by tundra ecotypes (e.g. Calamagrostis canadensis and Rubus idaeus) according to Stanley Smith (Pers. comm). Discontinuous distributions of several of these species on Whiteface Mountain has been discussed by Nicholson (1965) Holway et. al. (1969) and Breisch et. al. (1969).

A detailed floristic comparison with other tundra communities is beyond the scope of this paper, but data are presented with this purpose in mind.

Relative frequency of the twelve most common species is plotted against aspect in Figure 2. These data include all of the species which were found in at least three of the four aspects. Several distribution patterns may be recognized according to relative locations of maxima and minima and slopes of the curves joining relative frequencies. All but three of the twelve species had its highest frequency on north (5 spp.) or south (4 spp.) aspects. Two species had frequency maxima on the east aspect and only one on the west.

The five species (group I) with frequency maxima on the north (Vaccinium uliginosum, Betula papyrifera var. cordifolia, Ledum groenlandicum, Abies balsamea, and Carex deflexa) all had similar distribution patterns (Figure 2a). All except V. uliginosum were least frequent on the south and west, respectively. The latter was least frequent on the east.

Four widely tolerant species (Agrostis borealis, Potentilla tridentata, Vaccinium angustifolim, and Solidago Cutleri) were most frequent on the south aspect (group II). All except V. angustifolium had minima on the east and distribution patterns of all four species were quite similar (Figure 2c). The two major species with maxima on the east (Cornus canadensis and Calamagrostis canadensis) also had similar distributions (Figure 2b). The distributional pattern of Carex Houghtonii, the only species with frequency maximum on the west aspect was not common on any other aspect (Figure 2d).

Table 1: Relative frequencies of vascular plant species on the four major aspects and for all aspects combined in the treeless community of Whiteface Mountain, N.Y.

Species	East	North	West	South	All Aspects
Vaccinium uliginosum	1.2	27.2	16.8	11.7	14.4
Potentilla tridentata	1.6	5.8	11.5	19.8	9.6
Cornus canadensis	11.7	10.9	3.8	8.1	8.8
Ledum groenlandicum	4.8	17.0	11.5	2.0	8.3
Solidago Cutleri	-	6.4	6.2	13.2	6.1
Abies balsamea	2.8	13.6	6.7	1.5	5.6
Agrostis borealis	1.2	1.4	2.9	10.2	4.0
Solidago macrophylla	10.0	2.7	-	0.5	4.0
Arenaria groenlandica	-	-	7.2	6.6	3.6
Betula papyrifera v. cordifolia	2.4	5.8	5.3	1.5	3.6
Vaccinium myrtilloides	8.1	-	-	2.5	3.2
Calamogrostis candensis	11.7	-	-	-	3.2
Rubus idaeus	8.5	-	-	1.0	2.9
Juncus trifidus	-	-	1.0	10.2	2.8
Salix Uva-ursi	-	-	5.7	4.6	2.7
Carex Houghtonii	0.4	0.7	8.6	-	2.6
Lycopodium Selago	-	-	8.6	-	2.3
Vaccinium angustifolium	0.8	-	1.9	5.1	2.0
Gentiana linearis	4.4	2.7	-	-	1.9
Dropteris spinulosa[1]	4.8	-	-	-	1.5
Scirpus caespitosus	2.8	-	0.5	-	1.0
Clintonia borealis	2.8	-	-	-	0.9
Carex deflexa (?)	0.4	2.4	1.0	-	0.8
Spiraea latifolia	1.2	1.4	-	-	0.6
Picea rubens	-	1.4	1.0	-	0.5
Dryopteris Phegopteris	1.6	-	-	-	0.5
Aster acuminatus	1.2	-	-	-	0.4
Fragraria virginiana	1.2	-	-	-	0.4
Coptis groenlandica	1.2	-	-	-	0.4
Pyrus decora	0.8	-	-	-	0.3
Veratrum viride	0.8	-	-	-	0.3
Gaum macrophyllum	0.8	-	-	-	0.3
Achillea millefolium	-	1.4	-	-	0.3
Prenanthes Bootii	-	-	-	1.0	0.3
Maianthemum canadense	0.8	-	-	-	0.3
Gramineae sp.	0.8	-	-	-	0.3
Alnus crispa	0.4	-	-	-	0.1
Aralia nudicaulis	0.4	-	-	-	0.1
Linnea borealis	0.4	-	-	-	0.1
Amelanchier sp.	0.4	-	-	-	0.1
Prenanthes trifoliata	0.4	-	-	-	0.1
Carex Bigelowii	0.4	-	-	-	0.1
Poa palustris	-	0.7	-	-	0.1

[1] Thought to be a hybrid of D. spinulosa and another Dryopteris species (Smith, pers. comm.)

Table 2: Relative frequency and number of species in vascular plant families for the four aspects and for all aspects combined in the treeless community of Whiteface Mountain, N.Y.

Family	East		North		West		South		Total	
	No.	R.F.	No.	R.F.	No.	R.F.	No.	R.F.	No.	R.F.
Lycopodiaceae	-	-	-	-	1	8.6	-	-	1	2.6
Polypodiaceae	2	6.5	-	-	-	-	-	-	2	2.3
Pinaceae	1	2.8	2	14.9	2	7.7	1	1.5	2	6.7
Juncaceae	-	-	-	-	1	1.0	1	10.3	1	3.1
Cyperaceae	3	1.2	2	2.7	2	9.6	-	-	3	3.9
Gramineae	4	14.9	2	2.0	2	3.3	1	10.3	5	9.6
Liliaceae	3	4.4	-	-	-	-	-	-	3	1.6
Carophyllaceae	-	-	-	-	1	7.2	1	6.6	1	4.0
Salicaceae	-	-	-	-	1	5.3	1	4.5	1	3.0
Corylaceae	2	3.5	1	5.4	1	5.3	1	1.5	2	4.1
Ranunculceae	1	1.2	-	-	-	-	-	-	1	0.4
Saxifragaceae	1	7.7	-	-	-	-	1	0.5	1	2.8
Roxaceae	7	14.5	2	6.9	1	11.5	2	20.8	7	15.8
Araliaceae	1	0.4	-	-	-	-	-	-	1	0.1
Cornaceae	1	11.7	1	10.9	1	3.8	1	8.1	1	9.8
Ericaceae	4	14.9	2	44.1	3	30.1	4	21.3	4	29.6
Gentianaceae	1	4.4	1	2.7	-	-	-	-	1	2.1
Caprifoliaceae	1	0.4	-	-	-	-	-	-	1	0.1
Compositae	3	12.1	3	10.2	1	6.2	3	14.7	5	11.5

All but one of the major group I species with maxima on the north were woody perennials, and only one woody species (V. angustifolium) was not most frequent on the north. This would suggest that conditions for woody shrub growth are best on this aspect. The lack of Vaccinium uliginosum on the east, and prevalence on south, north and west aspects indicates a wide tolerance to contrasting microenvironments, but an inability to compete with the many species growing on the east facing slopes. Species in group I show an affinity for cold, moist sites, based on their distribution patterns over the aspect gradient.

The three species in group II (Figure 2c) with essentially similar distribution patterns are all considered to be true tundra species (Woodin, 1959); the fourth, Vaccinium angustifolium, is not. This group includes all tundra forbs which occurred on every aspect. Species in group II withstand the greatest extremes of temperature, transpirational stress, and lowest moisture levels, yet are apparently least able to compete on the densely covered east and north aspects.

Figure 3a includes two light-intolerant forbs which normally are found in the understory of the spruce-fir forest (Nicholson, 1965). These are most prevalent on the east and north aspects and least so on the south and west ones. The latter is apparently also least favorable for spruce-fir forest species.

The distribution pattern of Carex Houghtonii (Figure 2d) suggests that this species has a low competative ability, but can withstand the rigorous windswept climate of the west exposure. On the other hand, the many species confined to the east (Table 1) apparently have little or no tolerance for the extreme condtions found on the south and west aspects. Many of these species are characteristic of the spruce-fir forest.

Of the 43 species recorded in the treeless community, 25 (58%) were most frequent on the east. In all, 34 species were found on the east aspect, at least twice the number found on any other aspect. In contrast to the east, only four of the 43 species (9%) were most frequent on the west aspect.

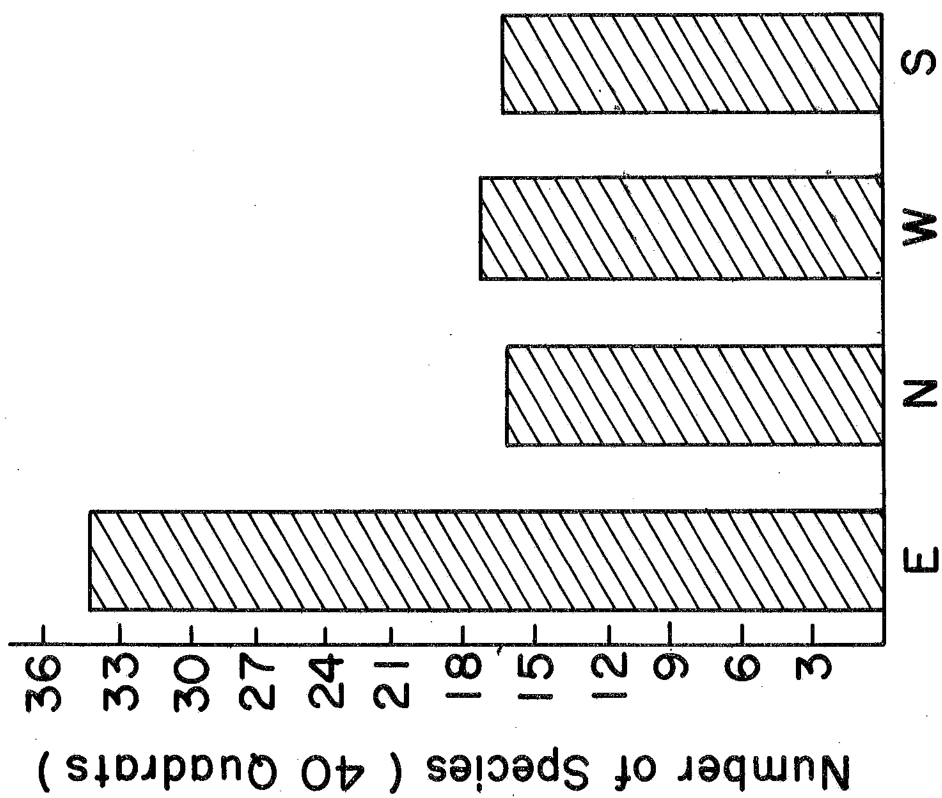
Twenty-one species were restricted to only one aspect. Of these, 17 were on the east aspect. The other four were: Poa palustris and Achillea millefolium (north), Prenanthes Bottii (south), and Lycopodium Selago (west). All have been observed on the east, but were not found within the quadrants sampled.

The absence of Poa palustris and Achillea millefolium on the south and west aspects, where bare soil areas are common, may be indicative of more severe growth conditions than on the east and north facing slopes. These are adventive species whose distribution does not necessarily reflect natural microenvironmental conditions, since they are often confined to disturbed areas. All 17 species which were restricted to the east aspect have strongest affinities to the spruce-fir or other forest types in the Whiteface Mountain area (Nicholson, 1965).

Figure 3: Area-based species diversity of the four aspects (page 156).

Figure 4: Average number of species per family on the four major aspects (page 157, left).

Figure 5: Average frequency per species in the 40 quadrant samples of the four aspects (page 157, right).


Number of Species (40 Quadrats)
36
33
30
27
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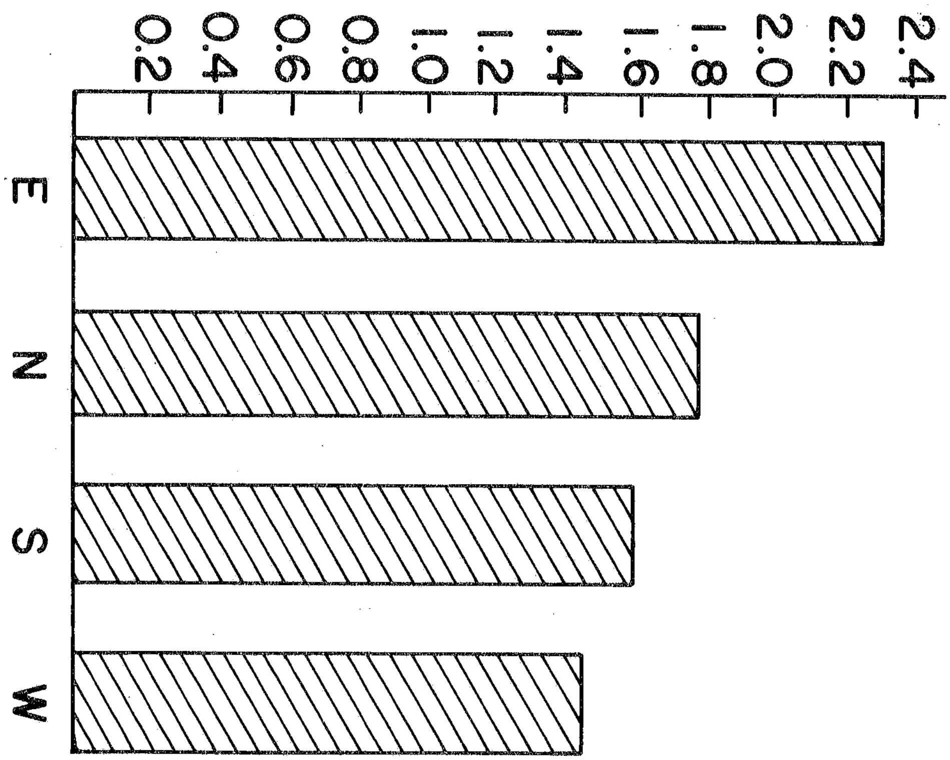
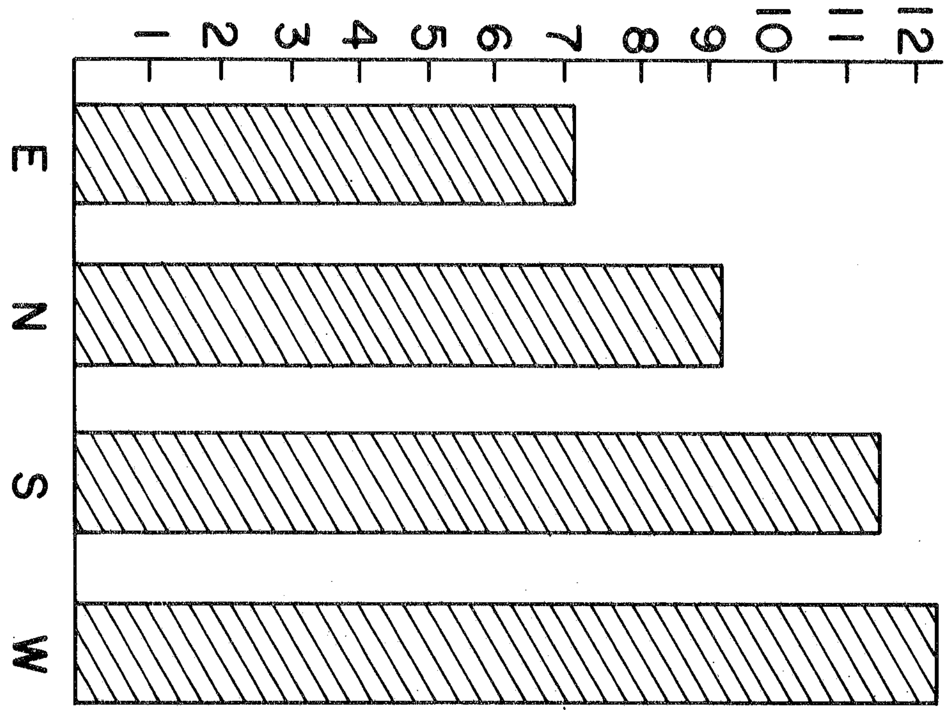
Average Number of Species Per Family



Average Frequency Per Species in 40 Meter Q



The relative importance of plant families estimated by summing the relative frequencies of component species is shown in Table 2. The Ericaceae was the dominant family in the treeless community with total relative frequency of 29.6%. It was the most important family on all four aspects. Its prevalence in tundra has often been reported (Oosting, 1958). Rosaceae was second in total relative frequency (15.8%), and was also common on every aspect but the north one. Three other families exceeding 7% in overall relative frequency were the Compositae (12.4%), the Graminea (9.6%), and the Cornaceae (9.8%). Cornaceae is only represented by one species, Cornus canadensis, while each of the other families which exceeded 4% in overall relative frequency were represented by at least two species.

The high prevalence of Rosaceae is not typical of most alpine tundra regions. The occurrence of several spruce-fir species on the east and Potentilla tridentata elsewhere accounts for its high value. Compositae, Gramineae, and Caryophyllaceae are frequently more characteristic families in tundra regions (Oosting, 1958).

Interesting relationships between family phylogenetic standing (after Fernald, 1950) and their distribution over the aspect gradient were indicated by the data. All 10 of the most advanced families recorded from the treeless community of Whiteface were present on the east aspect. Seven of the nine most advanced families were also most frequent on the east slope. In contrast five of the ten primitive families had maxima on the west, while none of the nine advanced families were most frequent on the west. This suggests that the more primitive vascular plant groups are tolerant of more rigorous environments such as are found on the west and south, but are intolerant of competition from the many species which can grow in the more favorable environment on the east aspect.

The total number of species for the four aspects are given in Figure 3. It is evident that from this area-based measure that species diversity was greatest on the east with little variation on the other three aspects. The east also had the highest species diversity when using a measure based upon number of species per family shown in Figure 4. Average number of species per family was lowest on the west and south. When the four aspects were compared for diversity expressed as total frequency of species divided by the total number of species, the east was again the most diverse as shown in Figure 5, followed in order by the north, south and west aspects.

DISCUSSION

From the evidence presented in Figures 3 thru 5 and also Tables 1 and 2, it is clear that the vascular flora of the east aspect is more diverse than that of any other aspect in the treeless community of Whiteface Mountain. Floristically the east aspect must be regarded as an ecotone, while that on the other three aspects may be more properly considered as true tundra. The species associations and diversity measure suggest spruce-fir grades into tundra from east-north-south-west. This is in close agreement with forest-slope aspect relationships described by Holway et. al. (1969).

On Whiteface Mountain the best developed soils are found on the east aspect. Soils on the west and south are thin and rocky. These unfavorable substrate regimes could account in part for the lack of vegetation and species found on these aspects. However, it is still probable that a rigorous microclimate permits the survival of only tundra species. The south and west aspects should have greater temperature extremes than either the east or the north aspects, and should also be drier. Thin soils and exposure to strong prevailing winds should result in more transpirational stress on south and west sites than on east and north aspects.

In summary, the less favorable microclimatic conditions prevailing on the south and west aspects is thought to be a major cause of species composition in the treeless community of Whiteface. Milder environmental conditions on the east aspect allow for the development of a more diverse flora which is "ecotonal" between spruce-fir and tundra. Increasing environmental stress with change in aspect results in a shift to more tundra-like vegetation which reaches its maximum development on the west aspect.

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ECOLOGICAL EFFECTIVENESS OF YELLOW BIRCH IN SEVERAL ADIRONDACK FOREST TYPES

By

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ABSTRACT

The ecology of yellow birch (Betula alleghaniensis) in certain forest types of the Adirondacks was studied by means of vegetational analysis of forested stands. Sampling data provided information on the size, distribution and reproduction of yellow birch in these forest types. Optimal ecological effectiveness was demonstrated in those forest types characterized by moist sites. In forests of the red spruce-yellow birch type, a competitive advantage was shown by yellow birch as a result of successful establishment of seedlings.

INTRODUCTION

Yellow birch (Betula alleghaniensis Britton), a species of the northern forests, has received passing notice in numerous investigations but has been of primary concern only recently. Special attention is justified by its economic importance and because it appears to be in decline in many areas. Yellow birch is considered the third most important hardwood, economically, in New York, first in importance in New Hampshire (Gilber 1960) and first in the Great Lakes area (Jacobs 1960). Nevertheless, this species has been decreasing in numbers in many areas due to "birch dieback" (Leak 1961) and poor growth or poor regeneration following cutting (Fraser 1956, Godman and Krefting 1960, Jarvis 1957).

Much research is presently being conducted in the Great Lakes Region and in northeastern United States including the Adirondacks. Although there is some current literature concerning yellow birch, mainly published by the U.S. Forest Service, the emphasis is often placed on studies of economic value and management. Ecologists, attempting to define the environmental niche of this species, have disagreed as to the physical, chemical and biological parameters determining its requirements for optimum success (Godman and Krefting 1960, Fraser 1956). It is important to obtain precise information on the regeneration, germination and growth characteristics of yellow birch.

Ecologically oriented research has been done by Winget, Cottam and Kozlowski (1965) who have studied species association and seedbed conditions for germination of yellow birch seed in Wisconsin. Stearns (1951) examined the role of yellow birch in a climax sugar maple-hemlock-yellow birch forest. These investigators conclude that yellow birch, although appearing in the climax, is a true gap-phase species normally dependent upon disturbance in the forest for regeneration. Godman and Krefting (1960), working in Michigan, studied some of the factors important to yellow birch establishment. Winget and Kozlowski (1965) also studied germination and seedling growth of yellow birch. All agreed that germination and establishment were poorest on undecomposed organic material and leaf litter. Godman and Krefting found that the best seedbed was one of mixed organic and mineral soil,while Winget and Kozlowski found that peak germination and establishment occurred on intact humus over mineral soil. Neither offered specific reasons to explain these observations. Tubbs and Oberg (1966), finding that height growth of yellow birch was best in a mixture of organic and mineral soil in a 1:1 ratio, concluded that this type of substrate offered the most favorable moisture conditions.

