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HEADQUARTERS
QUARTERMASTER RESEARCH & ENGINEERING COMMAND
U S ARMY

TECHNICAL REPORT
EP-80

TEMPERATURE DIFFERENCES IN HARVARD FOREST AND THEIR SIGNIFICANCE

QUARTERMASTER RESEARCH & ENGINEERING CENTER
ENVIRONMENTAL PROTECTION RESEARCH DIVISION

JANUARY 1958 NATICK, MASSACHUSETTS

HEADQUARTERS
QUARTERMASTER RESEARCH & ENGINEERING COMMAND, US ARMY
OFFICE OF THE COMMANDING GENERAL
NATICK, MASSACHUSETTS

Major General Andrew T. McNamara
The Quartermaster General
Washington 25, D. C.

Dear General McNamara:

It is a pleasure to transmit to you this report, "Temperature Differences in Harvard Forest and their Significance," by Colonel Herbert H. Rasche, QMC. This report is based on one of the first field studies of local climate sponsored by the Quartermaster Corps. The report provides much information concerning diversity of environmental conditions in a region of humid continental climate with severe winters, a type of climate encountered by our troops in many parts of the world. It is the third and most comprehensive report in a series dealing with aspects of microclimatology in diverse environments. Later microclimatic studies conducted under the auspices of the Quartermaster Corps are providing a wealth of detailed information concerning environmental conditions in subpolar, middle-latitude, desert, rainy tropical, and mountainous regions, and are showing the relationship between the local climates and the associated ground and vegetation conditions.

The author of this report, who is at present Corps Quartermaster, First Corps (Group), Korea, served in the Environmental Protection Research Division of this Command on two separate tours of duty after completing his graduate study. During these tours of duty he helped to supervise the active environmental research program of that division. A number of other officer-scientists trained under Army auspices have been or are now similarly assigned to the research divisions of this Command. Their total contribution to Army research has been significant, and fully justifies a vigorous policy of special graduate scientific training for Quartermaster officers. These officers take their turn with all other Quartermaster officers on general-service type field assignments, and as a result they develop a broad and realistic point of view based on both practical experience and theoretical training and research. This stands them in good stead on later assignments.

The present report, a significant contribution in the relatively new field of microclimatology, is an example of the scientifically fruitful results of the officer-scientist training program.

Sincerely yours,

C. G. Calloway

C. G. CALLOWAY
Brigadier General, USA
Commanding

1 Incl
EP-80

HEADQUARTERS QUARTERMASTER RESEARCH & ENGINEERING COMMAND, US ARMY
Quartermaster Research & Engineering Center
Natick, Massachusetts

ENVIRONMENTAL PROTECTION RESEARCH DIVISION

Technical Report
EP-80

TEMPERATURE DIFFERENCES IN HARVARD FOREST AND THEIR SIGNIFICANCE

Herbert H. Rasche, Ph. D.
Geographer

REGIONAL ENVIRONMENTS RESEARCH BRANCH

Project Reference:
7-83-01-005A

January 1958

FOREWORD

The complex nature of modern warfare has made it increasingly necessary for military planners to consider the nature of the environments in which war must be waged, and to consider the nature of the men called upon to wage such warfare. If a field commander can know in advance weather and ground conditions, and the capabilities of his men and weapons, he will be in a much better position to plan his operation than without such vital information. In these days when much highly specialized equipment is used by military forces and when weapons, before firing, must be carefully adjusted according to temperature, wind, humidity, and other ambient conditions, it is essential that the commander have knowledge of the weather at the weapon site itself. Military history is full of examples of opportunities lost and defeats sustained by field commanders who ignored or misjudged environmental conditions in their area of operations. Plainly observable or foreseeable differences or changes in such environmental conditions sufficiently advantageous or disadvantageous to assure victory or to impose defeat were overlooked until too late.

The Quartermaster Corps, because of its critically important mission of assuring that the fighting man is adequately and properly fed, clothed, and equipped for maximum efficiency in the field in any kind of environment, has for many years conducted a varied and far-reaching program in environmental protection research. Within this broad program a considerable effort has understandably been devoted to climatic research, particularly to the climate near the ground, or "the climate of the soldier". The products of this research have been widely applicable to military planning in many services and to many civilian scientific studies as well. The Quartermaster Corps has been assigned Army-wide cognizance for "Applied Environmental Research" and has played an important role in the responsibility for planning and conducting Defense Department environmental research.

The present report is one of a growing series dealing with local climate studies conducted by or under the supervision of the U.S. Army Quartermaster Corps. The program encompasses studies in very greatly contrasted regional environments, all of great military-scientific interest. The report illustrates the extent and nature of the differences that may be expected in temperature conditions within a relatively small area of moderately varied relief. The field study was conducted by the author, a Quartermaster officer-geographer, while completing his graduate residence under Quartermaster auspices at Harvard University in preparation for Army duty assignments involving direction of environmental research programs in Quartermaster Corps and General Staff assignments.

The report deals chiefly with temperatures at standard weather shelter height. It deals mainly with horizontal distribution of factors rather than the greater vertical differences to be found at the ground surface and at various depths below and heights above the ground at any single point. The study therefore may be considered to be "topoclimatic" rather than "microclimatic". Nevertheless, it points out that local differences even at standard height are much greater than is generally recognized, and that the factors accounting for such differences are numerous and complexly interrelated. The localized nature of certain atmospheric conditions, particularly those associated with temperature inversions and air layering are discussed at length, and in readily understandable terms. Although such local conditions are treated chiefly as they are applicable to forestry, in line with the nature of the field study on which the report is based, the applications to military operations are evident.

It is made clear in this report that if one is to calculate the effect of any given set of environmental factors upon any military operation, one must observe or measure those factors at the place for which the calculation is made, or at a place where conditions are known to be closely similar in kind and degree. Data furnished from stations miles away and in differing topographic situations may prove to be gravely misleading.

AUSTIN HENSCHEL, Ph.D.
Chief
Environmental Protection Research Division

Approved:

JAMES C. BRADFORD, Colonel, QMC
Commanding Officer
QM R&E Center Operations

A. STUART HUNTER, Ph.D.
Scientific Director
QM R&E Command

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The appendixes contain temperature data obtained at Harvard Forest during the period of study, together with data from other New England stations cited for comparison.

TEMPERATURE DIFFERENCES IN HARVARD FOREST

AND THEIR SIGNIFICANCE

ABSTRACT

This study deals with local temperature differences in numerous contrasted parts of Harvard Forest in central Massachusetts, in the Eastern Upland of New England. The study was sponsored jointly by Harvard University and The Quartermaster General, United States Army. Field study extended from August 1947 through July 1948. The present report is a revision of a doctoral dissertation accepted by the Division of Geological Sciences, Harvard University, in May, 1953.

Method of Study and Presentation

The study was begun with nine stations, and gradually expanded until 38 maximum-minimum stations (in shelters) and 15 stations with only minimum thermometers (not in shelters) were in operation. Readings were taken once weekly. Instruments were placed at heights of five to seven feet from the ground. Eleven thermographs were used. Snow depths were measured at many points and, in spring and early summer, water-temperature readings were taken.

The report includes numerous diagrams of conventional types, together with several new types, including scales of temperature rank and frost likelihood according to site characteristics. Descriptions are given for each station, and include elevation, situation, surrounding vegetation, shelter type, and instrumentation. Photographs show many of the stations and illustrate seasonal contrasts. Appendixes include comparative Weather-Bureau data from eleven widely scattered New England stations outside Harvard Forest, complete chronological tables of temperatures observed at Harvard Forest, and additional tables showing stations ranked according to relative warmth or coldness each month, by maximum and minimum temperatures.

Findings

Local differences at Harvard Forest covered 1/4 to 3/4 the total differences noted among the eleven widely separated New England stations.

In general, hill stations had low maximums and relatively high minimums; valley stations had higher maximums and much lower minimums.

Northeast slopes had relatively low temperatures in comparison to west and southwest slopes, owing to differences in insolation and in exposure to winds.