Statements by the above authors appear to apply to conditions existing around the Great Lakes, but studies and observations of yellow birch in the Adirondacks and much of the northeast are not always in agreement with these midwestern studies. Studies of the vegetation of the Adirondack region (France and Lemon 1963, Scott and Nicholson 1964, Kujawski and Lemon 1967) have indicated that yellow birch is indeed a strong competitor and seems to have a more important role in the climax than attributed by the authors of the Great Lakes studies.

The study described here represents an effort to examine some of the features of sites where yellow birch is growing and to determine the ecological effectiveness of yellow birch in certain forest types of the northern forest and of the Adirondack region in particular. The importance of some environmental factors determining effectiveness is briefly discussed.

The ecological effectiveness of yellow birch is assessed from the importance values calculated for it in the forest type concerned and from data on regeneration. The figures included were obtained from two regions of the Adirondacks. The first was in the area of Whiteface Mountain, typical of the rugged and mountainous portion of the Adirondack region (Figure 1). The second was around Cranberry Lake, less mountainous, but hilly and in the western portion of the region.

GEOGRAPHY

The Adirondacks exist over underlying formations of igneous and metamorphic rocks (Cressey 1966). The upland areas of the Adirondacks consist of a domed Pre-Cambrian erosion surface with the erosional remnants, monadnocks, forming high and rugged peaks such as Mount Marcy and Whiteface Mountain. The prevailing rock base is crystalline, resembling that of the Canadian shield. As a result of intense glaciation, most of the original soil has been removed and land surfaces smoothed

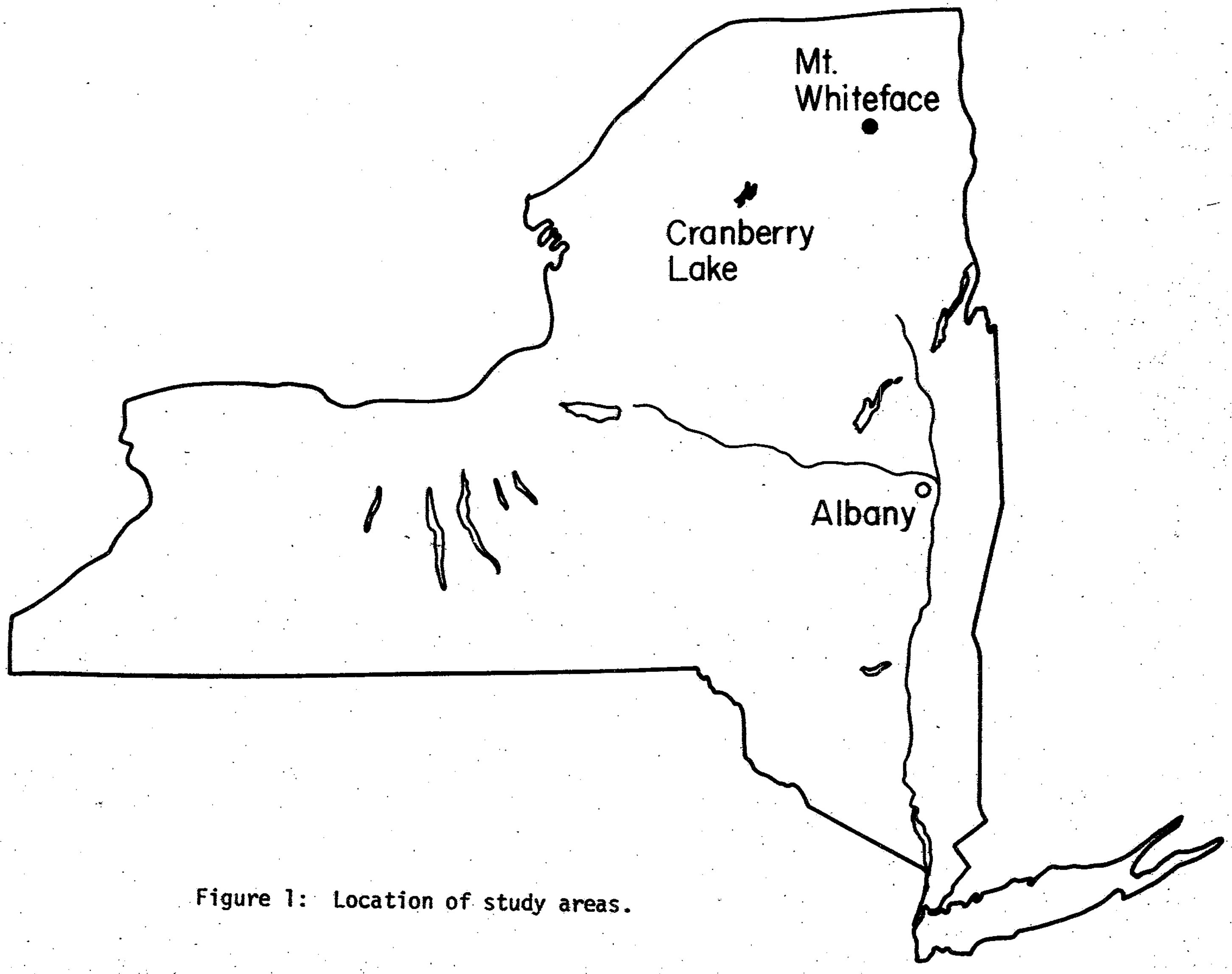


Figure 1: Location of study areas.

filling valleys with gravel, sand and silt. Some of the eroded material has clogged the preglacial valleys, upsetting drainage patterns and producing numerous lakes. Lacustrine deposits occur around the margins of the upland. The area around Cranberry Lake is in part covered by sandy lacustrine deposits laid down in glacial lakes.

Soils are typically shallow and acid on glacial till over steep terrain (De Laubenfels 1966). The effect of the glaciation has been to create stony conditions and to influence drainage patterns often creating poor drainage in many areas. The overall result is soils with extreme acid conditions, shallow profiles, rockiness and poor drainage.

High in elevation, the general climatology of the Adirondacks is cool and moist (Carter 1966). The usual number of frost-free days during a year ranges from 85 to 140 days. Annual precipitation is about 40 to 44 inches (1 to 1.1 m.), the wettest portion of the state. Snowfall ranges from 90 to 165 inches (2.3 to 4.2 m.) per year. The winters are cold with a mean January temperature of about 15 degrees F. (-9 degrees C.) and summers cool with a mean temperature of 65 degrees F. (18 degrees C.).

VEGETATION

The Adirondacks are in the vegetational domain referred to as the Hemlock-White Pine-Northern Hardwoods Region according to Braun (1950). She divides the vegetation of the Adirondacks into four major types defined by different topographical situations. These are the swamp forests, spruce flats or mixed woood, the hardwood forest and the spruce slope. Swamp forest occurs in the wet lands, partially filled depressions and low spots around streams and lakes. The major species occupying this type are red spruce, yellow birch and balsam fir. The second type inhabits moist lower slopes and rolling flats in valleys and around lakes. Spruce and yellow birch are the dominant species. The hardwoods occur on well drained benches and gentle slopes over deep soil. Again, red spruce dominates with beech, sugar maple and yellow birch high in density. The spruce slope is characterized by steep and rugged mountain slopes with thin soil. Spruce, yellow birch and beech are the leading species. Overall, Braun estimates yellow birch to be the second leading species in total density behind red spruce throughout the Adirondack region. Further consideration will be given to the observations of Braun and to these forest types later.

METHOD

There were two principal steps in the collection of data. The first phase was concerned with estimating stand structure or composition. A combination of methods was employed in gathering data. A 30 Basal Area Factor (BAF) forester's prism was used to estimate basal area (Bruce 1955).

Density data were obtained from 1/80 hectare circular plots. Frequency data were obtained by the quarter method since it was felt better resolution of frequency of species could be obtained by this method over that of the plot method (Lindsey, Barton and Miles 1958). The field procedure was to locate stands in which yellow birch appeared to be a prominent member. A starting point of sampling was arbitrarily selected by tossing a rod over a shoulder, the point for sampling being where the rod landed. All subsequent sampling points were at 20 paces (about 15 m.) from the previous point following a compass line so that a grid of points was established.

Basal area, density and frequency were converted to relative values following the procedure of Curtis and McIntosh (1951). The sum of relative basal area, relative density and relative frequency thus gave a value called importance value (IV) of a given species in the stand under study. Importance values here are relativized (RIV) and thus presented on a basis of 100%.

Using RIV as a measure of predominance, each stand, after careful examination, was then placed under the appropriate forest type. The forest types used for this grouping are defined by the Society of American Foresters for Eastern North America (1954). A total of 40 stands were grouped in this manner. The following criteria were used for accepting or rejecting a stand for analysis. First, yellow birch must have a relative density of at least 10% in the stand. This is to eliminate stands were yellow birch may have occurred only as an incidental. Secondly, the stands must be fairly homogeneous without signs of recent or gross disturbances.

The 40 stands finally accepted were grouped under four forest types which seemed to include all these stands. These were types 5, 24, 25, and 30.

Type 5 is dominated by balsam fir with yellow birch as one of the associates on moist upland but flat sites. Only one stand was found to fit into this type and care must be taken when interpreting results. Except in the zone just below timberline, this type is considered to be subclimax.

Type 24 is dominated by hemlock and yellow birch with sugar maple and beech among the associates. In the Adirondack region this type is found most often on moist flats or on north slopes. Stands found to fit this type were all on north facing gentle slopes. Considered to be a subclimax type, over long periods of time it may give way to hemlock or to sugar maple-beech-yellow birch on drier sites. It is in such situations that yellow birch has been found by many investigators to have achieved maximum development (Winget et al. 1965, Stearns 1951). Four stands were placed in this type.

Type 25, the sugar maple-beech-yellow birch type, included most of the stands sampled as might be expected since this is the most frequent type in the Adirondack region. Twenty-five stands seemed to fit into this type. The major associates were red maple and red spruce which occasionally reached high importance values. These stands, usually on more moist sites, may be considered as variant types though not acutally fitting any of the designated types given by the Society of American Foresters. These two species may be viewed as indicators of moist situations or areas of shallow soil (Braun 1950). Yellow birch does not seem to be affected in any consistent manner by increase or decrease in RIV of either or both of these species. Type 25, at least on more mesic sites, may be considered as climax.

Type 30, the red spruce-yellow birch predominant stands, have balsam fir, red maple, beech and sugar maple as associates. Found on lower slopes and moist well-drained flats, this type is probably climax on moist sites. This type may often be referred to as a yellow birch type, but the decline of yellow birch has been so great that pure yellow birch stands are rare and are no longer recognized as a separate type. One stand did have a high RIV for yellow birch, 61%, but since red spruce was of minor importance, 1%, the stand had to be typed with the sugar maple-beech-yellow birch type where sugar maple and beech had RIVs of 8% and 14%, respectively, justifying classification as type 25. This may well be a transition between type 25 and type 30. Braun who further subdivided this type into several spruce types (mentioned earlier) discusses McCarthy's (1920) view that the demarcation between mixed wood type (type 30) and hardwood type (type 25) may be where beech appears and balsam stops. This was taken into consideration when judging into which types sampled stands were to be placed.

To understand development of yellow birch in the various types both as individuals and in terms of total development per unit area, data are presented in terms of basal area per tree and basal area per acre. Regeneration characteristics are examined by calculating the relative frequency of saplings and seedlings in each stand. Sapling data were collected by the quarter method whereas seedling counts came from square meter plots.

The second major aspect of this study was the collection of data on the environmental factors that might be determining the importance and effectiveness of yellow birch on different sites. To assess the importance of these factors, two stands, varying in composition, but adjacent to each other were selected for this comparative study.

The stands selected are in a small valley south of Whiteface Mountain. The first site is at an elevation of 1950 ft. (594 m). The slope of the land is slight with the valley running in a south-west to north-east aspect. Slightly higher, 2044 ft. (623 m) on the average, the second site is situated on a slope of about 10°. The slope aspect is north to north-west. On either side of the two sites are small ridges.

The appearance of the topography suggested that this valley may have been a river valley, the river having been cut off by the continental glacier. As there are many large, rounded boulders and a profusion of shallow streams and of dry stream beds both on and under the surface of the forest floor, it would seem reasonable to arrive at this conclusion. The second site does not have as many boulders or streams, but lies south of the first site almost in line with the proposed direction of the river (Craft 1966, personal communication). It may be that some of this area had been filled with glacial till.

The first site was quite flat and poorly drained as standing water was frequently observed in areas of the stand. The second site, on the other hand, appeared to have good drainage.

The nature of vegetation in these stands was calculated from field sampling data. One tenth acre square plots were set up, five in each stand. These figures gave values for the basal area per acre and density per acre for the tree species. Trees were taken to a minimum dbh (diameter at breast height) of 4 in. as was true of the sampling of the sampling of stands for forest type analysis. Sapling data and seedling data were collected by the procedure given above.

In each stand an instrument shelter was installed containing a hygrothermograph, maximum-minimum thermometer and two alcohol thermometers. These were for the purpose of observing not only ranges of temperature and humidity during the short term of the study, but also to observe any differences in these factors between the two sites. Instruments were frequently checked for accuracy with a sling psychrometer. Within the same stand there may be differences in temperature and humidity due to variations in crown density or canopy. Major differences between the two sites therefore would have more meaning when considering any discrepancy in microclimate. Humidity and temperature readings were taken throughout each of the stands in order to note the degree of variation within a stand.

Selected characteristics of the soil in each stand were examined. Soil moisture was measured using a lawn moisture meter (electrical meter). The sensitivity of the meter was increased by connecting a potentiometer to the simple circuit and replacing the original meter with a more sensitive ammeter. Because ionic features of the soil would have an effect on the readings obtained by a meter of this sort, only relative measurements are obtained. Actual soil moisture was measured by oven drying samples of soil collected at each site. Soil temperatures were taken using dial thermometers inserted to a depth of 20 cm. Samples of readings were taken at each of the sites.

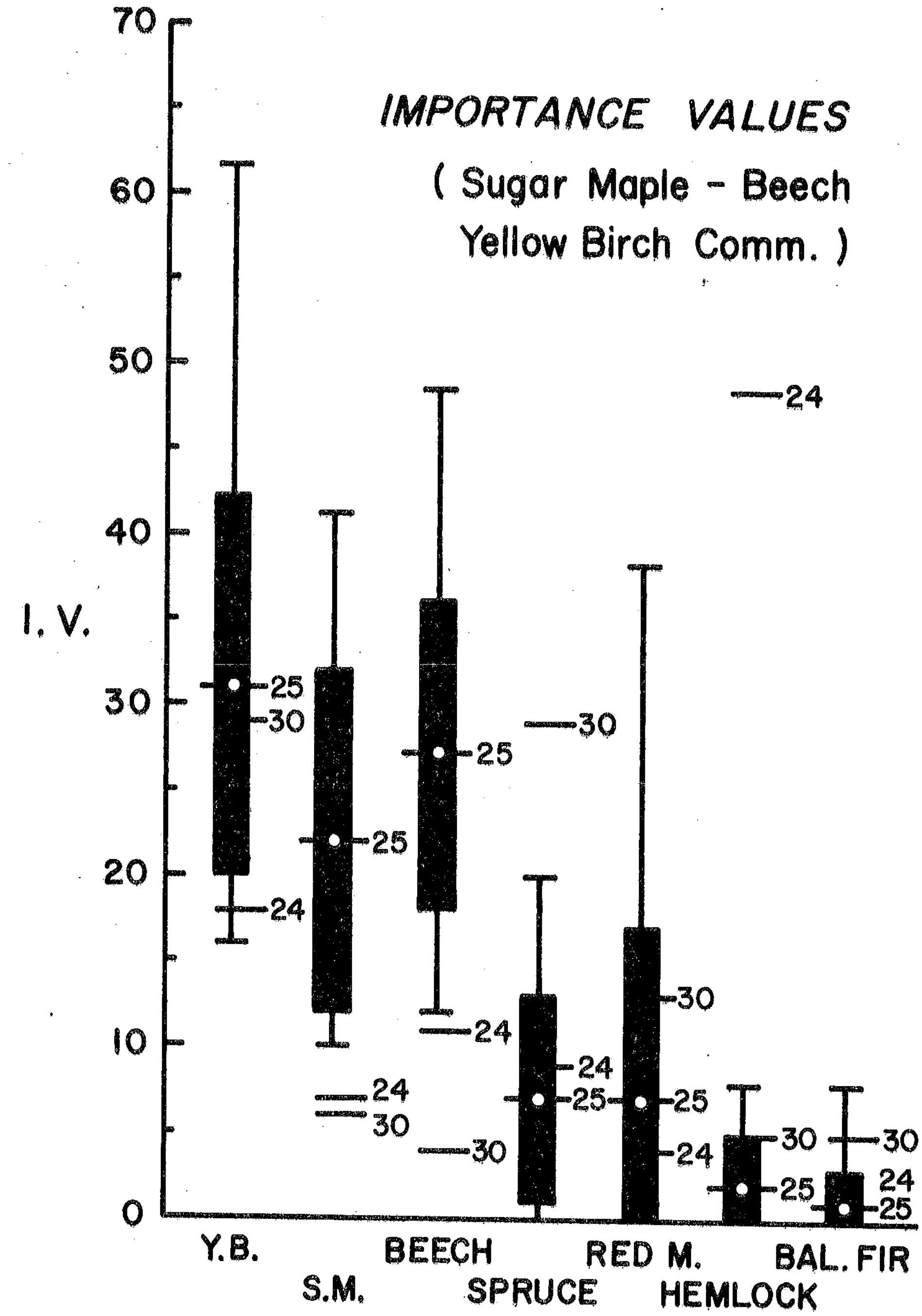
Soil texture was measured by sifting oven dried soil samples through a series of soil sieves. The mesh diameters of the sieves were checked using a stereo zoom scope. The mesh diameters were found to be 1mm., .7mm., .25mm., and .12 mm. Soil particles were classified as follows:

Table 1: Summary of importance values for major species in each stand.

Stand Number	Yellow Birch	Sugar Maple	Beech	Red Maple	Hemlock	Spruce	Balsam Fir
TYPE 5:	Balsam Fir						
182	21			1		22	47
TYPE 24:	Hemlock - Yellow Birch						
123	13	4	12	5	56	8	1
173	18	7	10	1	48	11	
125	19	9	18		49	5	
172	20	9	5	8	38	10	
Mean	18	7	11	4	48	9	—
TYPE 30:	Red Spruce - Yellow Birch						
83	19	20		4		41	1
135	20		8	13	18	29	10
85	21	4	5		2	51	
15	26	9		34	9	18	
106	27	1			6	45	10
164	33					31	12
128	32	1	3	12	8	26	13
14	33	5	11	37	6	5	1
107	41	10	10		3	22	7
3	40	6		29	1	22	
Mean	29	6	4	13	5	29	5
TYPE 25:	Sugar Maple - Beech - Yellow Birch						
149	16	31	29	1	7	14	1
97	19	12	22	9	5	20	8
19	20	35	32	5	3	5	
156	20	25	13	38			1
11	22	16	32	27	1	2	
18	20	39	34	3	2		
4	23	12	48		4	13	
87	23	41	21			13	
159	24	10	40	3	8	9	3
9	28	10	27	20		14	
5	30	27	32	2	2	1	
71	30	23	30	1		9	
12	29	16	23	21	7	2	
109	32	15	33			15	2
7	33	33	30			2	
1	34	34	25			4	
105	35	20	25			19	1
131	37	16	35			9	1
84	37	30	12			7	
6	42	11	35	1	3	7	1
2	41	35	16	1			
16	46	11	18	13	2	5	
130	52	13	12	10		6	5
17	61	10	14	12		2	1
Mean	31	22	27	7	2	7	1

Table 2: Summary of basal area data of yellow birch and topographic data in each stand.