Stations surrounded but not canopied by vegetation had higher maximums than comparable stations in the open. Those under a vegetative canopy had notably lower maximums. Both hardwood and coniferous forest had great moderating effect in summer; hardwoods had much less effect in winter.

Greater diversity in maximum temperatures was caused by differences of vegetation than by topographic situation. Open valley bottoms and west slopes had highest temperatures, open hilltops lower. Wooded valleys ranked still lower and wooded hilltops lowest of all.

In general, station ranks by minimum temperatures reversed the ranks for maximums. Hill stations had the highest minimum temperatures, upper slopes ranked next, lower slopes still lower, and valley bottoms (together with intermediate flats and hollows on slopes) lowest of all.

At all elevations the growing season was 1 1/2 times as long in well-wooded concave areas as in open concave areas of similar elevation. Contrasts between wooded and open areas were smaller on slopes and hilltops.

In late spring, water temperatures were 10 F. degrees higher in open ponds than below the shrub canopy in swamps; in summer, temperatures were 15 F. degrees higher in the open ponds than under the shrub canopy. Ponds in summer had a moderating effect on air temperatures at land stations nearby; but not when frozen, in winter. Nearby stations, "marine," in summer, became "continental" in winter.

Snow-cover was exceptionally deep and lasted 10+ weeks; its general effect upon the forest was benign, but contrasts in air temperature from place to place at night were exceptionally large. The ground became frost-free before the spring melt, and no serious flooding occurred.

Early winter snow-depths were greatest in the open. Later in winter, hardwood areas had as much snow or more. In coniferous stands accumulation was slow but steady, never so deep as in hardwoods, and remained longer in spring.

Conclusions

General Significance of Findings

From the findings in this study it was concluded that differences in topographic form, direction of exposure, and vegetative cover are all more important than local differences of elevation in determining temperature differences.

Standard-height readings, taken in open areas, give a useful general indication of regional temperatures. Such readings do not indicate contrasts characteristic nearer the ground, but reveal the diversity of local temperature patterns, and emphasize the importance of considering local site factors in choosing locations for climatic stations intended to be representative of the region. Large portions of New England's intermediate uplands have climates differing from those at nearby first-order Weather Bureau stations, situated mostly in valleys. The uplands, except in concave areas, have lower mean maximums, higher mean minimums, less frost danger, and longer growing seasons than are generally reported for the region.

Temperature Differences and Forest Patterns

Although temperature differences help to account for important local differences in forest type at Harvard Forest, the present distribution of species is probably influenced even more by differences in groundwater conditions and soils. Differences in daily maximum temperatures and in total amounts of heat energy available at given sites probably are more significant than differences in daily minimum temperatures or length of frost season in influencing species distribution.

Northern-forest types: Northern spruce forest is typical in poorly drained depressions with low soil temperatures, very low night temperatures, and the shortest growing season locally observed. Hemlock is common in all but the wettest parts. Northern mixed hardwood – evergreen forest is common on cool, moist, but well-drained sites, especially on lower slopes. Characteristic northern-forest species are yellow birch, beech, sugar maple, and paper birch, with some hemlock and white pine. In cooler, shadier places, hemlock is increasingly prominent. White pine is common in older-growth forests and on lighter soils; its distribution apparently is influenced less by temperature conditions than by soil factors, and by its long life span.

Transition forest occupies the major part of Harvard Forest. Numerous species compose it, together with northern species on cool sites and central species on warm sites. Red oak, though sensitive to frost when young, is an aggressive dominant on dry sites. White ash is common on terraces and swalesides, where water is abundant but not stagnant, days are sunny and warm, and nights comparatively cool for the region. On swale floors with standing water, red maple dominates, except where replaced by northern and other hardwood species through silvicultural management. The white pine-hemlock association is common on areas of lighter soil, where temperature conditions are favorable for either hardwoods or conifers.

Central forest is most common on warmer sites, especially on south and west slopes. Dominant species are white oak, shagbark hickory and (formerly) chestnut. White oak is most common on slightly lighter soils. Low minimum temperatures at bases of slopes do not inhibit hickory, which is remarkably resistant to frost; the long exposure of such sites to sunlight favors hickory.

Temperature Differences and Physiographic History

Preglacial and postglacial processes were controlled both by climatic cycles affecting the region as a whole, and by local small-scale climatic differences consequent upon topographic diversity. Minimum and mean temperatures probably were notably lower in valleys; and glacial and periglacial climates probably set in earlier and lasted longer there than on the rolling uplands. During periods of glacial wastage, ice probably remained in valleys long after uplands became clear.

In the early postglacial period, local temperature differences probably had a direct influence upon the manner of original establishment of the various forest types. Today each type persists in local areas having climate most like that which prevailed when that type was more extensive.

During almost all periods, and particularly when no general vegetative cover existed, temperature contrasts were marked; these affected physiographic agents and processes greatly and differently on uplands and in valleys. Through these processes, the temperature differences were an important contributing factor in the development of soil patterns and groundwater relationships which persist today; these soil patterns and groundwater relationships influence the present forest-type distribution even more than do the present-day temperature differences.

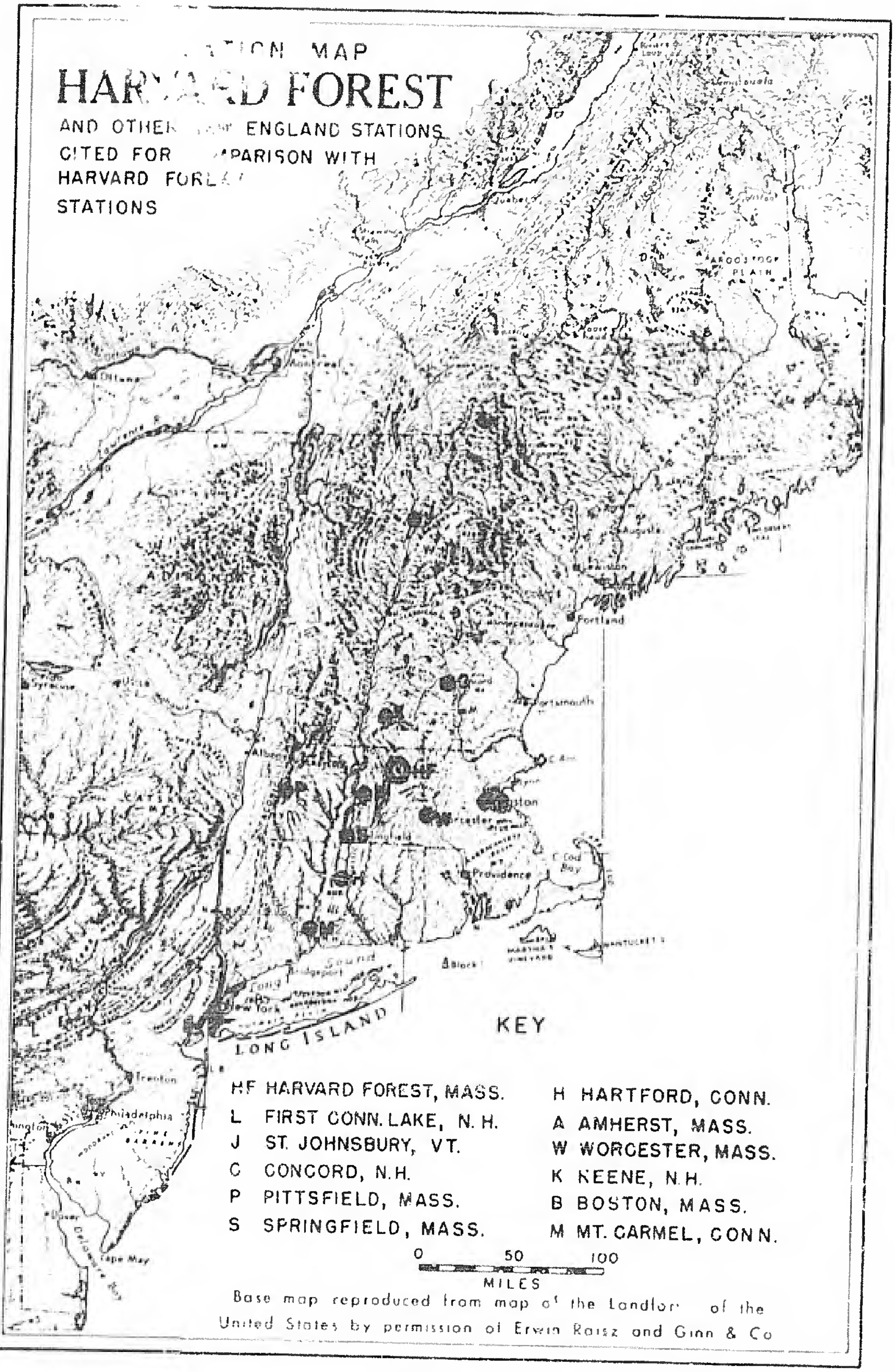

MAP
FOREST
ENGLAND STATIONS
HARVARD
STATIONS
Quebec
AROOSTOOK PLAIN
Montreal
Ottawa
Portland
Portsmouth
Boston
Worcester
Providence
Utica
Albany
Syracuse
Springfield
Bridgeport
New York
LONG ISLAND
Trenton
Philadelphia
Cape May
Block I.
KEY
HF HARVARD FOREST, MASS.
L FIRST CONN. LAKE, N. H.
J ST. JOHNSBURY, VT.
C CONCORD, N.H.
P PITTSFIELD, MASS.
S SPRINGFIELD, MASS.
H HARTFORD, CONN.
A AMHERST, MASS.
W WORCESTER, MASS.
K KEENE, N.H.
B BOSTON, MASS.
M MT. CARMEL, CONN.
0 50 100
MILES
United States by permission of Erwin Raisz and Ginn & Co

Figure 1

TEMPERATURE DIFFERENCES IN HARVARD FOREST AND THEIR SIGNIFICANCE

CHAPTER I - INTRODUCTION

The Harvard Forest is in central Massachusetts, in the heart of the Eastern Upland of New England, a region of complex geological history, diverse topographic form, and extremely varied human-use potentialities (Figure 1). Although the land-use history of the Eastern Upland differs in detail from place to place, it is essentially similar for the region as a whole, and present day land-use problems with which man must cope are similar throughout the region. In the uplands of New England, as in the river and coastal lowlands, many natural factors combine to favor a balanced and developing economy, but such development must be planned carefully in order to make the wisest use of the natural resources. Some of these resources, such as waterpower, are of limited quantity but of high utility; others, as for instance, the soils, are abundant but of limited utility in many places. The realities of environmental limitation must be faced, but the limitations must not be exaggerated. Much has been written about the stony upland soils and sandy valley soils of New England as contrasted with the deep, fertile soils in many parts of the Central West. Similarly, it has been emphasized frequently that the short growing season of New England places it at a serious disadvantage, both for farming and forestry, in comparison with regions farther south in the United States. The meagreness of its power resources, even of waterpower which was so valuable during the early years of industrial development but is inadequate to meet today's increased needs, places New England at an added disadvantage. High labor costs and other economic factors, although indicating a higher standard of living for New England, have worked to its industrial disadvantage in competition with other parts of the country. The signs are plain to be read, however, that New England is maintaining and expanding a diverse and stable economy based upon improved agricultural and industrial methods, upon modernized taxation procedures, and upon improved regional-national cooperation relationships. All of this, however, must be consequent, in large part, upon a careful adjustment of land use to land capabilities.

The economic activities by which a very large proportion of the people of New England earn their livelihoods — activities such as manufacturing and commerce — involve the physical occupancy of only a small portion of the land. Even farming, which, by emphasis upon intensive factory-farm dairying or upon high quality specialty crops, is increasing in productivity and income, occupies only a small part of the total area. Some of the remainder is water, which in combination with other factors, both natural and human, forms the basis of a most important year-round recreational industry. By far the largest proportion of land is in forest. The forest, therefore, is a very important part of many geographic or economic studies of New England.

The forest is not alone a physical element. It is a tremendous economic, social, and political factor, although it is chiefly permissive and for the most part exerts its influence only as man utilizes the wealth it has to offer. It is patent that improved forestry practices throughout New England should result in great benefit to the region as a whole. The efforts made to accomplish such improvement have taken many directions and are reported in an impressive variety of studies. A primary objective in some of these studies has been to determine the relationships between plant growth and the numerous factors of the natural environment. Among these factors one of the most important is climate.

The present study deals chiefly with a single, but important, element of the climate, namely, temperature. It reports the procedures used, and results obtained, during a year of field study of local temperature differences at Harvard Forest, from August 1947 through July 1948, as recorded at temperature stations established in numerous contrasted parts of the Forest. Such local differences in temperature are considerably greater than is commonly realized (Figure 2). The report also includes a comparative analysis, for the same period, of the general temperature conditions at eleven widely separated New England stations. This comparative analysis was based upon Weather Bureau records.

HARVARD FOREST, PETERSHAM, MASSACHUSETTS

TEMPERATURE RECORDS AT FIELD STATIONS

OCTOBER 20 TO 29, 1947

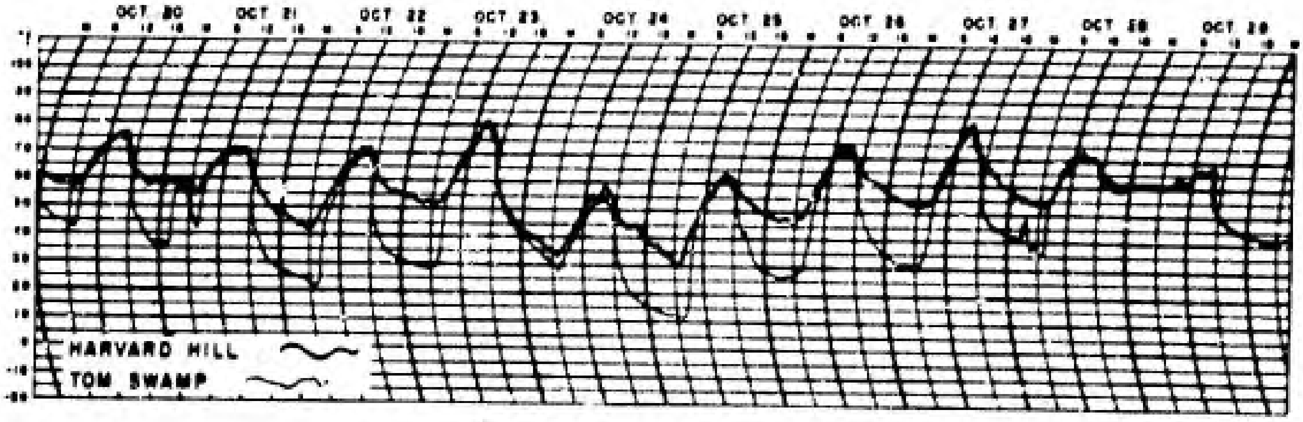


Figure 2

The specific objectives of the study were: (1) To gather a large body of temperature data during a one-year period from a network of stations in selected locations of widely different character. These data were to provide a basis not only for present analysis but for comparison with readings to be taken in the future under changed conditions. (2) To analyze the data gathered and determine the amount of local temperature diversity in Harvard Forest as compared to the regional diversity of New England, from the Atlantic margin westward to the Berkshires and from Long Island Sound northward to the Canadian border. (3) To delineate differing local temperature-type areas within Harvard Forest, and to attempt to establish scales showing relative day warmth and night coldness of these areas. (4) To determine the local importance and influence of elevation, direction of exposure, topographic form, vegetation, water bodies, and snow-cover in causing local temperature differences. (5) To compare selected stations within Harvard Forest as to temperature-frequency distributions, length of frost season and vegetative season, and number of frost days, ice days, summer days, and tropical days. (6) Finally, to apply the findings to the problem of the possible importance of temperature factors in influencing forest-type distribution and land use.