Stand Number	Sq. In. Per Tree	Sq. Ft. Per Acre	Elevation (feet)	Slope (degrees)	Slope Aspect
TYPE 5:	Balsam fir				
182	53.4	30.0	2650	16	29
TYPE 24:	Hemlock - Yellow Birch				
123	133.4	22.5	1720	4	200
173	209.7	49.5	1575	3	257
125	166.7	30.0	1780	4	126
172	172.6	33.0	1615	3	76
Mean	170.6	33.8			
TYPE 30:	Red Spruce - Yellow Birch				
83	57.2	18.0	2560	28	164
135	147.4	42.0	1640	1	29
85	109.1	27.0	2320	24	248
15	155.5	46.8	1550	15	300
106	92.1	43.5	2200	17	240
164	211.9	81.0	2520	11	125
128	116.2	54.0	1500	5	321
14	90.7	45.0	1500	8	302
107	107.3	70.0	1980	9	246
3	56.2	41.8	1500	6	278
Mean	114.4	46.9			
TYPE 25:	Sugar Maple - Beech - Yellow Birch				
149	228.6	36.0	1710	2	36
97	138.7	39.0	2000	15	268
19	92.2	20.3	1650	12	329
156	76.2	24.0	1660	6	131
11	161.3	34.5	1500	8	180
18	77.8	18.0	1700	6	142
4	73.4	26.2	1500	8	207
87	175.3	34.5	2550	7	243
159	317.6	50.0	1620	11	248
9	128.2	42.2	1700	13	327
5	100.8	36.0	1500	12	309
71	154.7	51.0	1920	10	54
12	118.1	45.7	1500	17	124
109	171.2	68.0	1950	5	161
7	190.1	45.0	1450	19	16
1	105.5	47.8	1480	18	8
105	126.0	68.0	2180	22	182
131	146.4	67.5	2044	8	316
84	239.3	73.2	2450	25	18
6	123.8	61.4	1500	7	270
2	57.6	39.7	1450	9	259
16	70.6	50.2	1500	19	22
130	106.5	71.3	1954	2	---
17	70.6	62.9	1600	9	11
Mean	133.6	46.3			


IMPORTANCE VALUES
(Sugar Maple - Beech
Yellow Birch Comm.)
I. V.
70
60
50
40
30
20
10
0
Y.B.
S.M.
BEECH
SPRUCE
RED M.
HEMLOCK
BAL. FIR
25
30
24
25
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30
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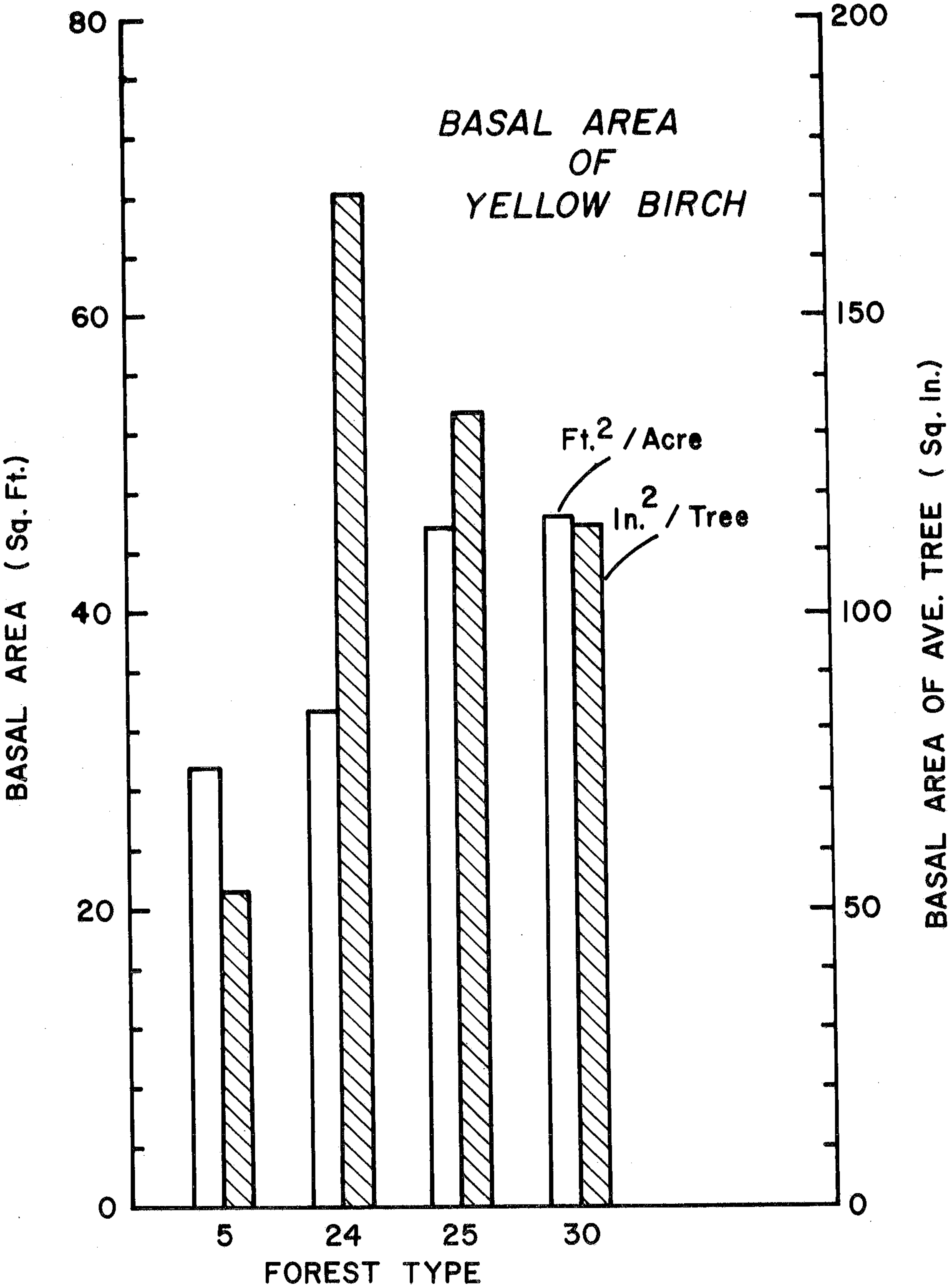
25



BASAL AREA OF YELLOW BIRCH
BASAL AREA (Sq. Ft.)
BASAL AREA OF AVE. TREE (Sq. In.)
Ft.2 / Acre
In.2 / Tree
0
20
40
60
80
0
50
100
150
200
5
24
25
30
FOREST TYPE

1 mm and greater .....gravel
.70 mm-1.0mm ....coarse sand
.25 mm-.70mm ....medium sand
.12 mm-.25mm ....fine sand
less than .12 mm .....silt and clay

A soil borer was used to take cores for the purpose of noting the depth of organic material in each stand. Soil samples were collected and placed in small vials for transport to the field station where pH analyses were made. Difficulty with electrical pH meters resulted in the use of pH paper to determine the pH. A mixture of 50% soil and 50% distilled water was made for each sample and the pH recorded to a range of .5 (e.g. 4.0-4.5).

RESULTS

Stand Composition:

Tables 1 and 2 present a summary of the stands sampled and used in this analysis. The RIVs for the major species in each stand are given as well as the mean elevation, slope and slope aspect. Basal area in terms of mean basal area per tree and the mean basal area per acre are given for each stand. Figure 2 represents the mean RIVs of the major species of stands grouped under their respective forest type. Only the species which achieved a RIV of 10% in one or more of the stands are presented. It is of interest to see whether there is appreciable variation in RIV of yellow birch from one type to another. Of the three main types considered, it seems as if yellow birch attains its highest mean RIV in type 25 and also the highest individual RIV as noted from the range (Table 3). It is somewhat surprising that the mean RIV of yellow birch in the spruce-yellow birch type is very similar to that of the maple type and is not very high in the hemlock-yellow birch. The range of RIV for yellow birch in type 25 is greater than that for the spruce type. The implications will be discussed later.

Basal Area:

Defining ecological effectiveness in terms of basal area may add more meaning to RIVs presented for yellow birch and may help resolve the question of optimal effectiveness. The data, as summarized in Figure 3 or from Table 2, indicate total basal area per acre is greatest in the maple and spruce types, but the best average development per tree occurred in the hemlock-yellow birch as has been observed by many investigators (Winget et al. 1965, Stearns 1951). The low basal area per acre for yellow birch in the hemlock type indicates a low density for yellow birch. Development of individual trees in spruce types is quite good though not the best.

Regeneration:

Tables 4 and 5 summarize the data on sapling and seedling relative frequencies for each stand under the appropriate forest type.

Table 3: Summary of importance values for yellow birch in four forest types (Soc. Amer. Foresters classification).

Forest Type	S.A.F. Code	No. Stands	Mean RIV	Range	Standard Deviation
Sugar Maple-Beech-Yellow Birch	25	25	31	16-61	11
Red Spruce-Yellow Birch	30	10	29	19-41	8
Hemlock-Yellow Birch	24	4	18	13-20	3
Balsam Fir	5	1	10	---	--

Table 4: Summary of % frequency of saplings for major tree species in stands sampled.

Stand Number	Yellow Birch	Spruce	Beech	Sugar Maple	Red Maple	Hemlock	Balsam Fir
TYPE 5: Balsam Fir							
182	10	17			2		47
TYPE 24: Hemlock - Yellow Birch							
123	3	15	18	3		40	
173		8	8	6		38	6
125		26	37		3	15	2
172		3	8	24	8		13
Mean	T	13	18	8	3	23	5
TYPE 30: Red Spruce - Yellow Birch							
83	9	24		22	4		20
135	2	34	7	3	5	3	25
85	16	12	2				17
15	15	19	2	2	29		
106	11	27	2	5			2
164	9	20	2	2			7
128	12	35	6	6	6		29
14	15	16	30	18	15		
107	9	12		7			8
3	17	17	17	18	27		
Mean	12	22	7	8	9	—	11
TYPE 25: Sugar Maple - Beech - Yellow Birch							
149		18	62	16			
97	10	15	23	18	5	2	8
19	8		47	41			
156	5		33	20	2		2
11	5	4	46	15	6		
18	6		42	44			
4	7	3	47	33			
87		14	23	37			2
159	4	14	25	9	3	4	8
9	10	16	39	20	7		
5	2	4	46	23			
71	2	13	18	48			
12	8	3	37	33	5		
109	4	7	28	33			
7	2	2	24	57			
1	8		27	38			
105	7	15	22	22	1		3
131	9	2	23	36			
84	2	2	8	29			
6	15	15	36	17	1		
2	5		32	43			
16	17		34	34	2		
130	13	20	13	21	6	3	2
17	21	6	24	33	1		1
Mean	7	7	32	30	2	—	T

Table 5: Summary of % frequency of seedlings for major tree species in stands sampled.

Stand Number	Yellow Birch	Sugar Maple	Beech	Red Maple	Hemlock	Spruce	Balsam Fir
TYPE 5: Balsam Fir							
182				18			
TYPE 24: Hemlock - Yellow Birch							
123		13	13	16	8	13	
173		32	4	11	15	4	4
125		17	14	31	4	10	
172		44	3	6		3	6
Mean		27	9	16	7	8	3
TYPE 30: Red Spruce - Yellow Birch							
83	13	19	6			23	2
135	4	4	4	62		10	4
85	12	15				19	
15	25	10	20	25			
106	14	9			13	22	16
164	8	16				11	8
128	10	13	13	5	27	3	
14	5	17	24	24	3	5	
107	3	48			3	3	20
3	37	16	3	26		5	
Mean	13	17	7	14	4	10	5
TYPE 25: Sugar Maple - Beech - Yellow Birch							
149		45	24				
97	4	23	9	12		8	9
19	20	30	22	5			
156	4	22	7	31			
11	19	22	15	20			
18	15	33	26	3			
4	17	27	37			1	
87		51	15				3
159	13	23	8	19			4
9	31	10	11	14		1	
5	23	24	27		1		
71	8	35	29	4			
12	28	24	13	19			
109	8	78	3				
7	29	29	11			1	
1	25	28	15	1			
105	4	43	8			3	10
131	3	44	19	6		6	
84		41					
6	31	24	18	5		2	
2	20	55	14				
16	8	29	21	13			
130	5	34	14	19		5	5
17	5	33	17	14			
Mean	13	34	16	8	—	1	1

Table 6: Summary of tree sampling in stand 1.

Species	Stems per acre	Sq. Ft. per acre	Sq. In. per tree	% Density	% BA
Betula alleghaniensis (Yellow Birch)	126	97.9	112	52.1	65.9
Fagus grandifolia (Beech)	40	20.2	73	16.5	13.6
Acer saccharum (Sugar Maple)	36	15.6	62	14.9	10.5
Picea rubens (Spruce)	10	4.2	60	4.1	2.8
Acer rubrum (Red Maple)	18	6.3	50	7.4	4.2
Betula papyrifera (Paper Birch)	8	3.1	55	3.3	2.1
Abies balsamea (Balsam Fir)	2	1.0	72	0.8	0.7
Pyrus decora (Mountain Ash)	2	0.4	28	0.8	0.3

Table 7: Summary of tree sampling in stand 2.

Species	Stems per acre	Sq. Ft. per acre	Sq. In. per tree	% Density	% BA
Fagus grandifolia (Beech)	80	41.8	75	44.0	22.4
Betula alleghaniensis (Yellow Birch)	44	77.5	254	24.2	41.7
Acer saccharum (Sugar Maple)	46	58.2	182	25.3	31.3
Picea rubens (Spruce)	6	3.3	80	3.3	1.8
Betula papyrifera (Paper Birch)	2	2.6	187	1.1	1.4
Acer rubrum (Red Maple)	2	2.4	175	1.1	1.3
Abies balsamea (Balsam Fir)	2	0.2	13	1.1	0.1

An estimate of effectiveness and of future trends may be obtained by examining sapling and seedling relative frequencies. Seedling relative frequencies for yellow birch are the same in the maple and spruce types thus continuing the similarity of effectiveness of yellow birch in these types. Regeneration under the canopy of hemlock-yellow birch was apparently negligible as no seedlings were counted in these stands. Table 4 indicates that the relative frequency of saplings was a little greater for yellow birch in the spruce-yellow birch type. This suggests perhaps less competition or better conditions for growth from seedling to sapling stage in the spruce-yellow birch type.

Site Comparison:

Tables 6 and 7 summarize the results of the tree sampling in the two stands under comparison. In stand 1, a flat and moist site, yellow birch was by far the dominant species. With a relative density of 52% and comprising 66% of the total basal area of the stand, it would appear that this site was well suited to the growth of yellow birch. Beech and sugar maple were the next most frequently appearing species. Other trees found but not as frequent were spruce and red maple with some paper birch, balsam fir and mountain ash.

Examination of size of the various species indicates that in terms of basal area per stem yellow birch was by far the largest with an average basal area per tree of 112 square inches. Beech with an average of 73 square inches per tree and sugar maple with 62 square inches per tree were the largest of the remaining species.

A further breakdown of trees into diameter classes indicates a broad distribution for yellow birch (Tables 8 and 9). The majority of yellow birch occurs in smaller diameter classes, but the range extends beyond the 16 in. class with a maximum at 33.3 in. Sixteen percent of the 63 yellow birch sampled had diameters larger than 16 in. Beech is more evenly distributed than the yellow birch yet the range of size is not as great with the maximum at 15.3 in. Sugar maple trees sampled do not exceed 14.5 in. in diameter and are concentrated in the smaller diameter classes indicating, as with yellow birch, that there are many young trees in this stand. It is interesting that in the case of red maple, there is an absence of trees in the range 10 to 16 in.

In stand 2, the table indicates that yellow birch is not the most common species, beech and sugar maple occur in larger numbers per acre, with beech comprising 44% of the total density and sugar maple 25%. In basal area per acre, yellow birch was calculated to have 78 square feet per acre or 31% of the total. Although the number of stems per acre is greater for many of the species in stand 2, yellow birch, spruce and red maple are substantially less.

On the average it appears that trees are much larger in this stand than in the first. Beech has a greater average basal area per tree. Examination of the breakdown of sampled species, with respect to diameter classes, indicates that beech is again fairly well represented in each class, with a majority in smaller diameter classes. Yellow birch has an average basal area of 254 sq. in. per tree, larger than that of the other species and much greater than that in the first stand. Of yellow birch sampled on this site, 36% had diameters exceeding 16 in. with the maximum at 33.2 in. Sugar maples were quite large and the majority of those sampled are more than 16 in. in diameter. The largest listed for sugar maple was 24.3 in. Most of the other trees sampled were quite large, with few or no small stems. This might indicate that they are incidentals or the last of a previous successional stage. The appearance of fewer red maple might suggest that this is less moist than the first.

Sapling data for each of the stands are presented in Tables 10 and 11. Sugar maple is the most frequently occurring species in either stand, but with a higher percent density and frequency in stand 2 where it was found to be the second leading dominant tree species. Spruce is well represented in stand 1 as a sapling but there are few mature spruce. There are fewer yellow birch saplings in stand 2. It may be that yellow birch reproduction is not as good in this stand or that the seedlings are not surviving or do not become established as readily.

Results of ground flora sampling do not necessarily give a good indication of the reproductive activities of the tree species due to variations in the number of seeds produced from year to year. However such data are important in identifying the plants associated with the types of stands under study. Very often these plants give to the trained ecologist an idea of the nature of the environment.

The ground flora data (Tables 12 and 13) indicate that sugar maple was by far the leading tree species sampled. Apparently a profuse seeding of maple occurred the previous autumn. The variation in the degree of occurrence of each species should be noted for the different stands. The fewer number of such species as red maple and Dryopteris spinulosa in the second stand may be related to a decrease in soil moisture as well. Yellow birch surprisingly did not vary in occurrence from one site to the other.

It is interesting to note the fewer number of species of trees, saplings and ground flora in stand 2 with respect to the first site.

The influence of climate upon vegetation is quite well understood at least in general terms. Yet the influence of small variations in climate due to topographic or other features of a given locale upon the vegetation of that area is not well understood. It might be suspected that subtle changes in local climate or microclimate may affect variations of vegetation in adjacent areas such as the two sites under observation in the Whiteface Mountain region.

Tables 14 and 15 summarize temperature and relative humidity data collected during the summer at each of the sites. Unfortunately much

Table 8: Distribution of trees in various diameter classes by percent in each class for stand 1. Diameter classes are in inches.

Species	Diameter Classes 4-6	6-8	8-10	10-12	12-14	14-16	> 16	Max.
Betula alleghaniensis (Yellow Birch)	19	33	22	6	2	2	16	33.3
Fagus grandifolia (Beech)	20	20	25	15	10	10		15.3
Acer saccharum (Sugar Maple)	22	17	33	17	6	6		14.5
Acer rubrum (Red Maple)	44	33	11				11	16.5
Picea rubens (Spruce)		40	40	20				10.6
Betula papyrifera (Paper Birch)	25	25		50				10.1
Abies balsamea (Balsam Fir)			100					9.5
Pyrus decora (Mountain Ash)	100							5.9

Table 9: Distribution of trees by percent in each diameter class for stand 2.

Species	Diameter Classes 4-6	6-8	8-10	10-12	12-14	14-16	> 16	Max.
Fagus grandifolia (Beech)	33	13	18	13	15	8	3	16.7
Betula alleghaniensis (Yellow Birch)	18	18	9	5	9	5	36	33.2
Acer saccharum (Sugar Maple)	22	9	17			13	39	24.3
Picea rubens (Spruce)			33	67				11.3
Betula papyrifera (Paper Birch)						100		15.3
Acer rubrum (Red Maple)						100		14.8
Abies balsamea (Balsam Fir)	100							4.1

Table 10: Summary of sapling data from stand 1. Data collected by quarter method using 40 points. Number refers to the number of stems counted and occurrence to the number of points at which each species was found.

Species	Number	Occurrence	%Density	%Frequency
Acer saccharum (Sugar Maple)	40	23	25.0	22.1
Picea rubens (Spruce)	28	21	17.5	20.2
Tsuga canadensis (Hemlock)	4	3	2.5	2.9
Acer pensylvanicum (Striped Maple)	26	16	16.3	15.4
Betula alleghaniensis (Yellow Birch)	19	13	11.9	12.5
Fagus grandifolia (Beech)	19	13	11.9	12.5
Acer spicatum (Mountain Maple)	13	7	8.1	6.7
Acer rubrum (Red Maple)	9	6	5.6	5.8
Abies balsamea (Balsam Fir)	2	2	1.3	1.9

Table 11: Summary of sapling data from stand 2. Data collected by quarter method using 20 points.

Species	Number	Occurrence	%Density	%Frequency
Acer saccharum (Sugar Maple)	33	16	41.3	36.4
Acer pensylvanicum (Striped Maple)	21	11	26.3	25.0
Fagus grandifolia (Beech)	14	10	17.5	22.7
Betula alleghaniensis (Yellow Birch)	7	4	8.8	9.1
Acer spicatum (Mountain Maple)	2	2	2.5	4.5
Picea rubens (Spruce)	3	1	3.8	2.3

Table 12: Summary of ground flora data collected in stand 1. One meter square plots were used in the sampling in which 40 points were taken.

Species	Occurrence	%Frequency
Acer saccharum	25	15
Dryopteris spinulosa	22	13
Viburnum alnifolium	21	13
Oxalis montana	19	11
Acer rubrum	14	8
Maianthemum canadense	11	7
Tiarella cordifolia	10	6
Trientalis borealis	8	5
Fagus grandifolia	6	4
Lycopodium lucidulum	6	4
Acer pensylvanicum	4	2
Acer spicatum	4	2
Cornus canadensis	3	2
Betula alleghaniensis	2	1
Abies balsamea	2	1
Picea rubens	2	1
Streptopus roseus	2	1
Aralia nudicaulis	2	1
Trillium erectum	1	1
Mitchella repens	1	1
Rubus hispidus	1	1

Table 13: Summary of ground flora sampling in stand 2. Twenty sampling plots were used in this stand.

Species	Occurrence	%Frequency
Acer saccharum	16	21
Lycopodium lucidulum	15	20
Viburnum alnifolium	9	12
Dryopteris spinulosa	8	11
Fagus grandifolia	7	9
Acer pensylvanicum	7	9
Oxalis montana	5	7
Picea rubens	2	3
Acer rubrum	2	3
Betula alleghaniensis	1	1
Acer spicatum	1	1
Clintonia borealis	1	1
Maianthemum canadense	1	1

of the data presented for temperature and humidity is incomplete due to difficulties with the hygrothermographs. Still some comparison can be made though the difference between the two sites does not seem to be significant. There was a slightly higher mean temperature in stand 2 than stand 1. In terms of daily average, maximum and minimum temperatures, stand 2 was almost always a degree or two higher. Such a small difference may be the result of error in the instrument. Interestingly there was not much variation in the weekly temperature summaries listed for the period of eight weeks.

Since daily maximum humidity readings were almost always 100% or near that mark, it is not of much value to present a summary of this data. Frequently fog could be observed during the early morning hours in the valley where the two sites were located. It would seem that maximum humidity would not be of much importance in affecting a difference in vegetation at the two sites. The summary of minimum humidity means for the weeks of study does indicate considerable differences existing between stand 1 and 2. As before, the degree to which this difference was a result of instrument error and site selection for the shelters is not certain. With a more dense cover of vegetation and a more moist soil it would seem reasonable to expect a more humid environment as in the first stand.