Corollary purposes of the study were: (1) To determine comparative value of readings taken regularly once daily, weekly, and monthly, or at infrequent intervals by rapid traverse methods. (2) To determine the extent to which data could be used comparatively when taken from different kinds of instruments and when instruments were housed in different kinds of shelters.

The entire study is documented with representative maps and photographs portraying the areas and conditions being analyzed; it utilizes new as well as previously used kinds of diagrams, which show temperature sequences and differences observed, and which set forth, comparatively, some of the major conclusions reached.

Appendixes include comparative data from other New England stations, complete chronological tables of temperature observations in the field at Harvard Forest, also additional maximum- and minimum-temperature tables showing stations rearranged according to relative warmth or coldness each month.

CHAPTER II - REGIONAL SETTING AND LAND-USE HISTORY

In this chapter the surface character of New England is described in general terms, and that of Harvard Forest is described in more detail. This is followed by brief discussions of soils, climate, and vegetation. The chapter concludes with a brief review of the land-use history of the Town of Petersham and a brief description of its present land-use status.

Many of the factual points concerning conditions in 1947-1948 discussed here were confirmed by personal observation in the field, or in interviews with local residents. The selections quoted from published sources deal both with present and with past conditions. They indicate that natural factors and present land-use problems in the vicinity of Harvard Forest are essentially the same as in an extensive surrounding area, and suggest that the findings of this study are applicable in many parts of New England and in other regions.

1. Relief (Figures 1, 3, 4, and 5).

Concerning the surface character of the New England Province as a whole, J. K. Wright says (1933, p. 14):

> "Much of New England is a country of ancient, worn-down mountains, a land of extremely complex rock structure. The ceaseless forces of erosion have etched out a pattern of valleys below the general levels to which the mountains were reduced far back in geological times, and the complexity of relief reflects the complexity of the underlying rocks. The invasions and retreats of the continental ice sheets did much to accentuate the diversified quality of the surface. The ice scraped off the earth and carried away pieces of rock from countless hillsides; it dropped its load in moraines, damming streams and impounding the waters in lakes and ponds. It turned rivers aside from their older channels. It scattered boulders and gravel far and wide. Its melting waters gathered along the ice fronts in lakes, now vanished. On the floors of these lakes sand and mud were laid down, and these deposits today form little plains, often terraced by postglacial streams."

Describing the Eastern Upland, Wright says:

> "The dissected surfaces of the Eastern Upland rise gradually from southern Connecticut northward across Massachusetts and New Hampshire to abut against the White Mountains at altitudes of between 1000 and 2000 feet. They also ascend from their eastern and western margins to a series of irregular longitudinal crest lines above which, in Massachusetts and New Hampshire, rise isolated mountains, the remnants of once much loftier peaks. Monadnock (3166 feet) the noblest of these, has given its name as a generic term for such residuals wherever found" (op. cit. p. 38).

The relatively recent continental glaciation and subsequent deglaciation probably had less modifying effect upon the major ridge pattern of the upland than was once believed, but did have a profound effect upon the surface conditions on the ridges. Great changes also took place in the valley bottoms, as a consequence of ice and water deposition, with the greatest changes occurring during the period of glacial wastage. In many places the drainage patterns were greatly altered as a result of glaciation.

2. Topography of the Three Main Harvard Forest Tracts.

Each of the three main tracts of Harvard Forest differs in topographic character from the others. Together, the three tracts give a representative sampling of the diversity exhibited within the Eastern Upland Region.

a. Prospect Hill Tract (Figures 3, 6, 7, and 8).

The Prospect Hill Tract includes the northern and somewhat complex beginning area of the Petersham Ridge, which forms the center ridge of three major north-south-trending drainage divides of the Petersham Township.

The northern part of the tract is dominated by Prospect Hill (1383 feet), the highest point in the Harvard Forest. Prospect Hill marks the southern edge of a broad gently rolling upland

Figure 3 - Prospect Hill Tract. Panorama from south slope of Little Prospect Hill, showing from east to west: 1. Prospect Hill; 2. Town Line Swamp; 3. Big Spruce Swamp; 4. Brooks Hill; 5. Secondary summit of Little Prospect Hill. April, 1948.

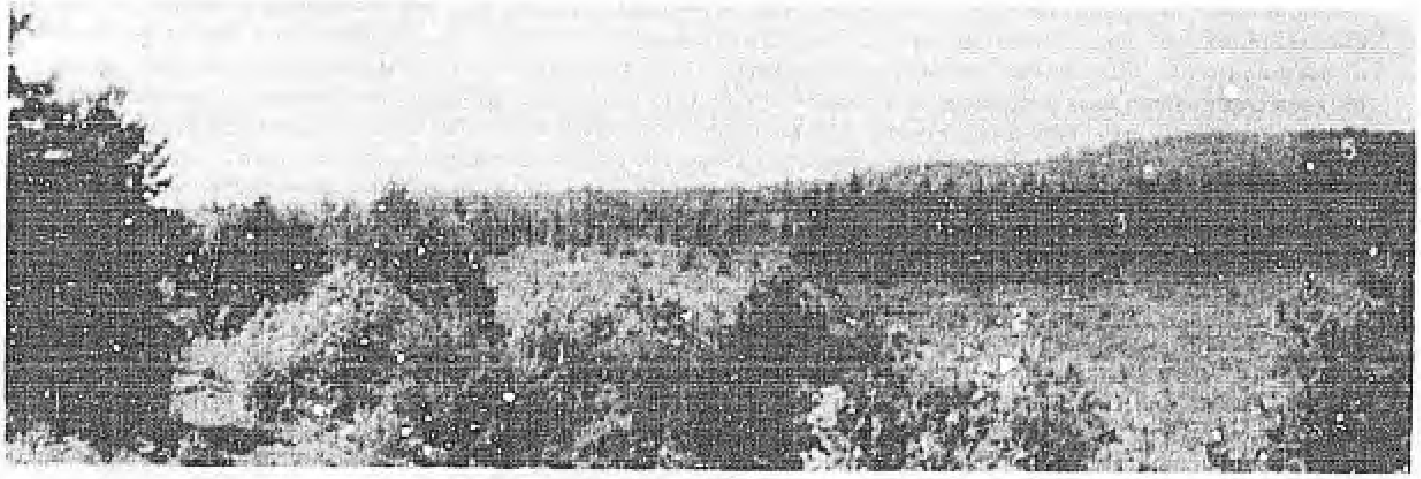
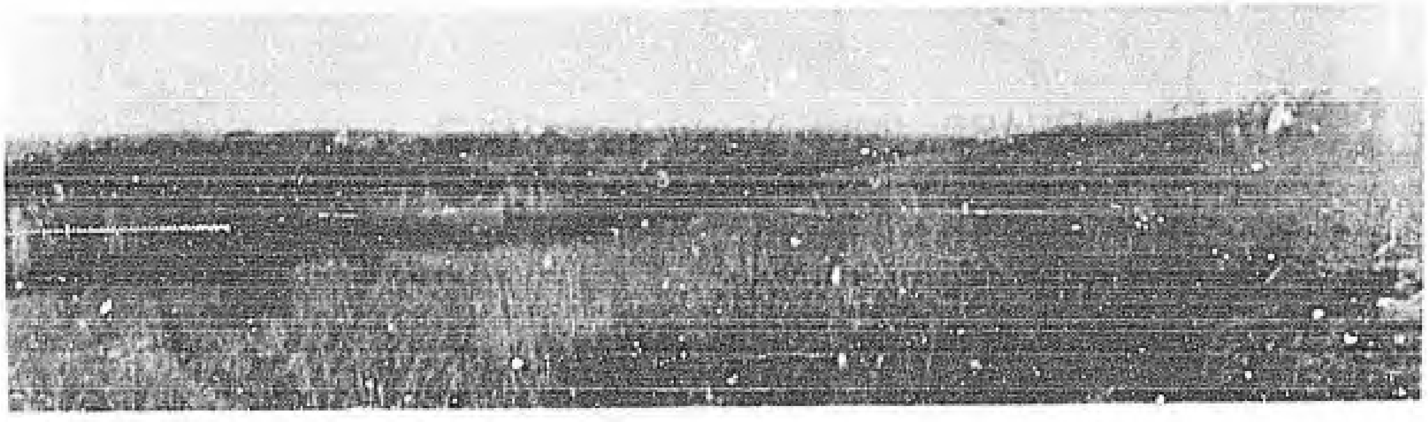
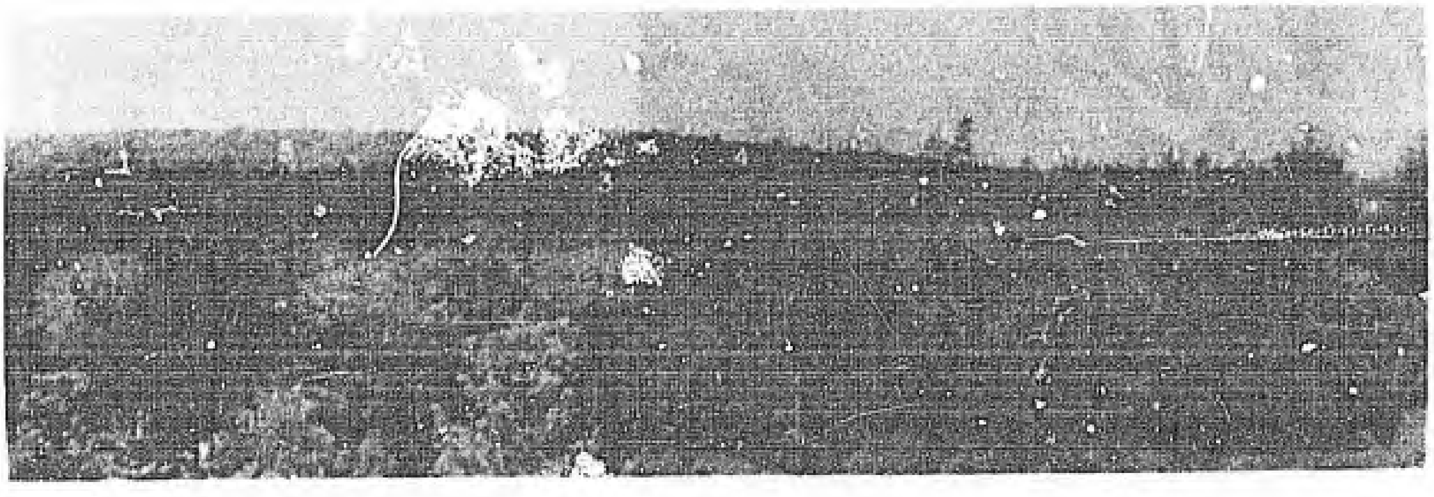
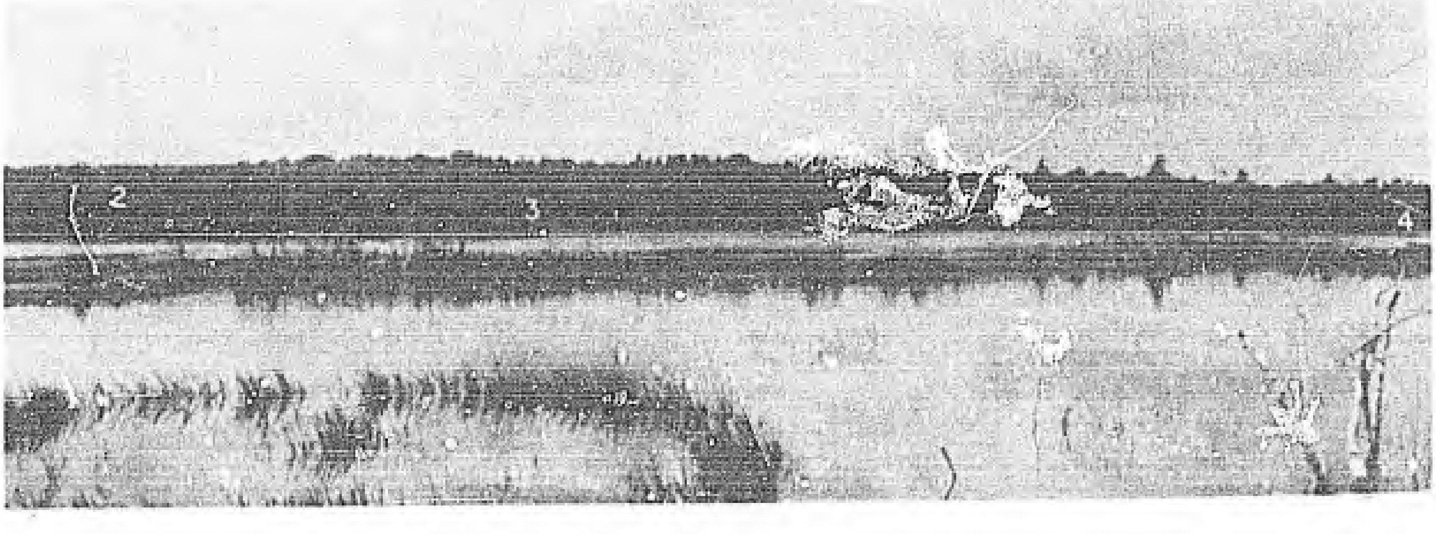


Figure 4 - Tom Swamp Tract. Panorama from south to north by way of west, taken from terrace bordering eastern edge of Tom Swamp, showing: 1. Mixed-forest growth at eastern edge of swamp; 2. Lowbush swamp growth; 3. Black spruce swamp forest; 4. White pine-hemlock forest on Fay Lot Terrace; 5. Deciduous forest on West Boundary Hill. July, 1948.

Figure 5 - Riceville Pond. Panorama from south to northwest by way of west, taken from east shore of pond, showing, on opposite shore: 1. Margin of Tom Swamp; 2. Fay Lot Terrace, with West Boundary Hill beyond; 3. Riceville Pond temperature station; 4. Pond outlet. July, 1948.