Wind is an obvious and important factor affecting humidity and transpiration rates of the various plants of a particular environment. At the sites described here, it seemed that the wind played a major role in affecting the nature of the community. Though no sampling or record was kept of the wind velocity in either stand, it was observed on many occasions that the valley was not well protected from strong winds. Many fallen logs were noticed throughout either site and it was not uncommon to find trees fallen that had been observed standing the day before. A result of this was the opening of large areas of the canopy and the penetration of more light to the forest floor or the lower strata. Frequently, yellow birch seedlings were observed growing on the older windthrows and in the exposed mineral soil turned up by fallen trees. It was only on such sites and decaying stumps, and stream beds free of leaf litter, that birch seedlings were seen growing. At no time were seedlings observed to becoming established where leaf litter covered the substrate.

One of the most important features of a forest site is the underlying soil. Vegetation along with climate and the geology of a site develop the characteristics of the soil, but also it must be realized that the soil has a role in determining the type of vegetation that will occur at a given site. It is for this reason that an examination of the soil characteristics in each of the stands was undertaken. Unfortunately, a lack of equipment prevented a more sophisticated approach to the study of soil conditions than would have been desired. Nevertheless, a summary of data is presented in Table 16.

Table 14: Weekly summaries of daily average, maximum and minimum temperatures for stations in stand 1 and 2 from July 6, 1966 to August 28, 1966.

Week Ending:	7/10	7/17	7/24	7/31	8/7	8/14	8/21	8/28
Station			Average°F					
1	61*	61	58	61	62	63	62	58
2			61*		62	66*	63	59
			Maximum°F					
1	74*	75	73	76	78	81	75	70
2			73*		79	82	76	70
			Minimum°F					
1	48*	44	41	44	51	44	47	48
2			42*		50	46	49	48

*Data incomplete

Table 15: Weekly summaries of the mean minimum humidity for stations in stands 1 and 2 from July 6, 1966 to August 28, 1966.

Week Ending:	7/10	7/17	7/24	7/31	8/7	8/14	8/21	8/28
Station			Mean of Minimum Humidity %					
1	46*	42*	50	52	55	64*	54	56
2	42*				55	59*	49	49

*Data incomplete

Table 16: Summary of data collected for various soil characteristics.

Soil Characteristic		Stand 1	Stand 2
Soil Texture:	greater than 1mm.	6%	11%
	.7mm.- 1mm.	12%	20%
	.25mm.-.7mm.	29%	34%
	.12mm.-.25mm.	32%	23%
	less than .12mm.	21%	13%
Soil Classification:		Sand	Coarse Sand
Depth of Organic Material:	Litter	4cm.	2cm.
	Fermentation	3cm.	1.5cm.
	Humus	5cm.	6cm.
Average of Soil Temperature Sampling:		10°C	10°C
Soil Moisture:	Average of Meter Readings (milliamps)	41ma.	18ma.
	Oven Drying Method	49%	35%
Soil pH:		4.5	4.0-4.5

As might be expected, considering the topography of stand 1, the soil texture was much finer consisting mostly of fine sand and silt. This soil was not deep, being located between and over the many boulders located at the site, and having been sifted by running water that still exists in some areas. The soil of stand 2 was more coarse in texture not having been recently affected by water as has been the soil in stand 1.

There appeared to be more leaf debris in stand 1, but the depth of the humus layer was about the same for each site.

The amount of soil moisture is not accurately represented by the data for stand 1 at least. It was not uncommon to see saturated soils in this stand and the 49% moisture given is indicative of surplus soil moisture. The soil reaction (pH) was quite variable, by our crude method.

There may well be a correlation between amount of soil moisture or amount of clay particles and pH of each site, but this remains unproven. Soil temperatures were taken on several occasions, but only an average is shown in order to make preliminary comparisons. Soil temperature fluctuates too greatly to be measured in absolute terms with anything other than a continuous recorder. So far, it seems that temperatures at the two sites did not vary importantly.

DISCUSSION

In terms of basal area yellow birch shows strong values in the total cross section area of stems as well as fairly large individual trees in the hardwood and the spruce types (Figure 3). The results of the two site comparisons indicate that yellow birch has a more even diameter distribution on the more moist site, which has a larger number of spruce and red maple than the second site, an obvious type 25 stand. The even distribution of trees in the different diameter classes reflects the even age distribution of yellow birch suggesting vigorous growth. Stands of the hemlock-birch type contain a number of very large and old trees. It would seem that yellow birch is declining and will lose its prominence in the hemlock-birch types.

A similar study made in Wisconsin (Winget et al., 1965) indicated that yellow birch reached its highest importance values in association with hemlock and with sugar maple. In our study it appears that yellow birch is most effective in the spruce-yellow birch type, although it is only slightly less effective in the sugar maple-beech yellow birch type.

In terms of density, yellow birch was more abundant in the spruce type but with smaller trees. The total basal area per acre as noted was about equivalent in the hardwood type. It would seem as if the yellow birch in spruce-birch stands were younger and more vigorous in growth judging from regeneration data and density considerations than in the

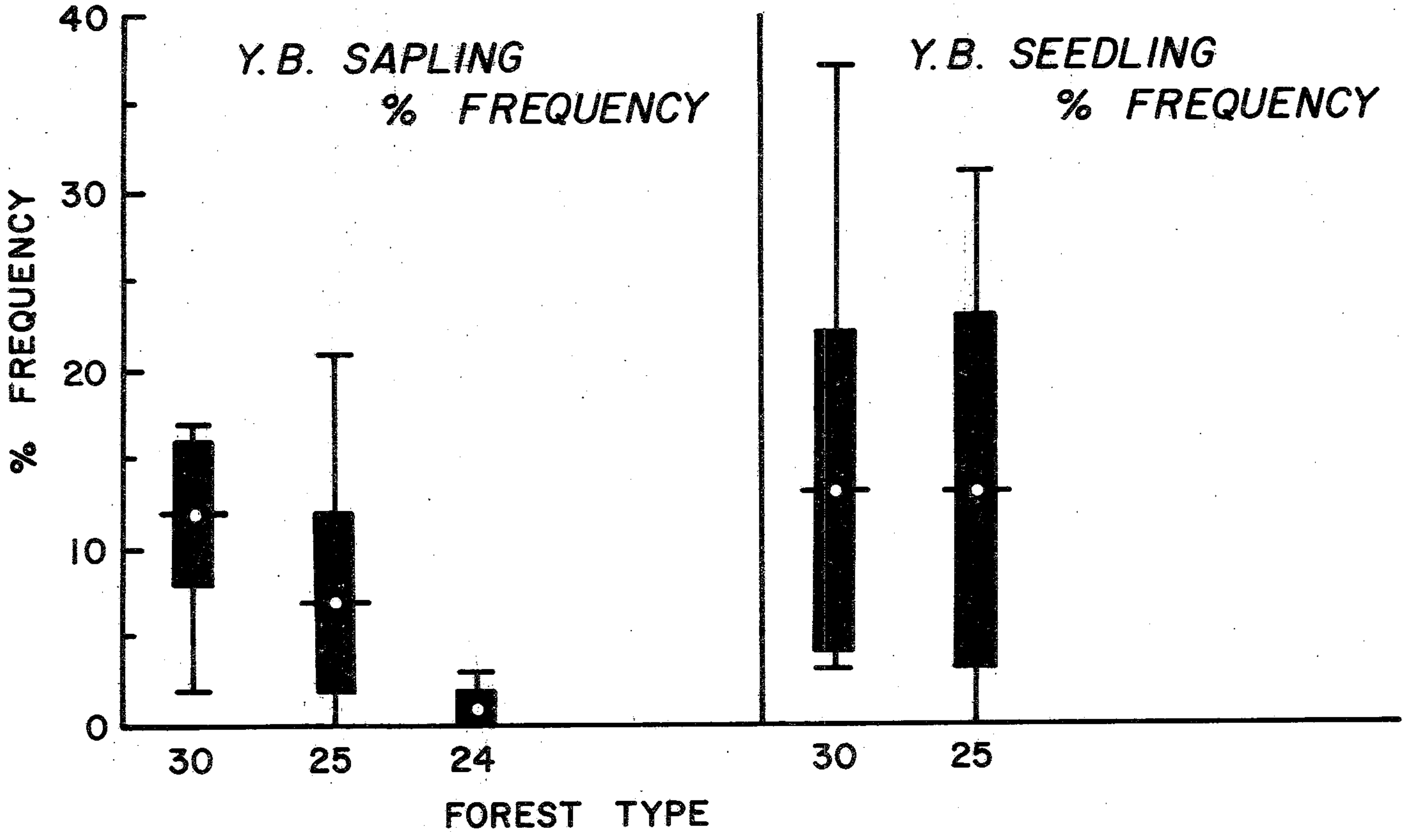


Figure 4: Comparison of frequency (%) of yellow birch seedlings and saplings by forest type.

other types. It would also appear that it was exerting its maximum effect on the stands of the spruce-birch type.

The site comparison data may aid in explaining further the greater effectiveness of yellow birch in type 30 stands. Hoyle (1965) discusses the fact that rootlet development of yellow birch is best in humus due perhaps more to the availability of essential nutrients in this soil layer than to availability of moisture. The data indicate a greater depth of humus at the first site, which is more analogous to a type 30 stand. The high moisture content of the soils in the first stand is however important in terms of birch effectiveness. Yelenosky (1961) reported that yellow birch seeds will tolerate excessive moisture and will even germinate in a free water medium. This certainly offers a competitive advantage over other species in all habitats suitable for yellow birch.

Figures 2 and 3 provide only indirect information concerning the successional status of yellow birch. Consequently we need to consider data in Figure 4 which presents material on regeneration. Type 30, except on moist sites, is probably a subclimax stage giving way eventually to hardwoods. The larger size of yellow birch, decreased density and regeneration in type 25, a climax type, support this view.

It appears that the common mode of yellow birch establishment, on elevated micro-sites, may give it a competitive advantage. Tubbs (1963) found that there is a more marked increase in germination and height growth of this species on naturally occurring mounds than on adjacent flats. Decaying stumps and windthrows are a frequent occurrence in spruce-yellow birch stands. Also, decreased canopy cover in this type, especially on moist sites, seems to be reflected in higher birch sapling frequency.

In the maple-birch type, yellow birch may be considered as a remnant of the most immediate seral stage. However the species does manage to persist for a very long period of time and will regenerate but not with the vigor displayed in spruce-birch forests. The ultimate effect would probably be complete elimination of yellow birch from the sugar maple-beech forest if it were not for frequent minor disturbances favoring yellow birch regeneration. The greater range of importance values of yellow birch in the hardwood types may be a reflection of the various directions of succession leading to the type 25 climax.

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APPENDIX

Nomenclature according to *Gray's Manual of Botany* (Fernald 1950).

Scientific Name	Colloquial Name
Abies balsamea Mill.	Balsam fir
Acer pensylvanicum L.	Striped maple
Acer rubrum L.	Red maple
Acer saccharum Marsh.	Sugar maple
Acer spicatum Lam.	Mountain maple
Betula alleghaniensis Britt.	Yellow birch
Betula papyrifera Marsh.	Paper birch
Fagus grandifolia Ehrh.	Beech
Picea rubens Sarg.	Red spruce
Pyrus decora Hyland	Mountain ash
Tsuga canadensis Carr.	Hemlock

THE DETERMINATION OF
VERTICAL MICROMETEOROLOGICAL PROFILES
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THE DETERMINATION OF VERTICAL MICROMETEOROLOGICAL PROFILES THROUGH A FOREST CANOPY WITH A SINGLE SET OF SENSORS

By

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ABSTRACT

A vertically-sweeping sensor system for the determination of forest microclimates has been designed, constructed, and successfully operated in a deciduous stand. The reproducibility of the results and their consistency with other published results indicates that the goal of developing a portable, low cost, forest microclimate sensing system that is easy to operate has been achieved.

The energy balance model for the determination of diffusivities and energy fluxes is discussed and applied to data obtained from the system. The time rate or change of latent heat storage term, which is usually not considered in previously reported forest studies, is found to have the same order of magnitude as the ground heat flux term. The calculated energy fluxes generally agree with other published results; however, on several occasions, the energy balance model fails to give physically meaningful results in the lower region of the canopy. The general applicability of the model to forests is discussed in light of the empirical results.

INTRODUCTION

The microclimate of a forested region is a major factor in determining the plant associations that will occur in the region. While forest microclimates in various locations have been the subject of many studies (Geiger, 1959; Munn, 1966), the interaction between the microclimate and the vegetation in a region is a complex process that has been neither understood well nor widely studied.

The microclimate of a forest depends on the energy exchanges that occur within the canopy. Under conditions of full foliage, the distributions of temperature, moisture, and carbon dioxide are determined primarily by the magnitudes of the net radiation energy and the turbulent fluxes of sensible and latent heat. The energy used in the physiological processes of the vegetation is of secondary importance. Under good growing conditions the energy used in photosynthesis is about five percent of the solar radiation (Lemon, 1960). The ground surface is another surface of active exchange, especially when the leaves are off of the trees.

The micrometeorologist studying forest energy balances has at least two options as to the approach to use. One method is to use profiles of temperature and moisture to calculate a coefficient of turbulent diffusion, a parameter used in the determination of the energy balance. Another is to derive the coefficient on the basis of wind profiles. The variety of micrometeorological studies that have been conducted in plant communities are described in books by Sutton (1953), Priestley (1959), and Munn (1966). Munn suggests that the former method is the better approach, when he states that "... an assumption about the ratio K_h/K_v is probably preferable to one about the value of K_m/K_v...", where K_h, K_v, and K_m are the diffusivities of sensible heat, latent heat, and momentum, respectively. He cites the fact that the determination of a coefficient from wind profiles requires a value for the friction velocity, which cannot reliably be obtained on a regular basis using present techniques. In addition, a conceptual problem arises, since the friction velocity would be a function of position within the canopy.

Denmead (1964) has calculated the magnitudes of the major terms of the energy budget using temperature and moisture measurements. He obtained profiles of temperature, humidity, and net radiation from sensors at six levels on a vertical tower located in a low pine forest in Australia. The energy exchanges between each layer were calculated from these profiles.

For the study reported here it was considered desirable to determine forest energy balances by this temperature-moisture profile method. Since future work would call for the determination of the energy balance in a number of forest stands, the system to be used was required to be reliable, portable, and relatively inexpensive. The study included the design, construction, and testing of a measuring and recording system, and the use of the system in a small deciduous forest.

EQUATIONS

The equation for the energy balance of a volume of air located between the ground surface and a horizontal plane at height z is

$$R(z) = LE(z) + H(z) + G_f(z) + G_a(z) + G_s + B(z), \quad (1)$$

where R(z) is the net radiative flux through the upper surface (positive when downward), LE(z) is the latent heat flux through the upper surface (positive when upward), H(z) is the sensible heat flux through the upper surface (positive when upward), $G_f(z)$ is the rate of thermal energy storage in the foliage below height z, $G_a(z)$ is the rate of energy storage in the atmosphere below height a, G_s is the flux of heat into the ground through the earth's surface, and B(z) represents the flux of other energy sources and sinks within the volume. All energy storage terms are defined as positive when storage occurs.

The assumption is made that there is horizontal uniformity of all energy sources and sinks, such that there is no net horizontal transfer of energy. Thus, only vertical fluxes through a horizontal unit area are considered. The terms are shown schematically in Figure 1.

The rate of energy storage in the forest air may be considered to be composed of two components: sensible heat storage, G_{ah}, and latent heat storage, G_{al}. For a volume of forest with unit area and vertical height z, these terms are expressed as

$$G_{ah} = -\rho \, c_p \, \dot{T} \, z \qquad (2)$$

and

$$G_{al} = -\rho \, L \, \dot{q} \, z, \qquad (3)$$

where ρ is air density, c_p is specific heat of air at constant pressure, L is latent heat of vaporization for water, $\dot{T}$ is the time rate of change of air temperature, and $\dot{q}$ is the time rate of change of specific humidity.

The rate of energy storage in the foliage is given by a similar expression:

$$G_f = h \rho_f \, c_f \, \dot{T}_f z \qquad (4)$$

where h is the areal foliage density, ρ_f is foliage density, c_f is foliage specific heat, and T_f is the time rate of change of foliage temperature.

Energy flow at the forest floor may be calculated from temperature gradient measurements, but in this study direct readings were obtained from a commercial soil heat flux instrument. Other sources and sinks to be considered in a forest are suspended particulates, animals, and photosynthesis in the vegetation.

For convenience, in the following development all storage terms will be considered as one cumulative term given by

$$G(z) = G_{ah}(z) + G_{al}(z) + G_f + G_s + B(z). \qquad (5)$$

The flux of sensible heat in air, H(z), is given by

$$H(z) = -\rho\ c_p\ K_h(z)\ (\frac{\partial T}{\partial z} + r), \qquad (6)$$

where $K_h(z)$ is the diffusivity for sensible heat at height z, $\frac{\partial T}{\partial z}$ is the environmental gradient of temperature, and r is the dry adiabatic lapse rate. The flux density of latent heat is similarly given by

$$LE(z) = -\rho\ L\ K_v(z)\ \frac{\partial q}{\partial z}\ , \qquad (7)$$

where $K_v(z)$ is the diffusivity for water vapor at height z and $\frac{\partial q}{\partial z}$ is the vertical gradient of water vapor. Substituting G(z), H(z), and LE(z) from Equations (5), (6), and (7) into the energy balance Equation (1) gives

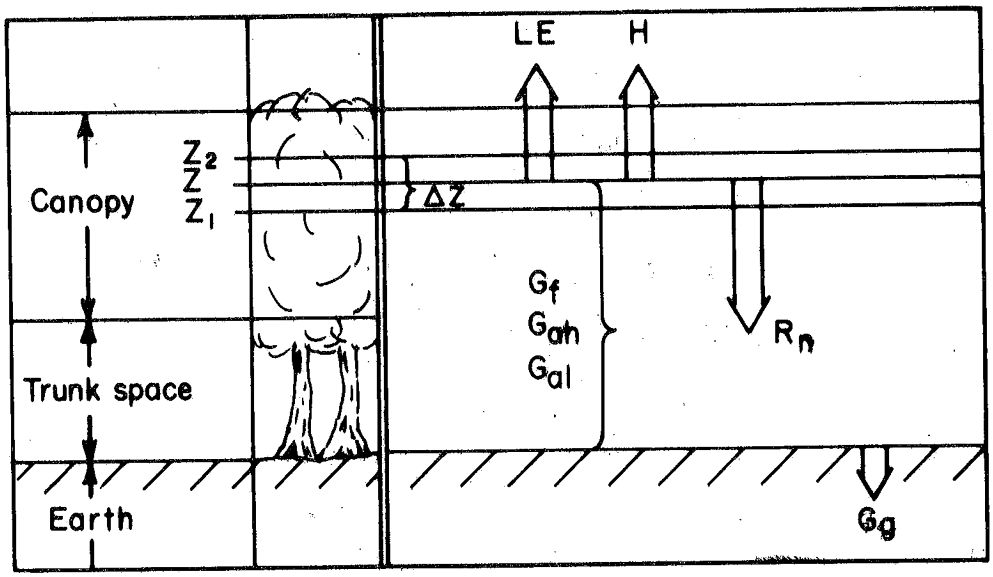
$$R(z) = -\rho\ c_p\ K_h(z)\ (\frac{\partial T}{\partial z} + r) - \rho\ L\ K_v(z)\ \frac{\partial q}{\partial z} + G(z). \qquad (8)$$

For actual calculations this equation must be put into finite-difference form. The forest floor is considered to be the lower surface of a volume under consideration. The upper surface is considered to be the middle of a layer of finite thickness, Δz, as shown in Figure 1. This layer is bounded by two horizontal planes at heights z_1 and z_2. The vertical change in temperature and specific humidity between these levels is ΔT and Δq, respectively. Equation (8) becomes

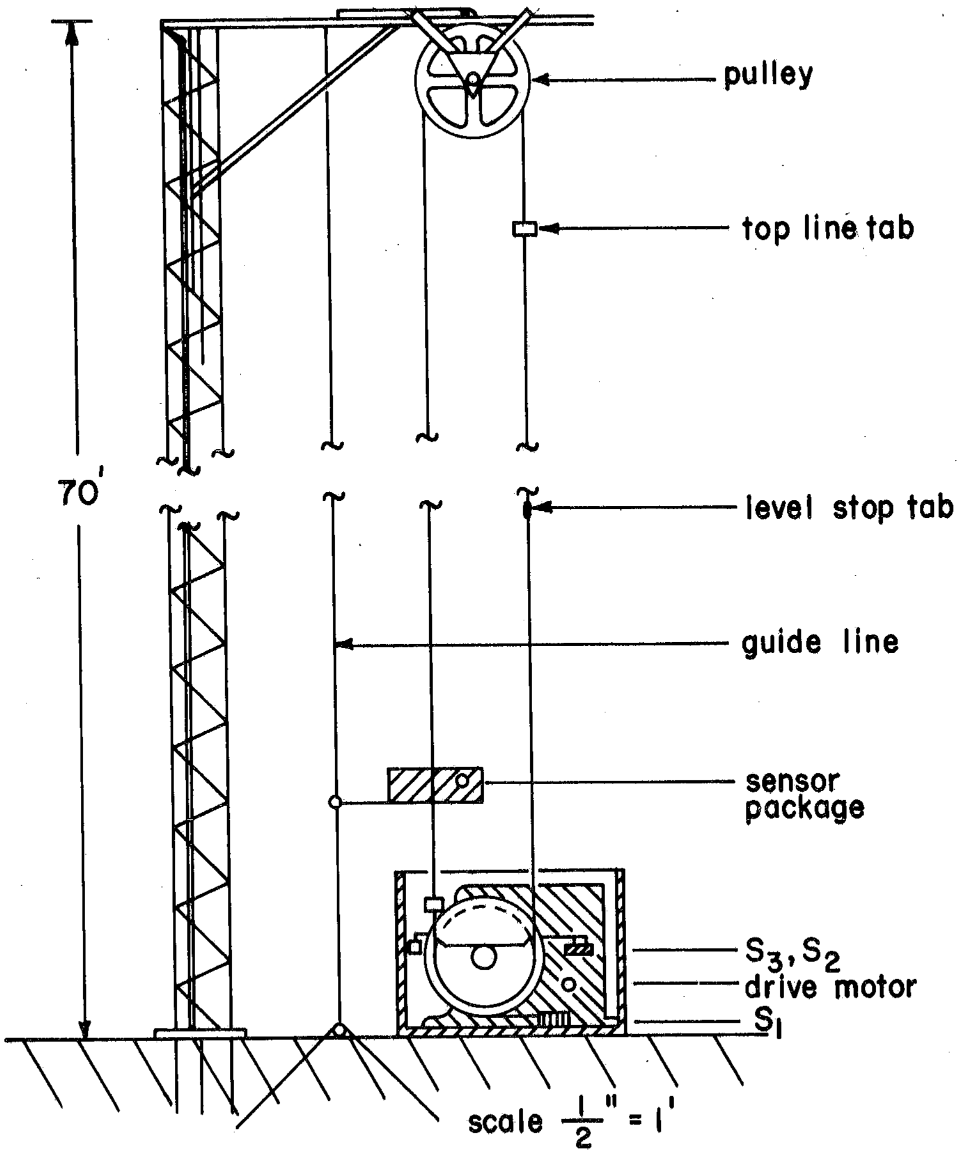
$$(R_1 + R_2)/2 = R(z) = -c_p\ K_h(z)\ (\frac{\Delta T}{\Delta z} + r) - \rho\ L\ K_v(z)\ \frac{\Delta q}{\Delta z} + G(z). \qquad (9)$$

Figure 1: Energy Budget Model. This represents a vertical cross section through a forest as shown on the left. The energy fluxes are represented by arrows which point in the direction defined as a positive flux. The brackets enclose the height through which the storage terms refer (page 198).

Figure 2: Tower with Sensor Package Drive System (page 199).



LE
H
Canopy
Z_2
Z
Z_1
ΔZ
Trunk space
Earth
G_f
G_{ah}
G_{al}
R_n
G_g


pulley
top line tab
70'
level stop tab
guide line
sensor
package
S3, S2
drive motor
S1
scale 1/2" = 1'

Adopting the assumption, also used by Denmead, that the diffusivities for water vapor and sensible heat are equal and solving for the "apparent" diffusivity gives for each level, then

$$K(z) = \frac{[R(z) - G(z)]\ \Delta z}{\rho[(c_p\ \Delta T + r\ \Delta z) + L\ \Delta q]} \qquad (10)$$

This layer analysis was used in the present study. In summary, these formuli are based on the following assumptions: (1) steady state conditions prevail, (2) the diffusivities of water vapor and sensible heat are equal, (3) all energy terms not explicitly used in the final equations are unimportant in the analysis, (4) the vertical distribution of energy sources and sinks is horizontally uniform. The first assumption is best approximated by taking data near the meteorological noontime. The assumption that the diffusivities of sensible and latent heat are equal has considerable support in the literature, although there is discussion on this point. The assumption seems to hold for stable conditions. Under stable conditions there is evidence that $K_h > K_v$ (Priestley, 1959), but the difference, if real, appears to be not enough to significantly effect the accuracy desired in the present study. The last two assumptions have not yet been verified for forests, but previous studies suggest that they do hold for relatively uniform forests.

This heat balance approach, although perhaps limited by the above assumptions, provides a consistent model for diffusion in the present study.

METHODS

Instrumentation

A single sensor package was constructed to obtain readings at all levels in the forest. Better relative accuracy between levels is one of the several advantages of using one sensor rather than many, as has been discussed by Hamilton (1964). The instrumentation used in previous studies of microclimate is described by Long (1957). With the development of small net-radiometers, it has recently become possible to include net-radiation profiles in forest studies (Funk, 1959, 1962). The sensor package was mounted on a vertical pulley system which was attached to the tower as shown in Figure 2. The top of the tower was about three meters above the canopy top in a wooded area near the campus of the State University of New York at Albany.

Two methods were used for data sampling: (1) data recorded every eight seconds as the package moved vertically at the rate of about eight centimeters per second, and (2) data recorded at discrete levels with the sensor package stopped at each level. Manually controlled switches were used to obtain data in the first method. An electrical switching circuit was constructed to control automatically the drive-motor and recording cycle in the latter method. The switching system is shown schematically in Figure 3.

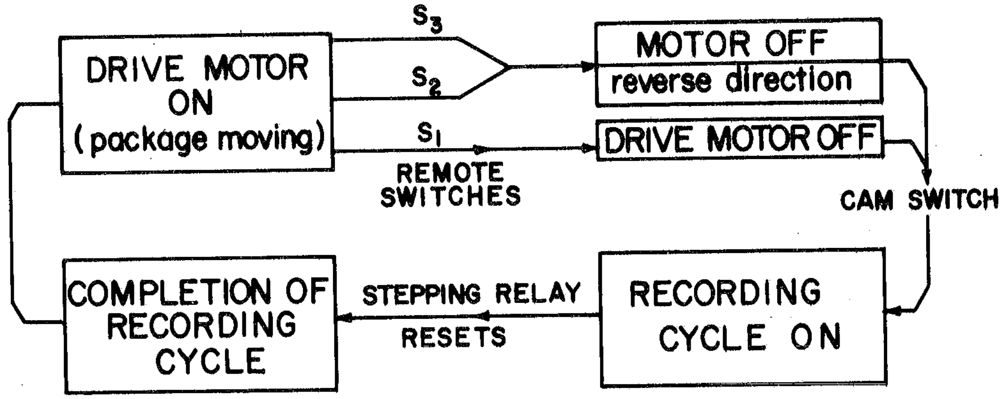
Except for at the highest and lowest positions, the package was stopped for readings by the level-control microswitch, S_1, when triggered by the level-control stop-tabs, illustrated in Figure 2. The highest and lowest positions of the package were set by the top and bottom stop-tabs as the stop-tabs hit microswitches S_2 and S_3, respectively. These switches, besides stopping the package, also switched the motor wiring circuit such that the package would next move in the opposite direction. When the sensor package stopped at each level, readings from all sensors were recorded. When the recording cycle was complete, the sensor package moved to the next level and the process was repeated. The use of remote, automatically controlled switches not only assured that the package always stopped at exactly the same level, but also allowed these levels to be quickly and easily selected in the field. The length of time the sensor package remained at each level could be varied by changing the timing cams.

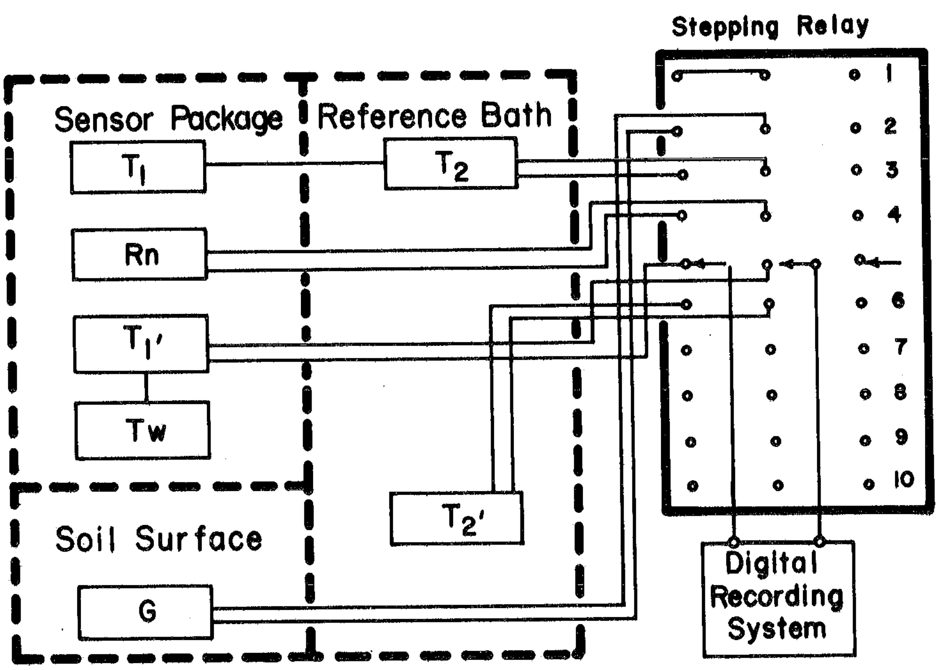
The circuit for recording is shown in Figure 3. The recording cycle began with the recording of the parameter connected to the first position of a stepping relay, which in the present case was a zero reference. The relay was then advanced to step two by a cam (not shown), where the second parameter was recorded. This process was repeated until the last variable was recorded, when the stepping relay automatically reset. The number of parameters recorded could easily be varied.

Figure 4 is a photograph of the sensor package before an outer aluminized plastic shield was attached. This package contained the temperature and humidity sensors, which were ventilated at four meters per second by an electric fan. The temperature and the wet-bulb depression were each measured with five copper-constantan thermocouples wired in series. Also shown in this picture are the thermocouple net radiometer and its mount. A commercially available version of Funk's net radiometer was used. A commercial soil heat flux plate was used to measure the ground heat storage. A thermistor circuit was used to measure the temperature of the reference bath. Signals from each of the above were amplified and then recorded by a digital voltmeter-printer system. When the sensor package stopped at specific levels the profile parameters were recorded in the order of their increasing lag times. There was a lag-error in the data taken by the moving package which will be discussed later. An event-recorder was used to monitor the motion and position of the sensor package.

Figure 3: Flow chart of the control circuit. The actual circuit used was a much more complex combination of switches, cams and relays (page 203, top).

Figure 4: Sensor Arrangement and Recording Circuit. The dotted boxes indicate the location at which the various parameters were measured. t is temperature, R_n net radiation, G heat flux into the ground, and T_w wet bulb temperature (page 203, bottom).


DRIVE MOTOR ON (package moving)
S3
S2
S1
REMOTE SWITCHES
MOTOR OFF
reverse direction
DRIVE MOTOR OFF
CAM SWITCH
RECORDING CYCLE ON
STEPPING RELAY
RESETS
COMPLETION OF RECORDING CYCLE


Stepping Relay
Sensor Package
Reference Bath
T1
T2
Rn
T1'
Tw
Soil Surface
G
T2'
1
2
3
4
6
7
8
9
10
Digital Recording System

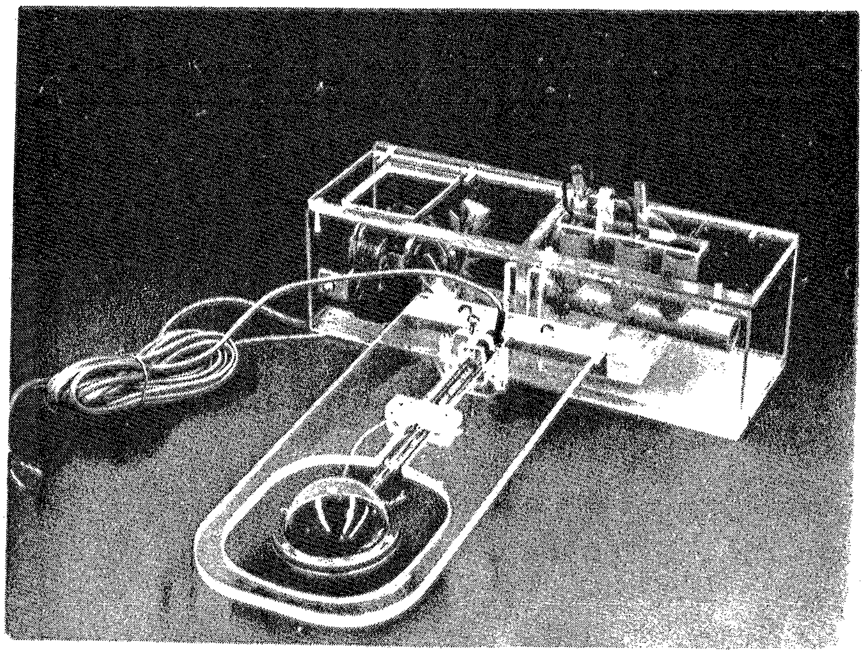


Figure 5. Sensor Package (without outer radiation shield).

Procedures

The cost of a data acquisition system has been greatly reduced by the use of a single set of sensors. Also, since moveable sensors yield more accurate vertical gradients than multiple fixed-sensors, the latter would have had to be more accurate in order to obtain comparable gradient results. The relative simplicity of the instrumentation made installation simple compared to mounting sensors at many levels.

The diffusivity for each level was determined from Equation (10). The sensible flux was obtained from Equation (6). The gradients were determined by taking differences across the finite layer, $z_1 - z_2$. The latent heat flux was then obtained from Equation (1).

Heat flux into the ground was obtained directly from the recorded heat flux plate. The other storage terms were found by use of a graphical technique. For a given time-period, the initial and final profiles of temperature and water vapor pressure were plotted and then the graphical areas within the various layers were determined. These areas, in units of °C-feet and mb-feet, were then substituted into special forms of Equations (2) and (3) to give values of sensible heat and latent heat storage as a function of height. These values of °C-feet were used as an approximation to the change in temperature of the foliage in Equation (4).

RESULTS

Profiles

Profiles of various parameters were examined and found to be physically reasonable based upon previously published results. Examples of detailed profiles are given in Figures 6, 7, and 8 for temperature, net-radiation and water vapor, respectively. These values were recorded at intervals of two feet without stopping the package as it moved vertically through the trees. The data were taken in late afternoon after an entire day of clear and calm conditions so that significant trends should occur. The profiles show the expected trends. For example, in Figure 6, the temperature falls about 0.7°C between the two runs twenty-four minutes apart. In Figure 7, the net-radiation also shows a significant decrease between the two sets of profiles. The slope of the individual profiles also were in agreement with expected results.

The results of the individual sweeps of the sensor package as shown in Figures 6 through 8 show large vertical fluctuations which conceivably would cause serious difficulties for the computation of heat balance. However, when the values for several sweeps are averaged considerable smoothing results as shown in Figure 9 where 21 sweeps are averaged. During the period covered in Figure 9 the individual profiles exhibited a great deal of vertical and temporal variations. The winds

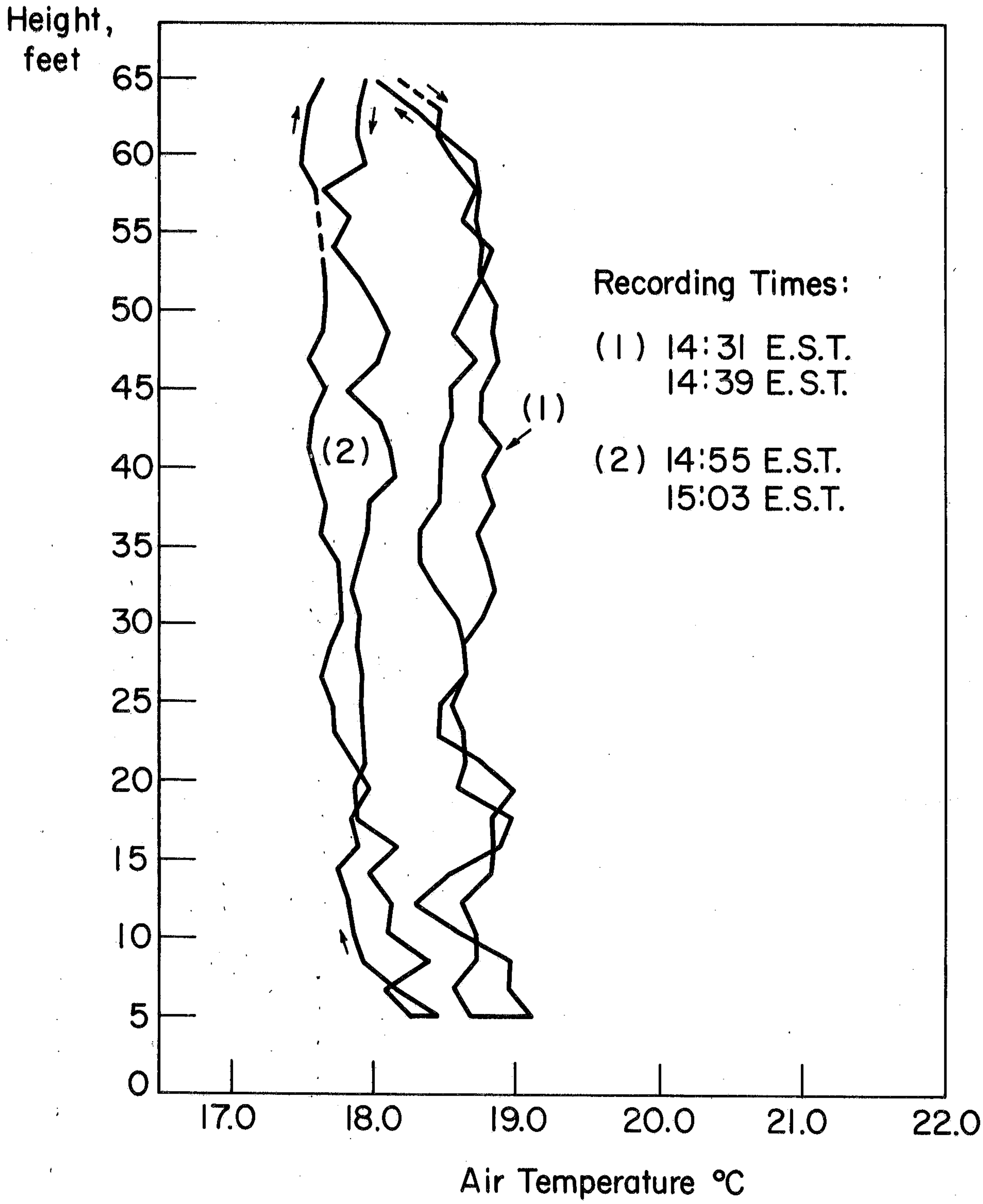


Fig. 6 Temperature Profiles, 5 / 25 / 67

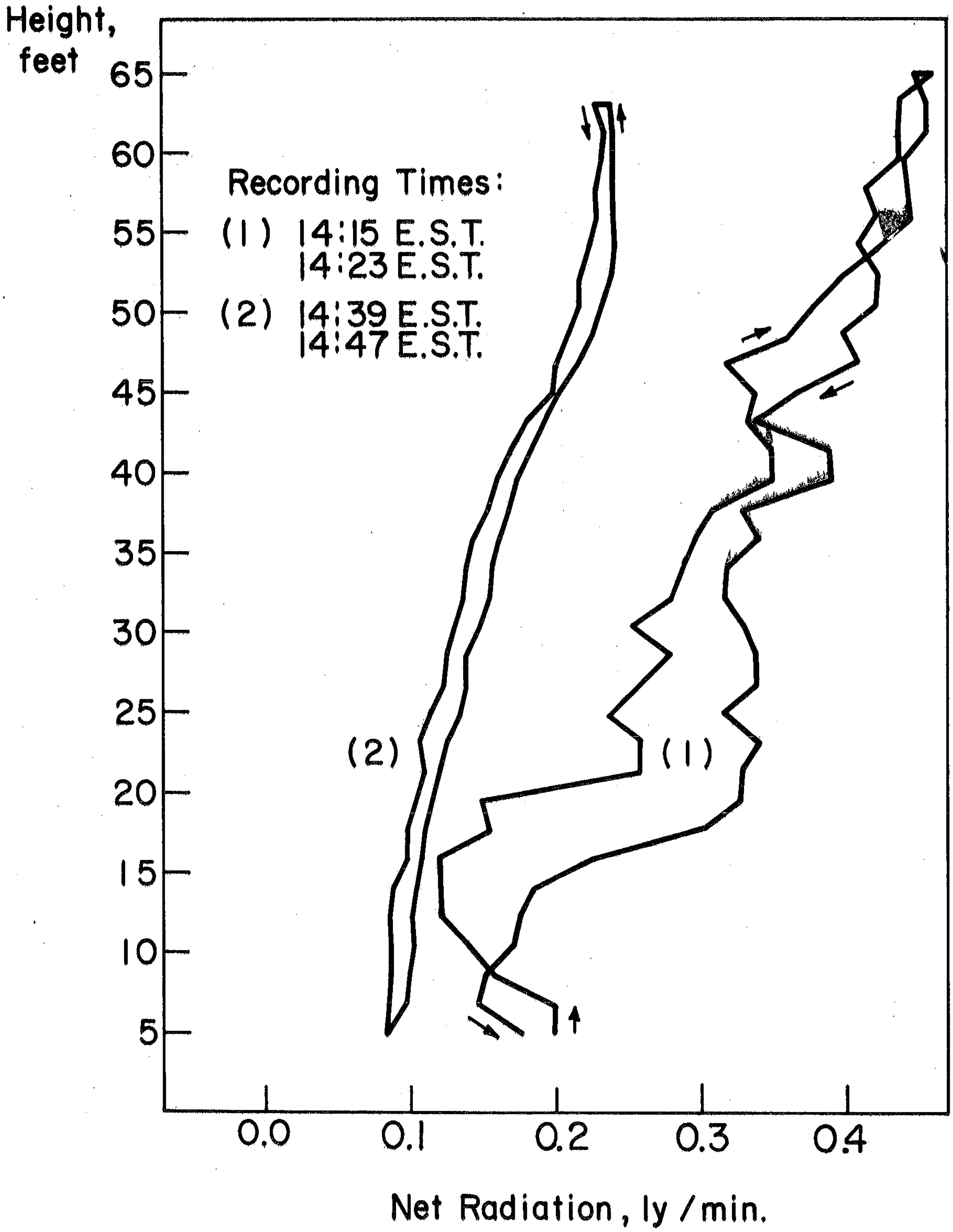


Fig. 7 Net Radiation Profiles, 5/25/67.