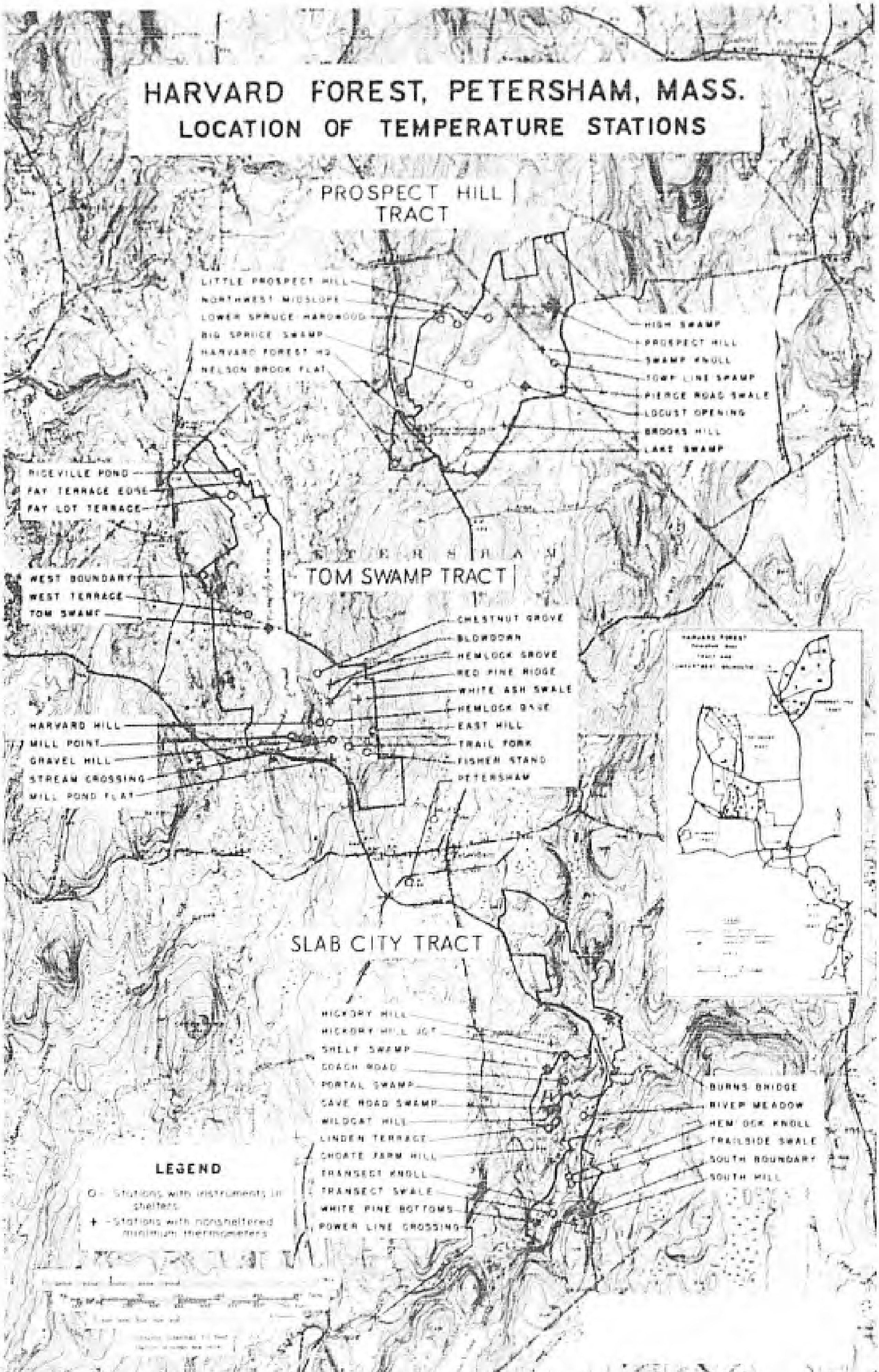

HARVARD FOREST, PETERSHAM, MASS.
LOCATION OF TEMPERATURE STATIONS
PROSPECT HILL TRACT
LITTLE PROSPECT HILL
NORTHWEST MIDSLOPE
LOWER SPRUCE-HARDWOOD
BIG SPRUCE SWAMP
HARVARD FOREST HQ
NELSON BROOK FLAT
HIGH SWAMP
PROSPECT HILL
SWAMP KNOLL
TOWN LINE SWAMP
PIERCE ROAD SWALE
LOCUST OPENING
BROOKS HILL
LAKE SWAMP
RICEVILLE POND
FAY TERRACE EDGE
FAY LOT TERRACE
WEST BOUNDARY
WEST TERRACE
TOM SWAMP
TOM SWAMP TRACT
CHESTNUT GROVE
BLOWDOWN
HEMLOCK GROVE
RED PINE RIDGE
WHITE ASH SWALE
HEMLOCK BASE
EAST HILL
TRAIL FORK
FISHER STAND
PETERSHAM
HARVARD HILL
MILL POINT
GRAVEL HILL
STREAM CROSSING
MILL POND FLAT
SLAB CITY TRACT
HICKORY HILL
HICKORY HILL JCT
SHELF SWAMP
COACH ROAD
PORTAL SWAMP
CAVE ROAD SWAMP
WILDCAT HILL
LINDEN TERRACE
CHOATE FARM HILL
TRANSECT KNOLL
TRANSECT SWALE
WHITE PINE BOTTOMS
POWER LINE CROSSING
BURNS BRIDGE
RIVER MEADOW
HEMLOCK KNOLL
TRAILSIDE SWALE
SOUTH BOUNDARY
SOUTH HILL
LEGEND
O - Stations with instruments in shelters
+ - Stations with nonsheltered minimum thermometers

Figure 6

area only slightly lower than the hill itself. Deep valleys border the hill to east and west, and a steep south slope leads down to the broad basin of the Town Line Swamp. The upper surface of Prospect Hill represents a small remaining segment of an ancient peneplain surface, scoured by ice during the glacial period and thinly covered with glacial drift and aeolian deposits. The slopes below are deeply and thickly littered with huge angular blocks of rock, intermingled with, or underlain by, glacial drift. Some of these may have been swept from the upland surface by the advancing glaciers; others probably were plucked from the steep faces of the hill and dropped, together with stagnating ice, on the slope just below, then overridden by later ice thrusting from the north and northeast. Some of the smooth upper slopes, side-hill terraces, and boulder-seas or rock fields on lower slopes probably resulted from processes of cryoplanation and congeliturbation common during glacial and postglacial periods.

Beyond the deep narrow valley on the west side of Prospect Hill, and only slightly lower, is Little Prospect Hill forming a southwestward extension of the upland. It is elliptical, with rather steep slopes to the north, northwest, and southeast. Its main axis is to the southwest; beyond a slightly lower secondary summit in this direction the hill has a gentler, somewhat terraced descent, and forms the long, drift-covered rock ridge on which the Forest Headquarters buildings stand. The two summits of Little Prospect Hill are rounded to flattish, and have a deeper covering of glacial drift overlying bedrock than is the case on Prospect Hill.

At the south base of Little Prospect Hill is the Big Spruce Swamp. This long, wide, flat, ill-drained peat bog may be underlain by outwash; it is traversed from northwest to southeast by a low, discontinuous, gravelly, esker-like ridge. The swamp lies athwart the drainage divide between the Swift River and the Miller's River. It drains eastward to the Town Line Swamp, which drains to the Swift. Westward drainage is to a little stream which has a rapid descent into a long narrow swale just east of the Forest Headquarters buildings. This swale drains southward to Nelson Brook.

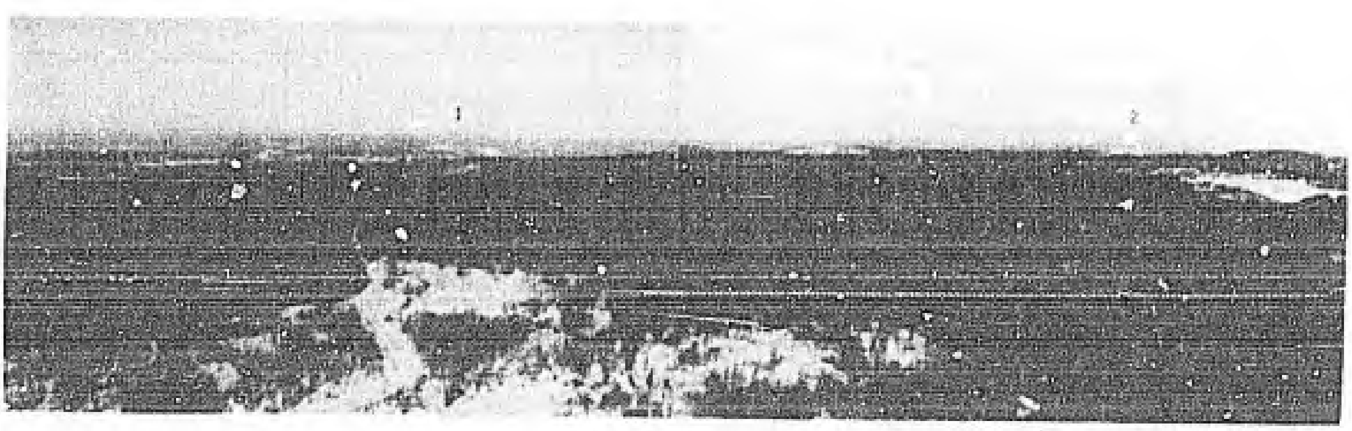


Figure 7 - Eastern Upland of New England. View northwestward and northward from Prospect Hill fire tower toward: 1. Mt. Grace, and 2. Mt. Monadnock. November, 1947.