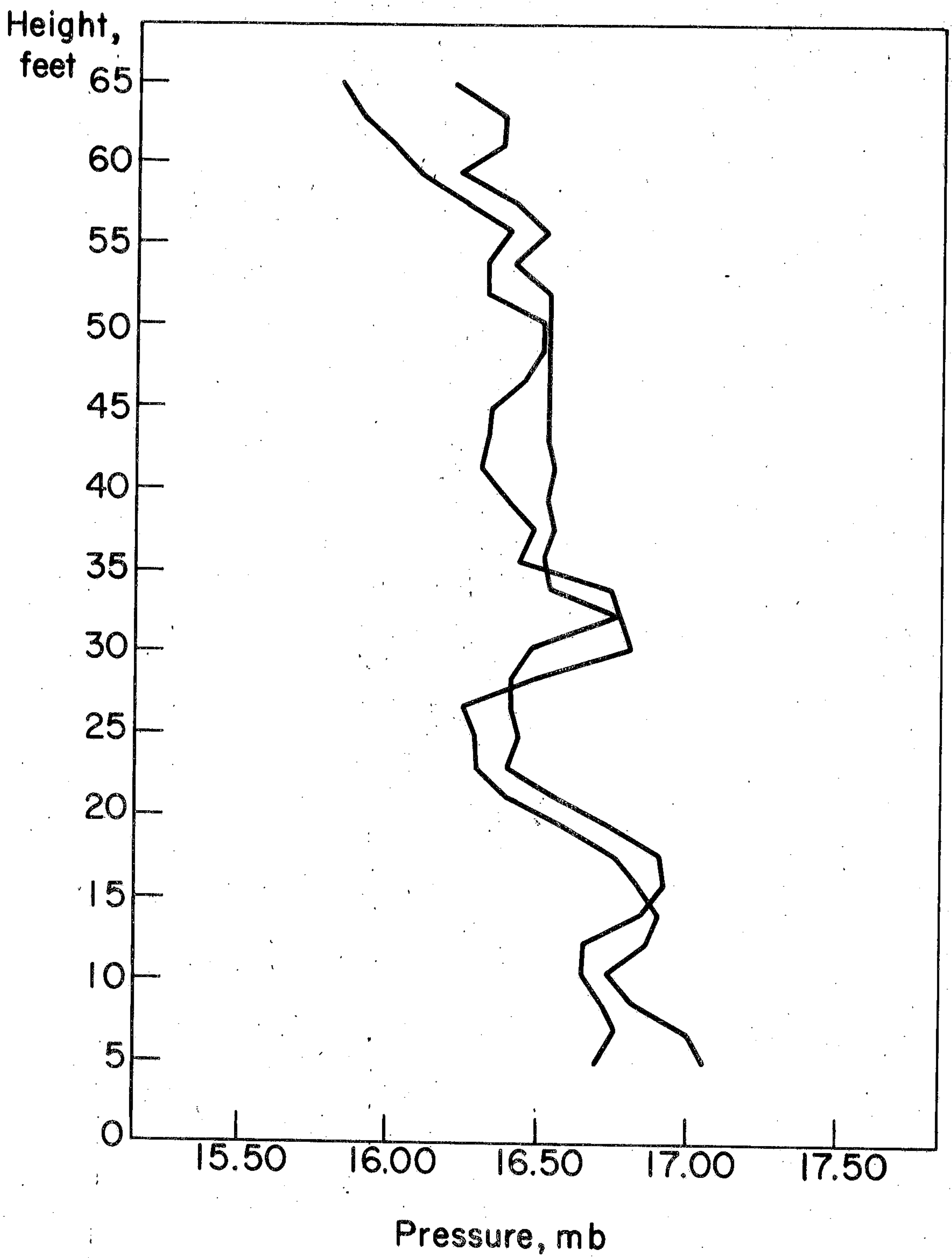


Fig. 8 Water Vapor Pressure Profile, 14:23-14:31 E.S.T. 5/25/67.

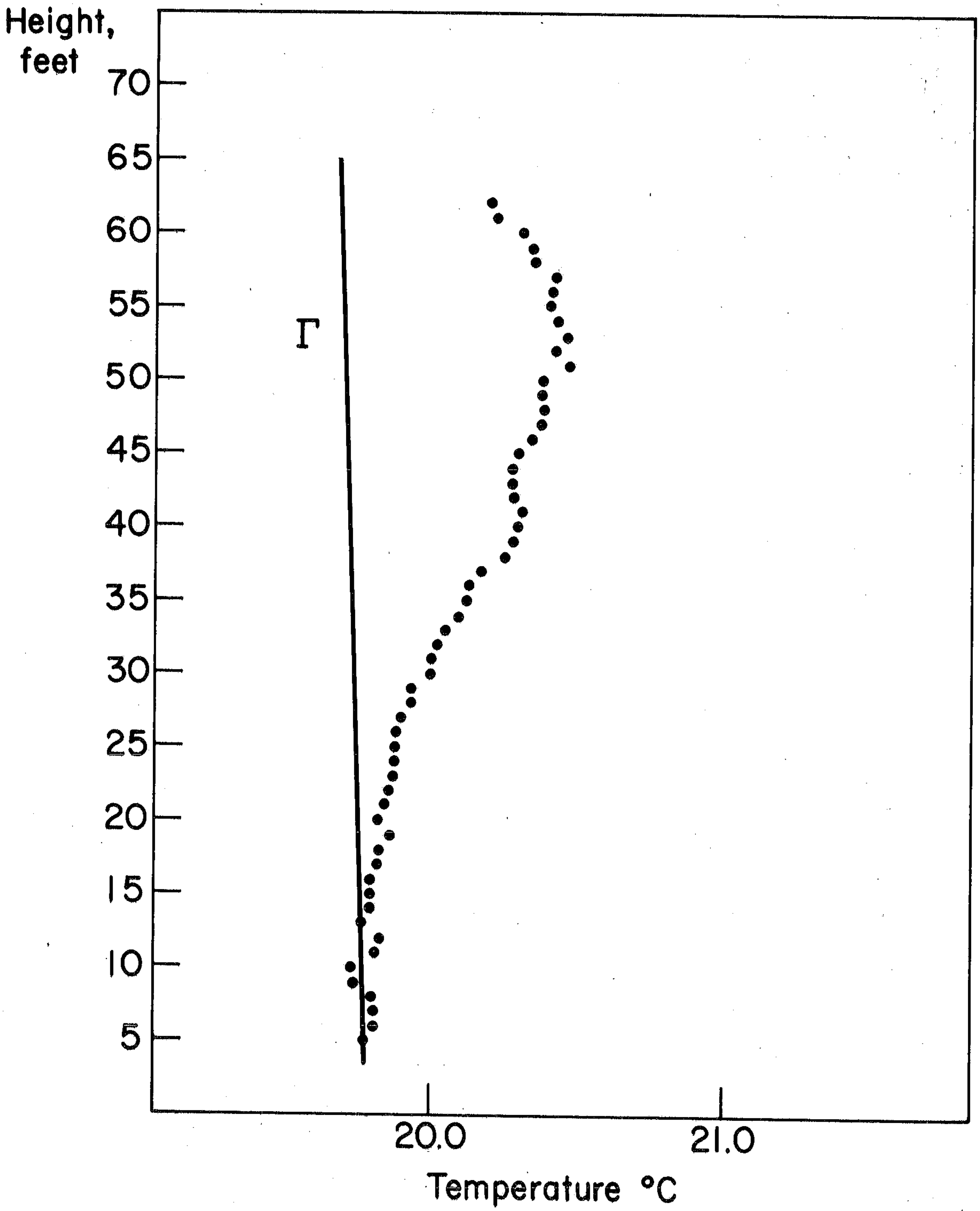


Fig. 9 Mean Air Temperature Profile, (one and a half hour period).

were variable, up to about seven miles per hour maximum at ten feet. The sky was about one-quarter covered with cumulus. Under such variable conditions the smoothness of this mean profile gives strong support to the use of representative mean gradients between five or six levels.

The average vertical profiles of temperature, water vapor pressure, and net radiation for two dates are plotted in Figures 10 and 11. These profiles indicate reasonable physical processes based on the prevailing meteorological conditions, which are summarized in Table 1. The profiles in Figure 10 clearly show a transition of conditions which agree with the observed meteorological changes. There were no leaves on the trees on this date. The first sampling period was characterized by clear and calm conditions, which had existed all morning. By the third period the wind had risen and the sky had become overcast. The recorded transition to lower and more uniform values of downward net radiation, temperature, and moisture are those which would be expected as a result of the rising winds and decrease of incoming energy. In Figure 11 are presented profiles for a situation with leaves on the trees. During the period 9:30 to 12:30 EST there was a change in the profiles typical of warm spring mornings. The middle profile shows the continuity of change between the first and third periods. This day was clear with light winds. The fact that the dominant warming and evaporation occurred both in the upper canopy and at the earth's surface is evident from the profiles of temperature and vapor pressure in Figure 11. The net radiation profiles on this date show a peculiar maximum at the forty-five foot level. This maximum in the canopy region was also evident in the individual profile values. The effect was even more pronounced in profiles taken in June. This unexpected variation was also observed in the profiles taken every few feet under similar conditions of strong incoming solar radiation and the foliage on the trees. In the latter case, the net radiation increased as the sensor package came down into the upper part of the canopy and was observed to reach a peak value at the level of one particular tree branch near the top of the canopy. The radiation then decreased below this level as should be expected because of shading. This maximum may be the result of increased downward radiation from leaves above the radiometer or the result of decreased upward radiation from below the sensor, or a combination of these two effects.

The most consistent of the results included in Figures 6 through 11 were those of the temperature and moisture profiles, while the net radiation profiles were less consistent. This may be attributed to horizontal variations in the net radiation flux. Fortunately, the calculation of the heat budget requires the mean radiation through a layer rather than a gradient. This means that vertical variations in the net radiation will have only a small effect on the determination of energy fluxes of sensible and latent heat.

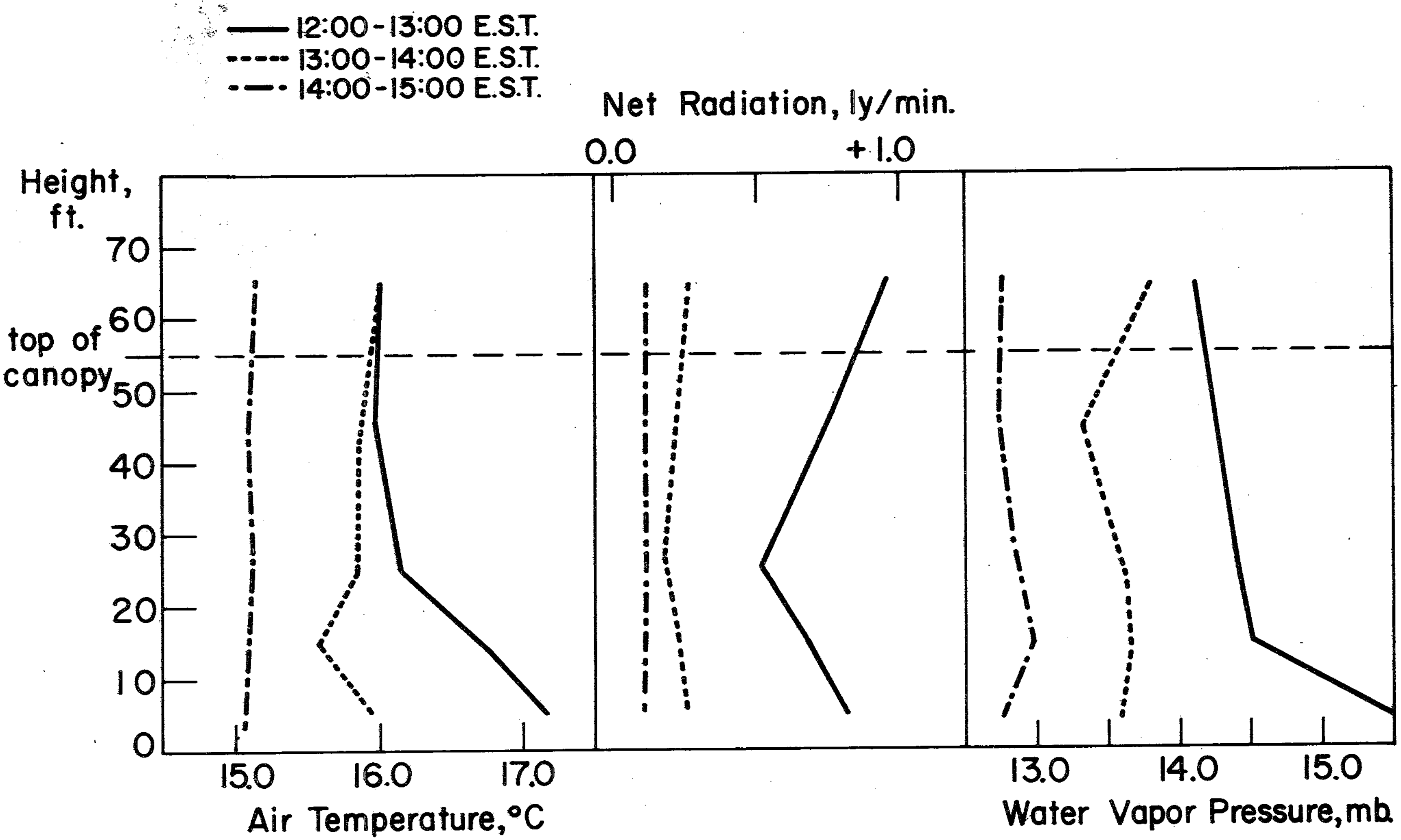


Fig. 10 Vertical Profiles through the Canopy at the Mohawk Campus, 4 / 9 /67.

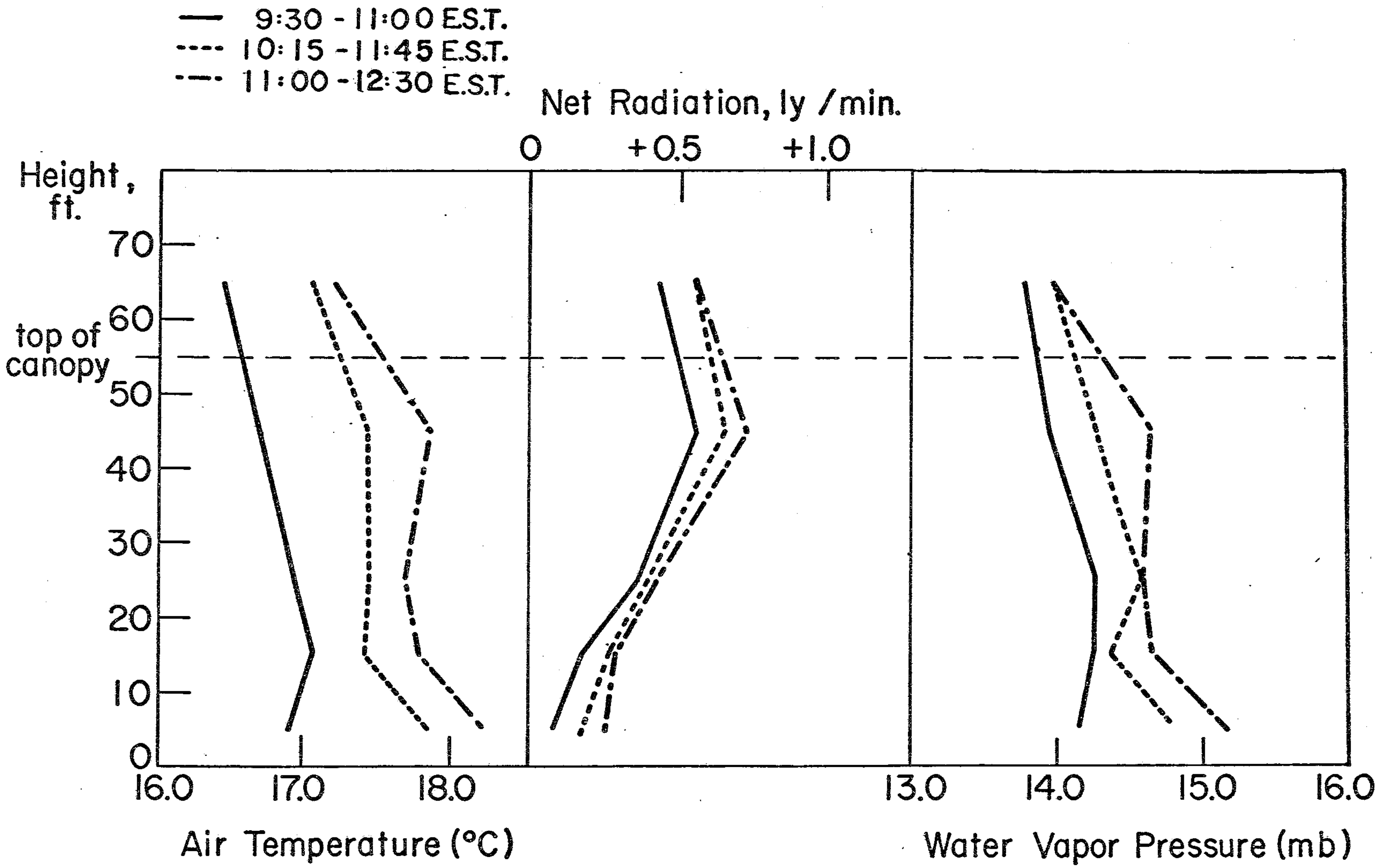


Fig. 11 Mean Vertical Profiles through the Canopy at the Mohawk Campus, 5/23/67.

Table 1: Meteorological conditions during sampling periods.

Date	Time Interval EST	Mean Air Temperature at 8'	Sky Cover	Mean Wind Speed at 10'	Comments
4/9/67	12:00-13:00	15°C	Clear	5 mph	Forest floor covered with fairly dry dead leaves, last precipitation was light snow two days ago, no leaves on trees, no precipitation during sampling period.
	13:00-14:00	16°C	Variable, sky hazy	7 mph	
	14:00-15:00	17°C	Overcast thick stratus	9 mph	
5/23/67	9:30-11:00	17°C	Clear	4.2 mph	Forest floor flora and trees are foliaged.
	11:00-13:30	18°C	Clear	6.7 mph	

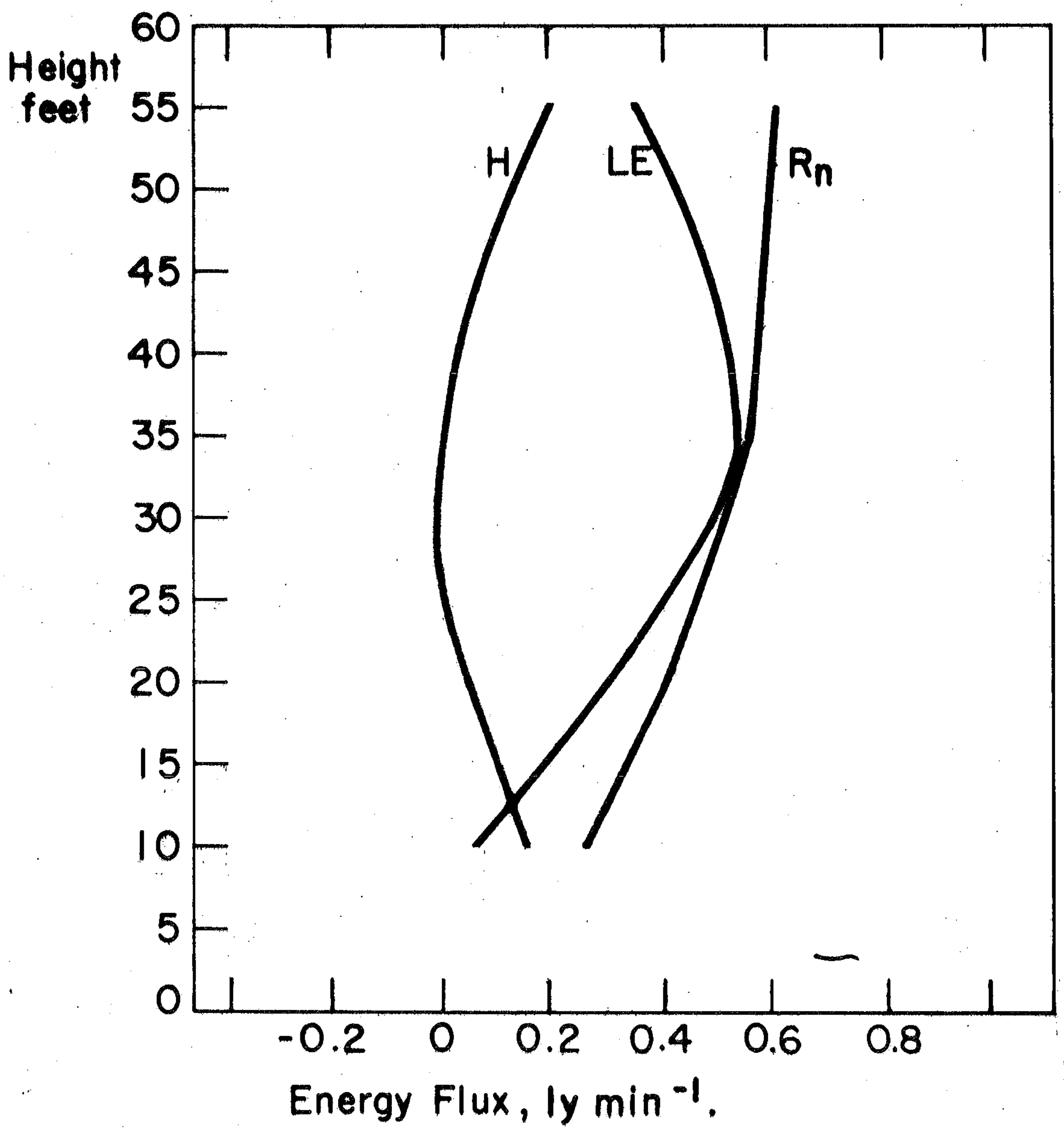


Fig. 12 Energy Flux Profiles, 10:15 - 11:45 E.S.T., 5/23/67.

Energy Balance Calculations

The energy balance has been completely computed for the conditions of May 23, 1967. The results agree with those of Denmead (1965) with regard to the vertical distribution of sources and sinks of energy in the forest.

The terms of the energy budget as measured and calculated are summarized in Table 2 and plotted in Figure 12. The flux of latent heat is greater than the sensible heat flux everywhere except at the lower layer. The latent heat flux profile shows the canopy to be the major source of water vapor on this date. Both the canopy and the surface of the earth are sources of sensible heat flux. An encouraging aspect of these calculations is that the net vertical flux of energy between any two horizontal levels is very close to zero.

Some storage terms which Denmead (1965) neglected were found to be significant for the conditions in the present study. Figure 12 shows the vertical variation of the three storage terms as a function of height. All three terms have similar profiles. The greatest storage per unit vertical height occurs near the earth's surface. A secondary maximum occurs in the lower portion of the canopy and the storage is less in the upper parts of the canopy where the maximum attenuation of incoming radiation is occurring. This may be a result of the effect of turbulence being greater in the upper canopy.

The values of the fluxes at the twenty-foot levels are uncertain. The actual gradient of temperature and water vapor pressure is positive at this level indicating that there should be downward fluxes. Substitution of the data for this level into Equation (10) results in a negative diffusivity, which when used in the flux Equations (6, 7) gives a net upward (positive) flux. The physical significance of a negative diffusivity is that there is an active diffusion against the normal gradient diffusion. The values in Figure 11 at the twenty-foot level do not seem to represent real physical energy fluxes. Assuming that the profiles are correct, then the storage term, G(z), would have to be larger to obtain a positive diffusivity. This means that at least 0.33 ly/min must be accounted for. Since this is inconceivable considering the order of magnitude of the calculated storage terms, there must be an energy sink such as horizontal advection which is not being considered in the present model. Another possibility is that penetrative convection occurred in this layer as a result of the warmer surface layer below, resulting in the breakdown of the energy balance model, which is based on gradient transport mechanisms. Preliminary calculations of energy budgets have been done on other occasions and this failure of the model occurs several times in the same lower layer of the canopy.

DISCUSSION

The equipment designed and constructed in this study has fulfilled

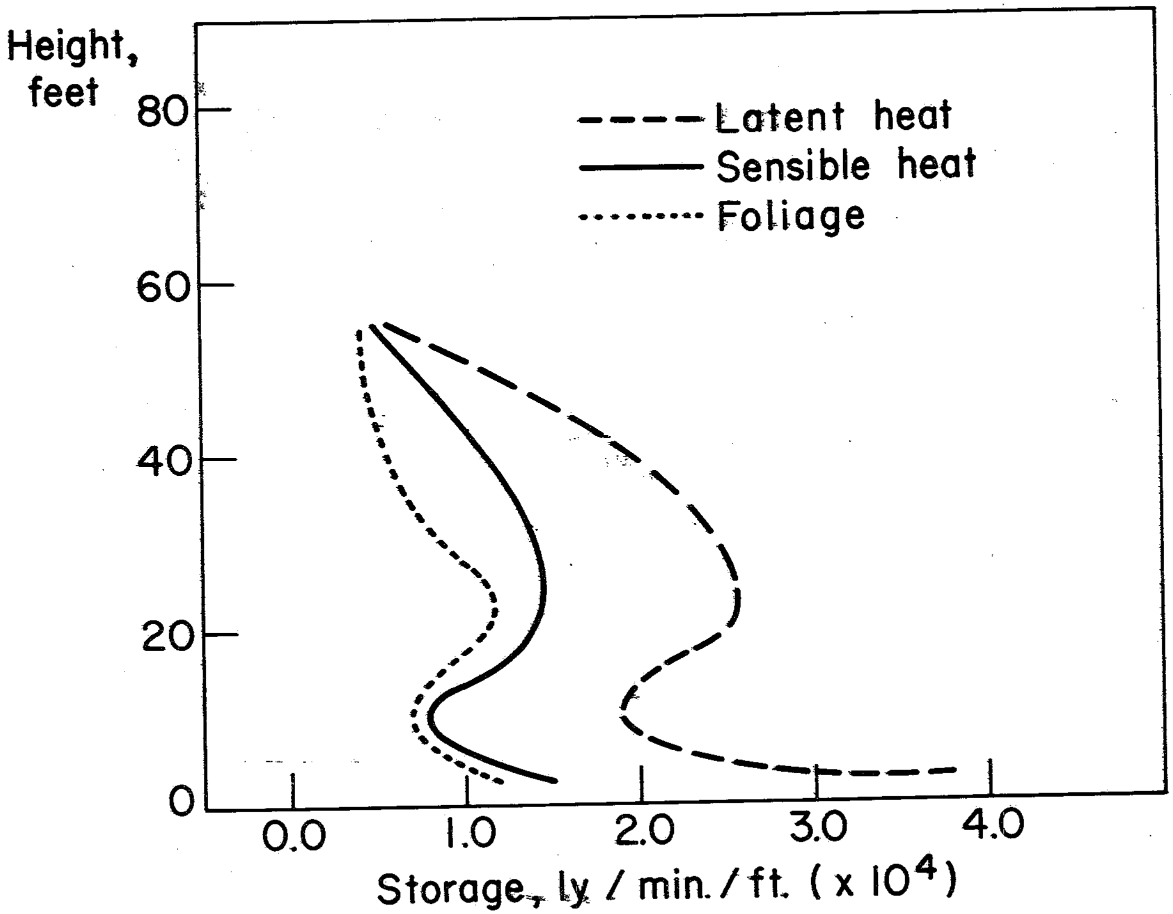


Fig. 13 Atmospheric and Foliage energy storage per unit height, 10:15 - 11:45 E.S.T., 5/23/67.

Table 2: Terms of the energy budget, 5/23/67.

Height Feet	Diffusivity cm^2/sec	Sensible Heat Flux ly/min	Latent Heat Flux ly/min	Net Radiation ly/min	Storage Rate ly/min
55	20,900	0.199	0.358	0.612	0.054
35	18,400	-0.011	0.532	0.567	0.046
20	-8,320	0.032	0.304	0.376	0.041
7.5	5,320	0.182	0.064	0.248	0.038

original expectations. The installation and maintenance of a single package of sensors was easier and safer than those for sensors at fixed levels on the tower in that all work was done at the base of the tower after the upper pulley had been installed. The use of the remote microswitches proved to be an accurate and reliable method of controlling the sequencing of data levels. The economic advantage of the equipment is shown by the fact that the cost of constructing the instrumentation and control system without the recording instruments was about $1,500, including labor. This is about the same as the cost of net-radiometers alone for a five-level fixed-sensor system.

The only limitation to recording extended periods of data in the present work was the size of fuel supply on the portable electric generator. Analysis of data revealed interesting changes in gradients during the averaging periods. An increase in the speed of movement of the sensor package to about 15 cm/sec is recommended in order to allow use of shorter averaging periods.

A comparison of profiles with those from a fixed-level system is not yet available. Five hours of temperature data from clear and fairly calm conditions were studied for the temporal variation of gradients. The results under these conditions were encouraging because: (1) the gradients between levels were clearly defined; (2) the gradients usually showed reversal either as the result of general trends or when conditions were nearly isothermal during the entire period; and (3) the unequal spacing of data in time for the different levels did not appear to have any effect on the results. The agreement between the calculated profiles and observed conditions, gives strong support to the use of a single sensor package system in forest studies.

In general, the energy balance calculations were reasonable for the observed conditions and were comparable to the results of Denmead (1965). The reason for the failure of the model in the lower canopy is not understood, although it is strongly suspected to be the result of horizontal variation of net radiation. This points out the need for extending the model to account for horizontal variations as has been suggested by many authors. The present equipment could easily be used for measuring horizontal variations. The fact that the method of recording would allow the use of a single set of recording instruments from several sensor packages is an added advantage. Hence, the instrumentation developed promises to be ideal for future research on the horizontal as well as the vertical processes in forests.

CONCLUSION

It is concluded that the single sensor package system of data acquisition in forests is economically and operationally superior to a fixed level sensor system for determination of several days of data.

Although no absolute check on the accuracies of the computed means are available, the physical consistency of the results can be taken as an indication that the system is giving accurate results. The comparison of results with a standard tower will be necessary before a statement can be made regarding the potential of the system.

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THE PREVAILING WINDS ON WHITEFACE MOUNTAIN AS INDICATED BY FLAG TREES

Edmond W. Holroyd, III

The Prevailing Winds on Whiteface Mountain as Indicated by Flag Trees

By

Edmond W. Holroyd, III

ABSTRACT

The flag trees on Whiteface Mountain in New York's Adirondack Mountains were studied to determine the direction of the prevailing winds. Using both the direction of branch growth and the position of reaction wood in the trunk tops a very complex wind pattern was found. Wind instruments placed at various locations on the mountain during summer recorded the same prevailing winds as indicated by the trees.

INTRODUCTION

A flag tree or banner tree, as it is sometimes called, is a tree with a conspicuously asymmetric crown, having the longest branches on the opposite side if the trunk from the shortest. The asymmetric shape may be related to the wind direction through a number of possible mechanisms. Trees exposed to severe winds near the summit of a high mountain may lack branches on their windward side due to the killing of the buds by desiccation and by abrasion of ice particles, as discussed by Daubenmire (1943, 1947). During a particular storm branches on the windward side of the tree may be removed by breakage due to an excessive accumulation of glaze (Lawrence, 1939). A fourth method of flagging is by a constant, strong wind pressure from one direction during the growing season; this results in the bending of nearly all branches, especially those on the windward side, toward the leeward side of the tree (Warming, 1909, Lawrence, 1939, and Daubenmire, 1947). These mechanisms have their effect during different seasons: branch bending is an expression of winds during the summer months; abrasion by ice particles and sand occurs when these are present and airborne; desiccation of buds acts during the winter months; breakage by glaze and rime results from the winds during the seasons when glazing occurs or from particular storms which produce the damage.

The trunk of the tree may be influenced by the prevailing winds during the growing season. There is an asymmetric growth of the annual rings in conifers, with most growth on the leeward side due to the formation of reaction wood (Daubenmire 1947, and Sinnott 1952).

Phototropism frequently produces asymmetries in trees, but the directions in which the branches point are random. A tree flagged by the wind can be distinguished from these because they point in the same direction as all the other flag trees in the neighborhood. Only wind-flagged trees were considered in the work which follows.

PROCEDURE

The trees on Whiteface Mountain were examined to determine the causes of flagging. There was rarely evidence of breakage, even on trees near the peak. This indicates that accumulation of glaze and rime ice has only a small role, if any. A few dwarfed trees near the summit were cut about two feet from their tops to determine the direction of the summertime prevailing winds from the position of reaction wood. This was found to coincide with the direction of flagging, produced by summertime branch bending and wintertime desiccation of the buds. Since desiccation has the greater effect on these trees, this indicates that the directions of the summer and winter prevailing winds near the summit are approximately the same. Trees lower on the mountain were flagged by branch bending only and so record the direction of the prevailing winds during the summer.

During the summer months of 1963 and 1965, records were made of the direction of flagging of the trees on Whiteface Mountain in the northeastern Adirondack Mountains of New York. The directions were measured by aligning the edge of a Silva magnetic compass with the flagging direction. For each tree true direction rounded to the nearest ten degrees was recorded along with species, an identifying number, and an indication of the point from which the tree was observed. The last identification was required since most trees were examined from a distance. The flag trees in the valleys were most easily seen from a nearby ridge, and often such a vantage point was required. Whenever the trees were observed from distances greater than about one hundred yards, binoculars were used to determine direction of flagging. It is believed that the error in distant observations is within $\pm 10°$ for the first half mile, $\pm 20°$ for the next half mile, and $\pm 30°$ from there up to two miles. The direction of flagging was often checked in conifers by observing the position in the trunk of reaction wood, which is on the leeward side of the tree. The locations of the trees and the observation points were recorded on enlarged topographic maps.

Different species growing together flag different amounts. The order of sensitivity on Whiteface Mountain is white pine, red pine, red spruce, balsam fir; other conifers, scotch pine, hemlock, and white cedar, which were encountered less frequently, show good flagging, but their relative degrees of flagging could not be determined. The deciduous trees do not show good flagging, but of this group the birches and aspens are best. The conifers were preferred as indicators; hardwoods were used only if conifers were absent and when the trees could be examined from a distance of less than one hundred feet.

The prevailing winds at a few locations were measured for a comparison with the flagging directions. Several wind instruments have been set out by the Atmospheric Sciences Research Center during the summer months for various purposes. The months and duration of these observations are shown in Table 1. Some instruments were well exposed to the winds; others were not and indicate very light winds. The data from these instruments were analyzed to determine the average velocity from each direction and the vector

Table 1: Times and durations of wind measurements on Whiteface Mountain. The wind data are plotted in Figure 6.

Station No.	Operation Dates	Total Operation Hours
1	July 1965	365
2	July, August 1965	1214
3	July 1965	239
4	September 1962	1218
5	August 1965	308
6	July, August 1964	1123
7	July 1965	422

average of all winds. The vector average of the winds was determined by reducing the winds to north and east components, adding the components for all winds, dividing by the number of observations comprising the sum, and converting the average components back to direction and velocity. This computation gives the averaged resultant of the flow of air. Its direction is most important in this study. The velocity of the vector average indicates its significance. A low velocity would result from light winds or winds having a highly variable direction.

RESULTS

Figures 1-5 are maps showing the direction of the prevailing winds as indicated by the flag trees. Figure 1 shows the indicated wind patterns around the entire mountain. Figures 2-5 are enlargements of sections of Figure 1 and show the details of the wind patterns. Short lines indicate the directions shown by the flag trees at nearly two thousand points on the mountain. Each point may represent up to a hundred trees, especially near the summit, or only one tree in regions where conifers are scarce. Long arrows are interpolated to show the general flow of air. The length and spacing of the arrows have no significance in any of the figures. Segmented arrows show the direction of the air flow as it passes into the upper air at ridges. Areas of no flagging can be assumed to be areas of light or turbulent winds or even calm. They are generally in places sheltered from the prevailing winds by nearby ridges or cliffs.

The polar coordinate diagrams of Figure 6 show average velocity of winds at the several points studied, together with their vector average. Only those directions having a frequency of occurrence of five percent or greater have been plotted. During the ten day period of operation of the wind station north of the peak of Whiteface Mountain there was an abnormally large amount of east and southeast wind. This has considerably distorted the wind rose for this station. Although these are summertime data and of short duration, comparison with adjacent flag tree directions shows that the direction of the vector average is nearly the same as that of the flagging of nearby trees.

While the observations of the flagging directions were being collected, it was noticed that usually the wind actually blew in the direction indicated by the trees, particularly along the ridges. The eastern valleys were the only places where the winds were flowing in the opposite direction when the observations were made. This reverse flow of air was due to the heating of the eastern slopes of the mountain by the morning sun, causing up-valley breezes. These winds sometimes reached velocities in excess of twenty knots, but they were mostly in the range of five to ten knots. During the night in these same valleys there were strong drainage winds of a much higher velocity and parallelling that indicated by the flag trees. In these localities the night drainage winds apparently had more of an effect on the trees than the daytime up-valley winds.

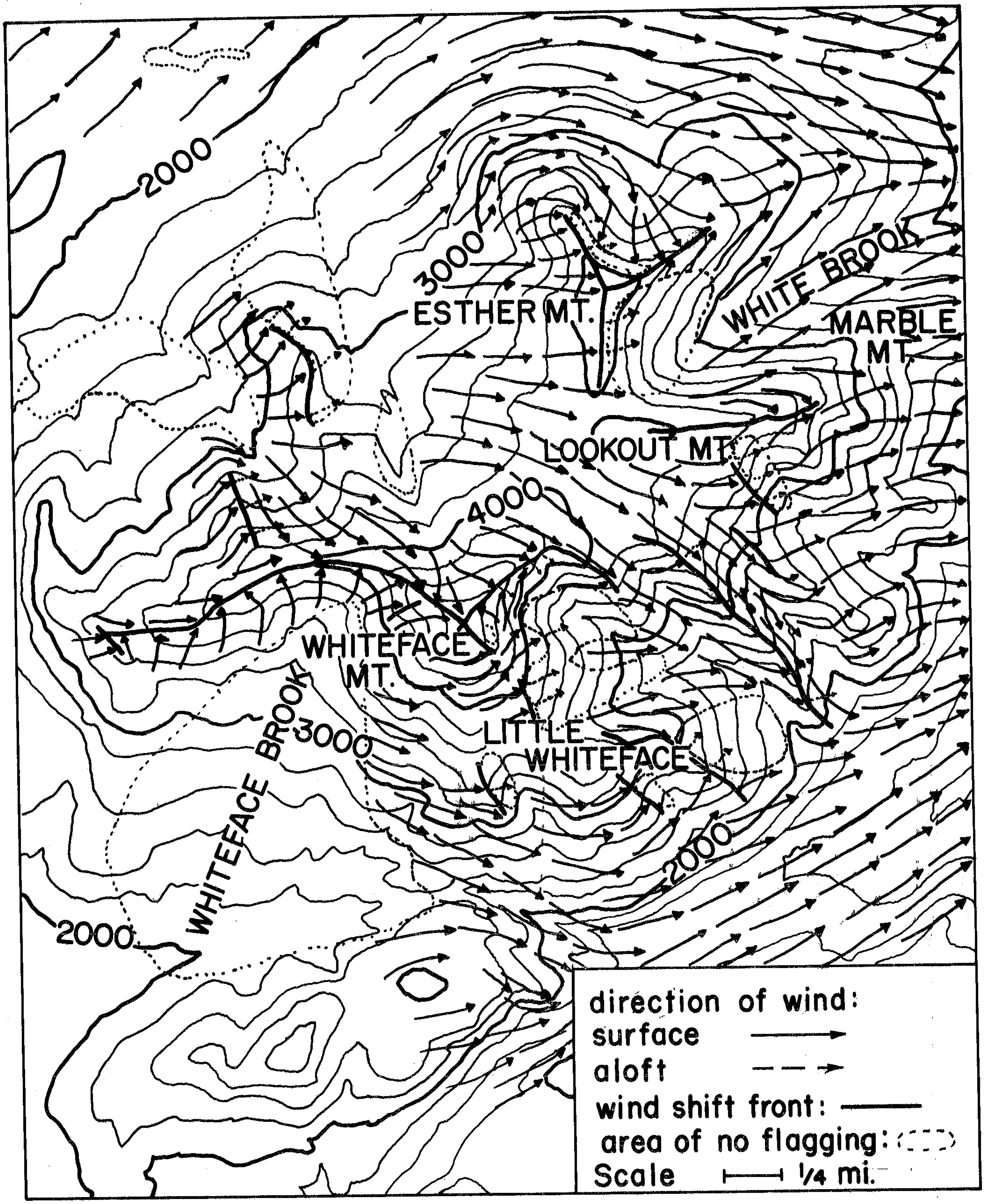


Figure 1: The wind patterns on Whiteface Mountain as indicated by flag trees.

As shown in Figures 1-5, ridges are often the positions of wind-shift fronts. Streams of air from the two sides of a ridge meet at the top at an angle or sometimes head-on. In such cases, one wind is usually stronger than the other. By observing cloud fragments in these streams of air, the flow pattern can be determined in such regions. Along the northeast ridge of Whiteface Mountain above 4400 feet the air coming from the northwest rides over the air coming from the south and both go into the upper air. This pattern is repeated on Esther Mountain and at many other places in the Whiteface area.

DISCUSSION

The eastern ridges and valleys shown in Figure 3 have a complex flow pattern. The general wind direction for that region is from the southwest, as indicated by the winds in the Ausable River Valley below and on the tops of the ridges. However, there are drainage winds in the bottoms of the mountain valleys whose heads meet the northwest winds of the plateau near Lookout Mountain. The air flowing over the mountain travels down these valleys beneath the air coming around the mountain from the southeast. Figure 7 shows the vertical cross section from Little Whiteface Mountain to Marble Mountain of the air and ridges to illustrate this pattern.

The White Brook Valley east of Esther Mountain (Figure 2) is the location of very strong night drainage winds, averaging more than fifteen knots with gusts often reaching forty to fifty knots. These winds were instrumental in the closing of the ski slopes on the north side of Marble Mountain since they blew the snow off the trails and into the woods shortly after it fell. The steep sides of this glacial valley channel the winds into one large stream of high velocity air. Some air flows up the west side of the northwest ridge of Esther Mountain. The rest goes around the ridge and up the east side and forms an opposing wind at the top. The westerly winds are stronger on that ridge.

Little data could be obtained from the northwest side of Whiteface Mountain below the toll road (Figures 1 and 4), a region of few tall conifers, due to logging and fires about a half century ago.