Figure 8 - Eastern Upland of New England. View eastward and southeastward from Prospect Hill fire tower. January, 1948.

Southward from the Big Spruce Swamp the land surface slopes gently upward, forming a broad platform. Rising from the center of this platform is the great oval mass of Brooks Hill, a drumlin aligned northeast-southwest (Alden, 1924, Plate XIII). The platform itself breaks to the east, south, and west in a series of terrace-like steps. On the east these terraces lead down into the Town Line Swamp, which lies south of Prospect Hill and some 50 feet lower than the Big Spruce Swamp. West of Brooks Hill a stream valley cuts the upper platform level and drains into Lake Swamp, which is perched on a lower level and is drained by Nelson Brook. The Lake Swamp was artificially extended by damming, and once formed a large millpond, the waters of which spread to the north. At present the ope pond is very small, and much of the swamp is now heavily overgrown with thicket. South of the millpond is a small rock-cored hill. Westward from Lake Swamp, and at least 40 feet lower, is the swale whose stream begins in the Big Spruce Swamp. Many places in the various swales are very bouldery, but the platform surfaces appear to consist of till, possibly worked by glacial meltwater but not necessarily covered with outwash deposits except locally.

The portion of the Prospect Hill Tract west of the Headquarters building consists essentially of the steeply sloping, amphitheater-like valley of Nelson Brook. The valley has numerous knolls of bedrock, and many fields of loose angular boulders, which may have been accumulated here by frost action and by glacial plucking and dropping. The lower part of the Nelson Brook compartment is almost flat, and is terraced, but in many places the surface is stony. Still farther west and downstream, Nelson Brook has cut itself into the broad, sandy, kame terraces of the Riceville Pond valley.

Prospect Hill is not only the highest point in Harvard Forest, but the highest point in the wide area between Mt. Wachusett, Mt. Monadnock, and Mt. Grace. One might expect it to have very extreme temperature readings. Despite its considerable elevation, however, Prospect Hill has the mildest temperature conditions of any open place in the Harvard Forest. Other parts of the Prospect Hill Tract, of only slightly lower elevation, but of concave shape, have considerably greater temperature contrasts. Even more severe conditions are characteristic of parts of and two other main tracts.

b. <u>Tom Swamp Tract</u> (Figures 4, 5, 6, and 9).

The Tom Swamp Tract consists essentially of an important segment of the deep trough separating the central or Petersham Ridge of Petersham Town from a western and somewhat more discontinuous ridge which includes Bald Hill, Camel's Hump Hill, and others. The eastern edge of the tract forms a portion of the long westward slope of the Petersham Ridge. Much of this slope is thickly strewn with angular boulders, which in places form veritable boulder seas. In between and underlying these is glacial till intermixed with or covered with loess. Locally the slope is interrupted by platform-like swales occupied by swamps of limited extent but of considerable land-use significance. Westward the bases of the slope merge into a somewhat flatter kame terrace, which is undulating to flat and locally pitted. At the western limit of this terrace a small but abrupt drop marks the edge of Riceville Pond, Tom Swamp, and Harvard or Brooks Pond.* Projecting segments of outwash terrace form peninsulas extending into Tom Swamp and Harvard Pond. Isolated segments form islands.

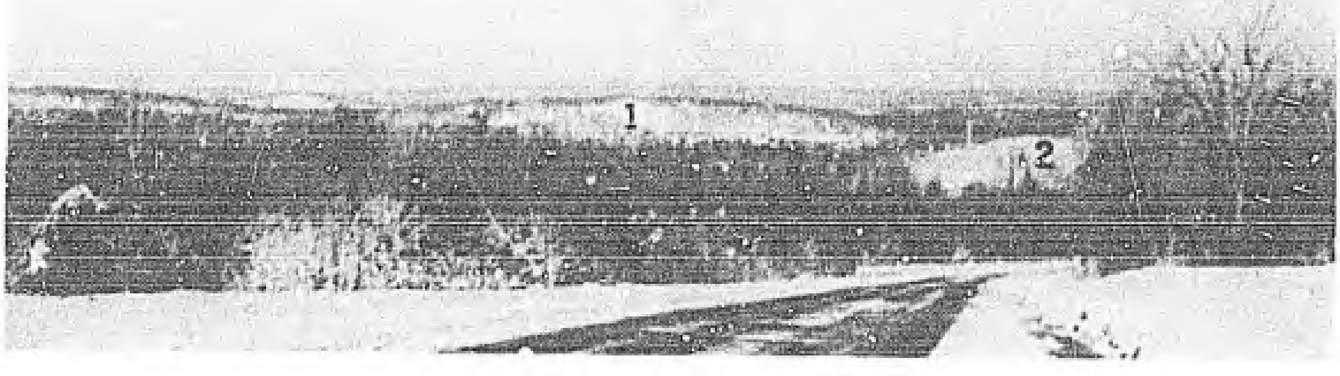


Figure 9 - Tom Swamp Tract. View northwestward down Highway 122 from Petersham West Road toward Tom Swamp lowland, showing: 1. West Boundary Hill, with Mt. Grace beyond on skyline; and 2. Harvard Hill. November, 1947.

* The original names given the pond were Brooks Pond or Meadow Water. In all Harvard Forest publications it is called Harvard Pond. The name given on the topographic map is Brooks Pond.

Tom Swamp, like the Big Spruce Swamp, lies athwart the divide between Miller's River and Swift River drainage. Riceville Pond and Riceville Brook continue the Nelson Brook drainage to Miller's River. Harvard Pond and Fever Brook drain southward to Swift River.

Along the western edge of the Riceville Pond — Tom Swamp — Harvard Pond depression is another outwash terrace comparable to that on the eastern edge. This terrace is especially well developed on the western margin of Riceville Pond, where it forms the broad platform of the Fay Lot. Westward from this rises the long, drift-covered slope of the West Boundary Hill. This hill terminates on the south, at the Tom Swamp Road, in a series of craggy prongs, with many bare rock exposures and with steep cliffs forming their eastern and western edges. Several much-broken but roughly parallel lines of rocky knobs and ridges form southward extensions of these ridges, to the south of the Tom Swamp Road, in the area west of Harvard Pond. Between these knobs are flattish areas at various levels. Some of these are surfaced with till. The lower terraces are to the east, near the swamp and Harvard Pond, and are partly covered with outwash. Poorly drained flats here as elsewhere are occupied by peat bogs, with swamp-forest vegetation.

The area immediately east of Harvard Pond is dominated by a high, rock-cored, drift-covered elliptical hill with a long north-south axis. The Harvard Hill station is at its summit. Although the hill rises steeply 150 feet above the pond, its eastern slope drops only 60 feet to a wide long swale (Compartment V Swale) lying on a plane some 90 feet higher than the pond. The stream draining southward from this swale was once dammed, and the swale itself once comprised a millpond of considerable proportions. A string of small rock knolls to the southeast, linked by low ridges of glacial drift, made it easy to dam a tributary stream to form a small auxiliary upper millpond. The main swale has secondary drainage around the northern end of Harvard Hill.

A discontinuous esker with a southeast-northwest trend lies just inside the southern boundary of the Tom Swamp Tract, near the State Highway. Its northwestern, and most notable, segment forms a high, steep-sided hill of well-washed and sorted gravel and sand near the edge of Harvard Pond.

c. Slab City Tract (Figures 6 and 10).

Although the general trend of the ridges in the Petersham region is north-south, most of the main drainage lines lead to the southwest. Some of the most broken country is that bordering the streams where they cut through the main ridge lines. No part of the Town of Petersham is more broken than that bordering Swift River in the area occupied by the Slab City Tract, south of Petersham Center.

In the most northern part of the Slab City Tract the Swift River valley is deep and narrow. The eastern side of the valley is formed by a high conical hill which rises steeply 235 feet from the river, then drops as abruptly to Moccasin Brook farther east, outside the tract boundary. A terrace borders these streams. Southwest of the stream junction, and just north of Burns Bridge, a low knobby ridge once stood; this was a good source of gravel and has been mostly removed.