The large area on the south side of Whiteface Mountain in the Whiteface Brook Valley is one of no detectable flagging, indicating a region of calm or light winds. Neither are there any of the blowdown areas which are so frequent elsewhere on the mountain. The lack of strong winds in this region may be due to a blockage of the winds by mountains on the northwest side of Lake Placid, but it is more likely caused by a damming of the air by the south ridge of Whiteface Mountain. The south ridge, when seen on a relief model, seems to have a shape which could produce and hold a pool of relatively stagnant air in the Whiteface Brook Valley over which the prevailing wind rides. It was observed that there are trees on the south ridge which were flagged by a west wind, but due to poor weather and a lack of time, this ridge has not yet been examined in detail. The cause of the area of no

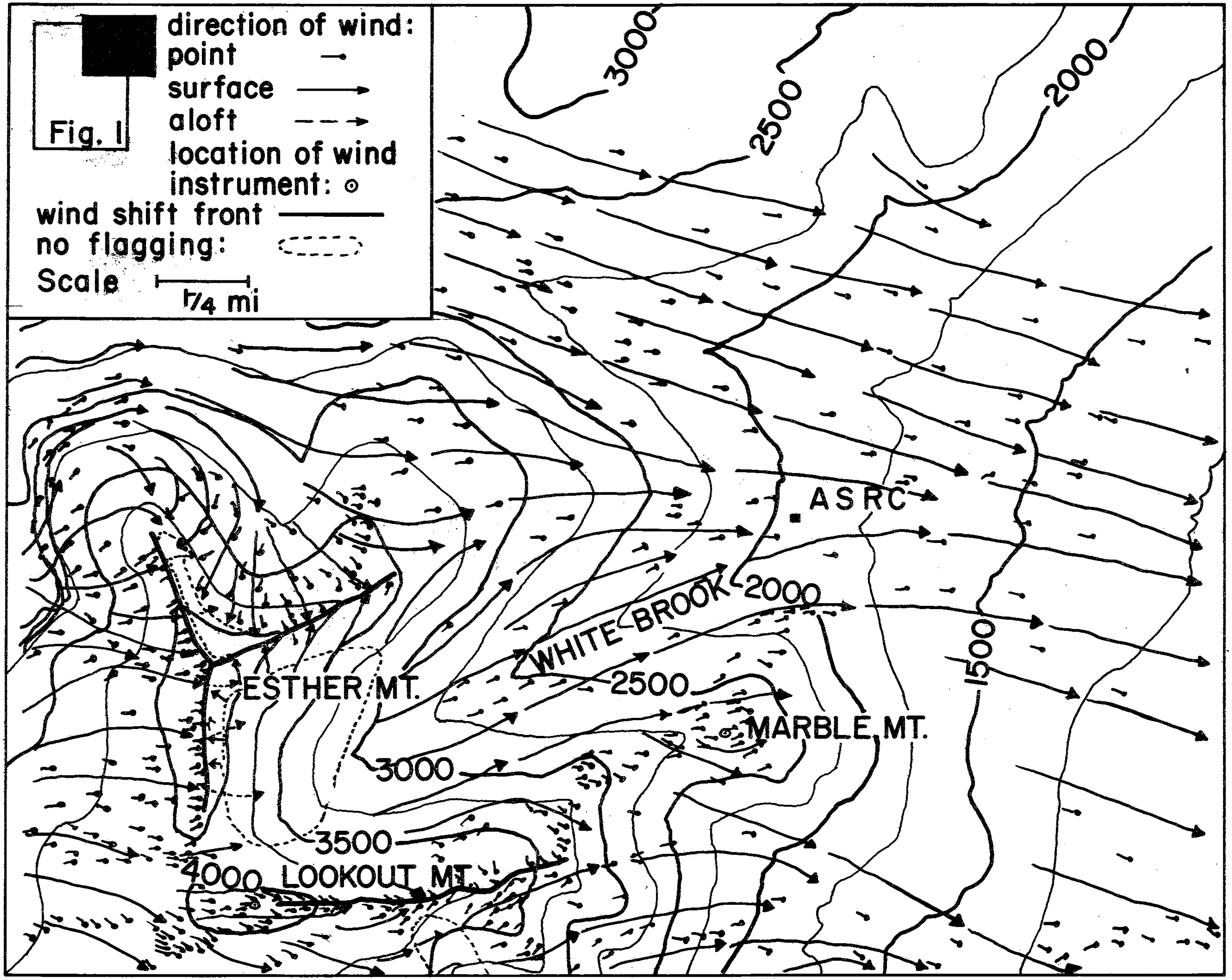
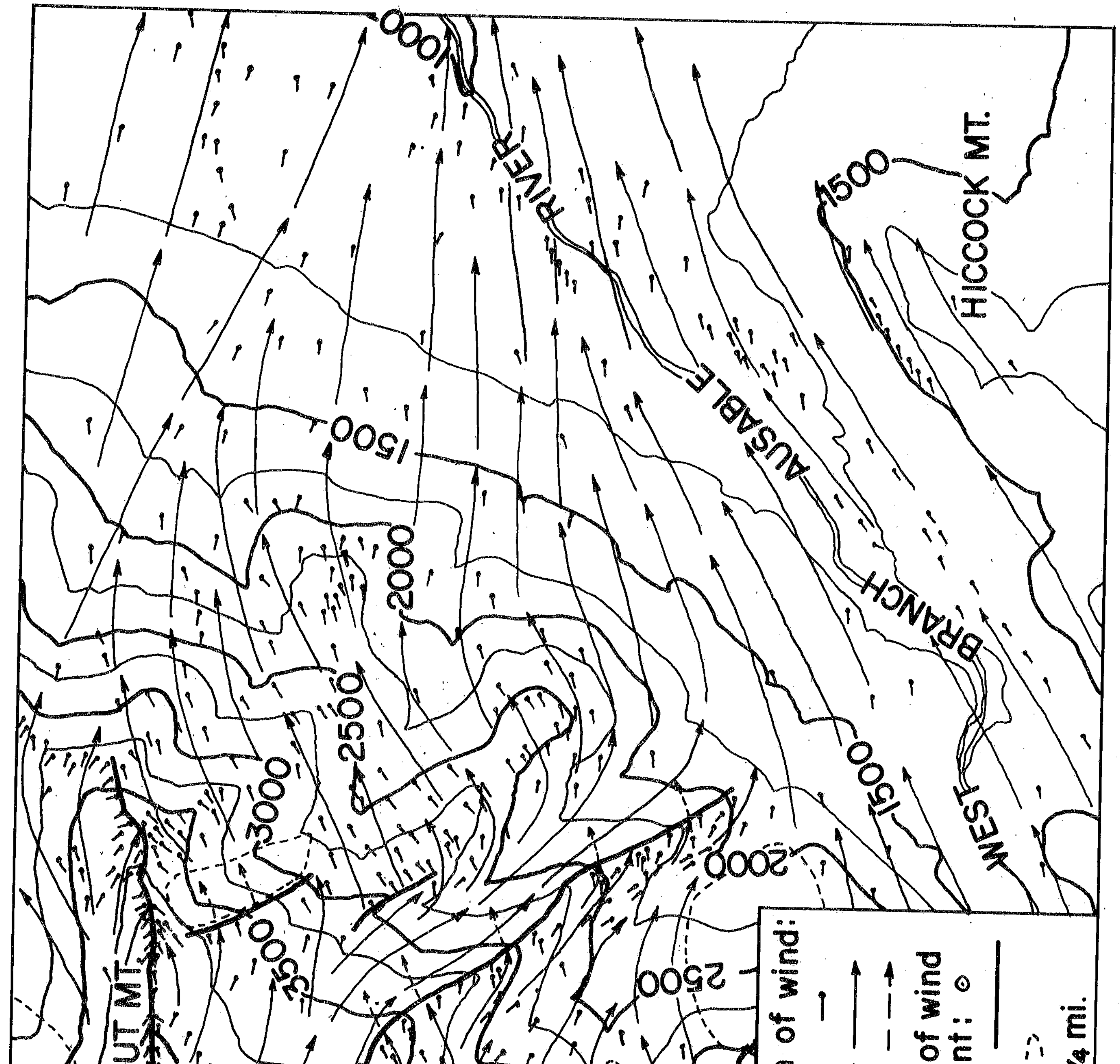
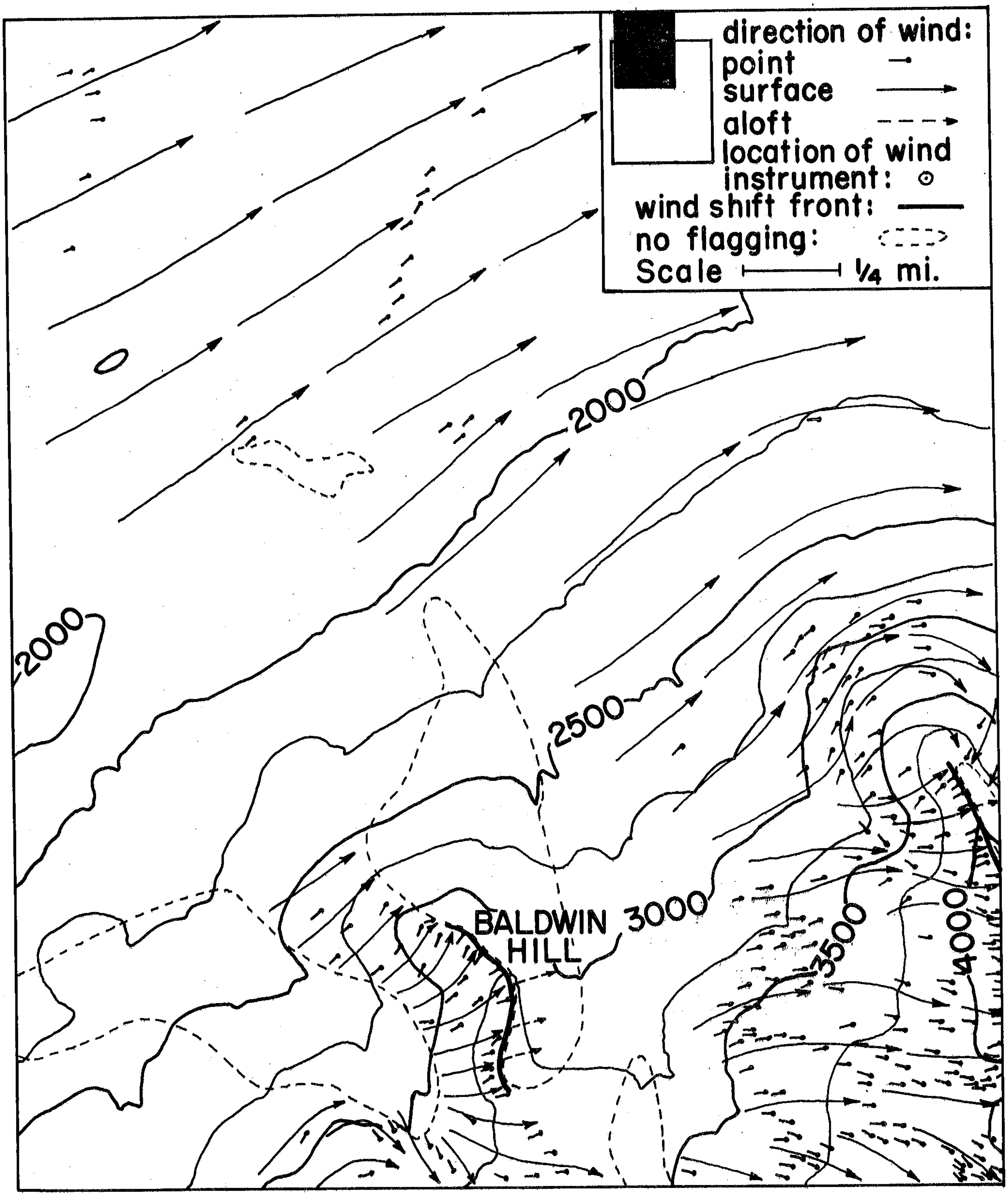
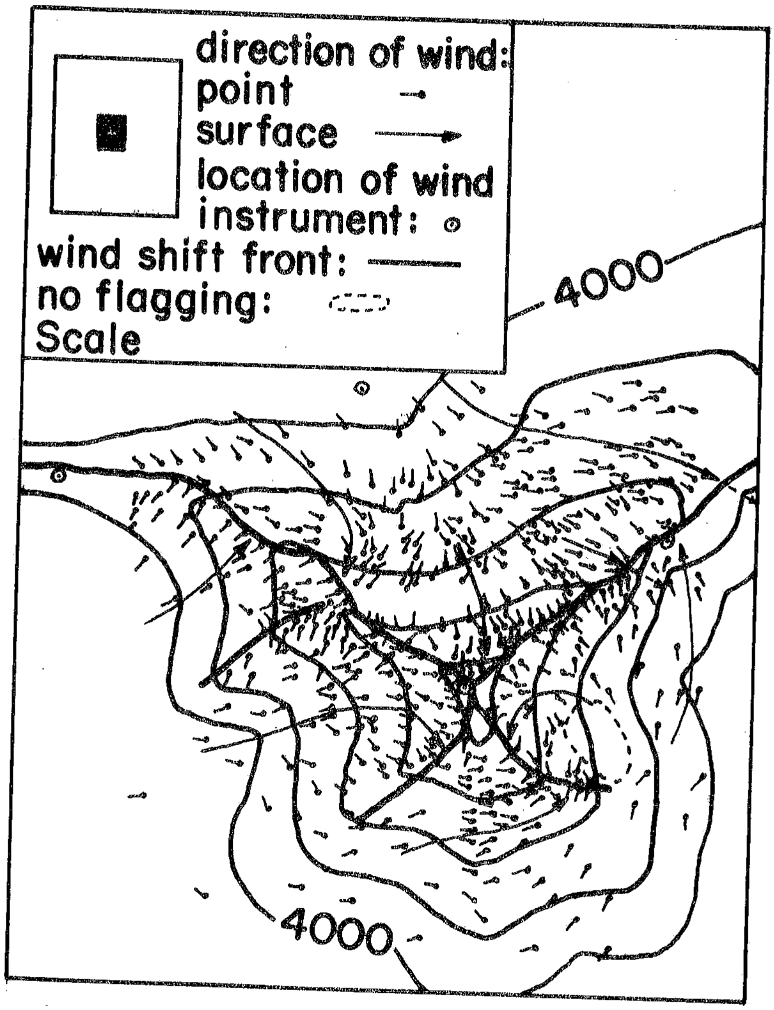


Fig. I
direction of wind:
point
surface
aloft
location of wind instrument:
wind shift front
no flagging:
Scale
1/4 mi
3000
2500
2000
1500
ASRC
WHITE BROOK
2000
2500
3000
3500
4000
ESTHER MT.
MARBLE MT.
LOOKOUT MT.


LOOKOUT MT.
HICCOCK MT.
WEST BRANCH AUSABLE RIVER
1000
1500
2000
2500
3000
3500
4000
Fig. I
direction of wind:
point
surface
aloft
location of wind instrument:
wind shift front:
no flagging:
Scale
1/4 mi.


direction of wind:
point
surface
aloft
location of wind instrument:
wind shift front:
no flagging:
Scale 1/4 mi.
2000
2000
2500
3000
3500
4000
BALDWIN HILL


direction of wind:
point
surface
location of wind instrument:
wind shift front:
no flagging:
Scale
4000
4000

flagging may be resolved once this ridge has been accurately mapped for flagging directions.

The most complex pattern is found on the peak of Whiteface Mountain shown in Figure 5. Flagging indicates that air is rising upwards towards the peak from every direction, and every ridge produces some anomaly in the wind pattern. The vortex just east of the peak is shown by the behavior of cloud fragments as well as by the tree crown.

Looking at the mountain as a whole in Figure 1, one sees that air tends to flow over this mountain rather than around it. This resulting orographic uplift is the cause of the frequent cap clouds which obscure the top of the mountain and the view from it. These clouds are an important source of moisture for the peak, depositing water on all exposed objects in the form of fog drip, or as rime ice in the winter.

The method presented in this paper for obtaining detailed wind direction information over a large area does not require the establishment of wind recording stations or other elaborate equipment. Using binoculars, a compass, and a map the many years of wind data recorded in flag trees may be studied in a few days or weeks, depending on the area investigated. The detail of such a tree survey depends on flag tree density and on the analyst's ability to concentrate the data for regions of high density on a map. The disadvantages of this method become evident in regions of low wind velocity. The slight asymmetries in the flag trees makes measurement difficult, and errors of ±20° are common.

The ultimate proof that flag trees are good indicators of the direction of the prevailing winds will come from long, detailed measurements of the prevailing winds. This would require instrumentation of the region under study, which for Whiteface Mountain with its complex wind patterns, would be expensive in either time or money.

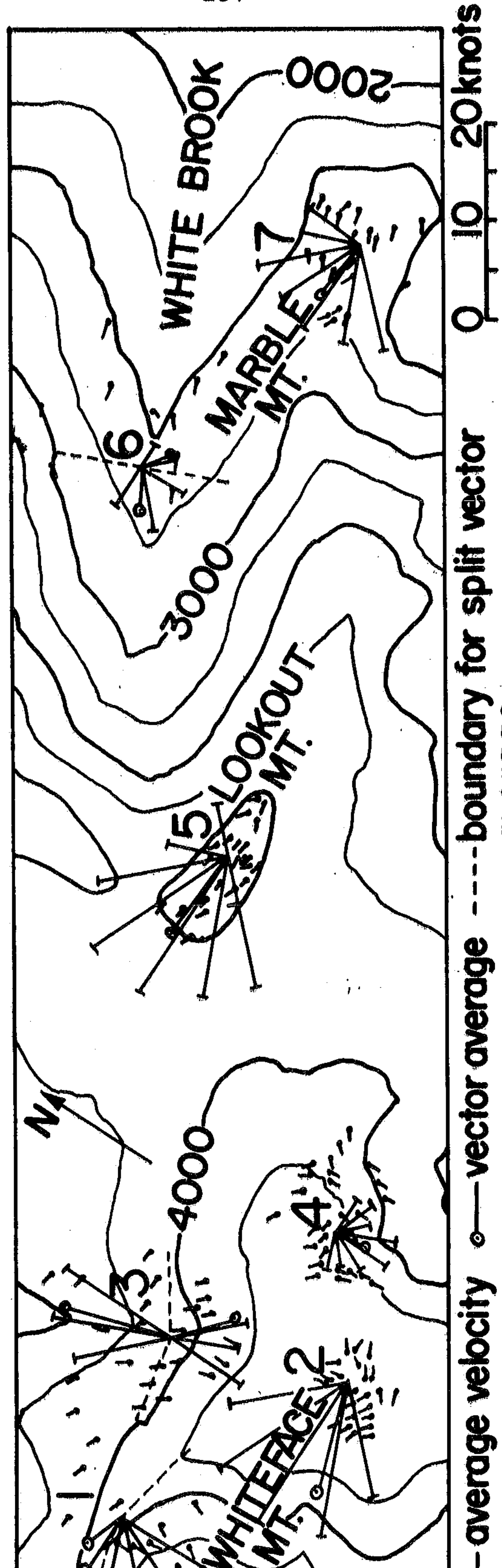
The above method of examining trees gives the average wind direction during the growing season very easily. However, to obtain wind velocity the degree of flagging might be calibrated to give a rough value for the velocity. Since different species flag different amounts for the same winds, it would require a calibration of each species of flag trees to obtain velocities for a region like Whiteface Mountain.

APPLICATIONS

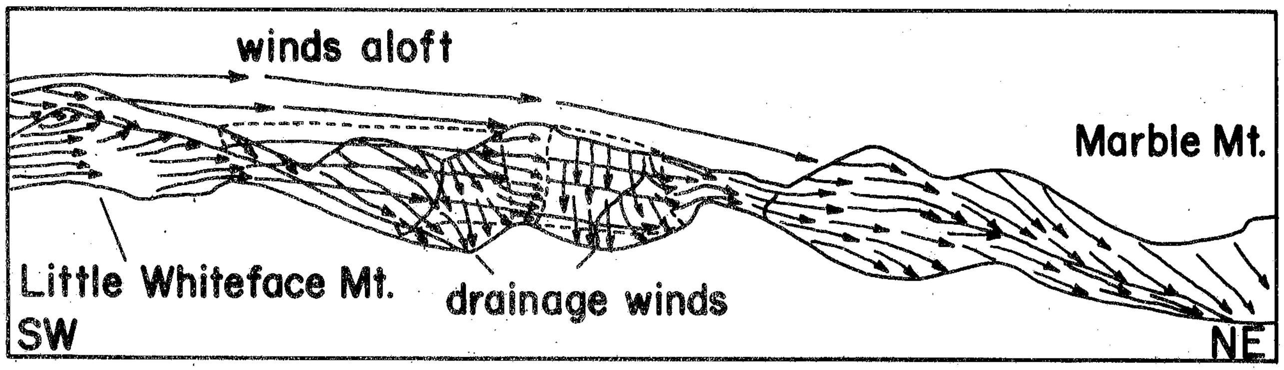
Even without velocities, tree flagging indications of the wind should be very useful. When combined with a topographic map, the direction of the wind will show regions of rising or subsiding air. The regions of uplift will generally be more moist due to orographic condensation and precipitation, while areas of subsidence will generally be drier. Tree flagging can show areas of exposure to strong winds and the drying associated with them. Flag trees can warn loggers of potential blowdown and help them pattern their

Figure 6: The average velocity from each direction and vector average of measured winds on Whiteface Mountain. The duration and months of the measurements are shown in Table 1. The center of each diagram is the instrument's location. The length of the lines shows velocity. Flag tree directions are plotted for comparison. For two stations the winds were split into up-valley and down-valley winds for the computation of two vector averages for each station; for a third the winds were split according to the valley from which they came (page 234).

Figure 7: A vertical cross section of the air flow in the eastern valleys from Little Whiteface Mountain to Marble Mountain showing the overlap of the streams of air. The vertical scale is unexaggerated. The depth of view is two-thirds of a mile, and the horizontal extent of the sketch is two and one half miles (page 235).



—— average velocity ○—— vector average - - - boundary for split vector average


winds aloft
Marble Mt.
Little Whiteface Mt.
drainage winds
SW
NE

cutting according to the local prevailing winds (Alexander, 1964). A map of these winds would aid in predicting fire behavior and movement, and the dispersal of seeds and pollen. A close observation of flag trees would also aid in the location of ski runs. Pockets of calm air would be ideal, and failures due to high winds across the runs, such as occurred on Marble Mountain, could be avoided.

ACKNOWLEDGEMENTS

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