West of the State Highway leading down past Connor Pond the Petersham Ridge breaks into a compact mass with five major heights. The four northernmost of these, with their intervening saddle ridges, form a U-shaped series enclosing a deep valley, utilized in colonial days by the

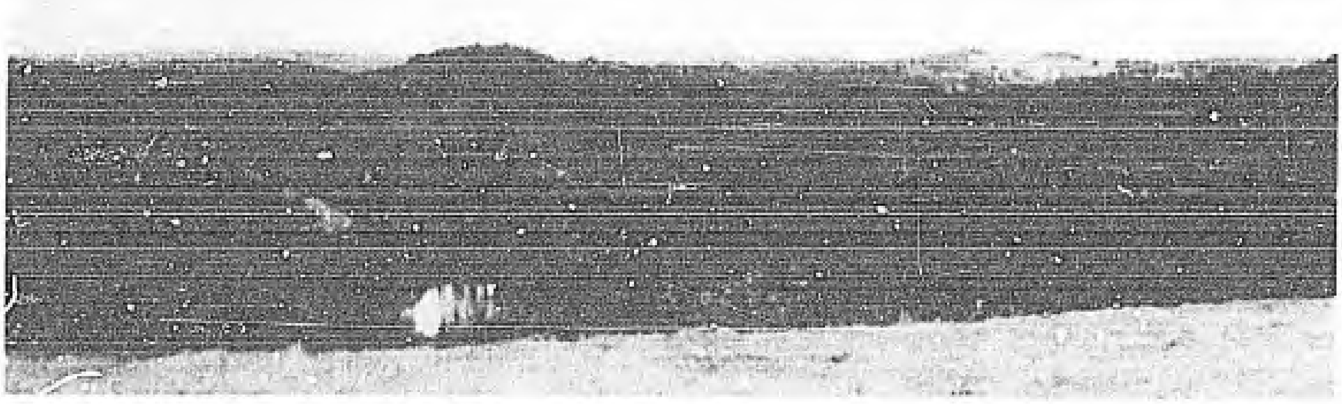


Figure 10 - Slab City Tract. View northward from Pat Connor Road, across Connor Pond and up Swift River and Moccasin Brook Valleys. Prospect Hill is on distant center skyline. October, 1947.

coach road leading from Worcester to Greenfield. The highest hill is Hickory Hill (1075 feet); this is flanked on the southeast, across a high saddle, by a hill some 1010 feet high. These close the curve of the U. South of Hickory Hill proper is a broad shelf or platform, partly swampy. From the eastern edge of this platform a steep cliff drops sharply to the Coach Road valley below. Southward from the shelf platform with its swamp, the land rises gently to form a long broad-topped ridge, also some 1010 feet high. The steep-cliffed southeast face of this upper ridge forms one wall of an upland gap, the floor of which has an altitude of 935 feet. The cliff face has several water-smoothed surfaces, also pot-holes and small caves. The valley forms a corridor trending northeast-southwest. It may represent one segment of a high channel cut by an ice-marginal stream across all the north-wall spurs of the Swift River valley at a time when the valley was deeply filled with ice. The course of such a stream is suggested by the saddles cut in each spur in succession along the side of the present Swift River valley.

On the opposite side of the corridor formed by the upland gap is the isolated knob of Wildcat Hill (996 feet). The northwestern slope of Wildcat Hill, toward the corridor, is moderately steep, drift-covered and strewn with huge angular blocks, most of them slumped from the bedrock composing the hill. The southeast face of the hill has a precipitous 200-foot drop, broken by several narrow ledges, to a hidden swamp, perched in a narrow part of the lower Coach Road valley. The hidden swamp is some 40 feet above the broad meadow flat bordering Swift River

The east side of the Swift River valley also consists of high rock hills, of rounded aspect but covered with loose stone at many places. South Hill (1041 feet), traversed east-west somewhat north of its highest point by the tract's southern boundary, has distinct terraces at several elevations on its north face. These might be due to the land slumping down against an ice wall, or they could have been carved into the bedrock by ice-marginal streams, or they may consist of kame-terrace deposits later covered in places by land slump.

The valley bottom itself, on the south bank of the river, consists of a series of terraces, the main one of which averages some 30 feet to 40 feet higher than the river. A whole series of rounded knolls rises above the general terrace level. Several more knolls stand at higher levels in the tributary stream valley east of South Hill, where the State Highway leads up from the Swift River valley to the Barre Upland. Numerous other such knolls form a cluster at the mouth of Silver Brook, which drains Carter Pond and enters the Swift River about a half mile below the southwest corner of the tract. These gravelly and sandy knolls, of glaciofluvial origin, may represent successive pauses in the melting away of an ice front, where rivers issuing from the ice dropped their sediments and built high kame deltas. The sides of these probably slumped to form conical hills when the ice front melted back a little farther. The tandem arrangement of the knolls overlooking the river-bottoms swamp in the extreme southwestern part of the tract (White Pine Bottoms) could suggest simultaneous formation as an esker. The river has cut a steep cliff into the north face of the northernmost knoll of the ridge, revealing till sheets buried beneath the sorted outwash deposits. The en echelon arrangement of the knolls farther upstream suggests individual but not necessarily successive development.

Alden (1924, pl. VII) relates the morainal and outwash deposits of this area to successive stages of the gradual melting away of the last ice sheet. At each stage the ice front remained stationary for a considerable period before retreating, by melting, to a slightly more northerly position.

3. Soils.

In general the soils of southern New England are derived from materials left by glacial, glacial-water, or wind deposition of one kind or another. They are chiefly of the Gray-Brown-earth type, are slightly acidic in reaction, and do not have fully mature profiles.

Little time has elapsed, geologically speaking, since the parent materials of most New England soils were deposited. For this and other reasons, including that of repeated disturbance consequent upon uprooting of trees by wind-throw, the soils differ considerably according to differences in the parent material. The soil types represented in Harvard Forest may be considered in two groups: (1) upland soils, derived largely from unstratified glacial till deposits, locally covered and intermixed with loess, and (2) valley soils, derived largely from glacial outwash and loess. (Morgan, 1933, pp. 120-126; Lutz and Cline, 1947, pp. 13-15; and Simmons, 1939).

a. Upland Soils.

(1) Stony Soils Undifferentiated. Many upland areas have thin soil with much stone. Even where the soil layer is deep, the land may be so stony that little surface area consists of soil. Except that they are excessively stony, many of these soils have the same qualities as do the less stony soil groups with which they are associated. Although many of the stony areas are uncultivable and cannot be used feasibly for pasture under present economic conditions, they are productive forest lands.

(2) Light-textured Upland Soils. The soils of this group are derived from less stony parent material, and consist chiefly of loams and sandy loams. Those which developed from deposits containing much granitic and granite-gneiss material form the Gloucester soils. Those derived from micaschist materials high in iron comprise the redder and more platy soils of the Brookfield series. The soils of both these series are quite fertile, but they dry out quickly because of porous subsoils. On lands having less rapid drainage, owing to less permeable subsoils, a high water table is characteristic; here the Whitman series is common.

(3) Heavier Upland Soils. In many upland areas the parent material is less stony, and is heavy and compact. The soils formed from such material belong to the Charlton series. They retain moisture better and are more productive than either the Gloucester or Brookfield soils. Associated with the Charlton soils, but on less well-drained lands are the Sutton soils. These also are highly productive both for agricultural use and for forestry.

b. Valley and Lowland Soils.

(1) Sandy Soils. As has been noted, many of the valleys in this area have extensive deposits of stratified glacial outwash, forming broad terraced plains. The surface materials composing these are mostly sandy or loessial, with little or no stone except where intermixed or covered with materials brought downslope by congeliturbation and other processes. They are underlain by gravel or by alternating layers of sand and gravel. The common soil type developed on such deposits is the Merrimac, a light sandy loam. Low rounded knolls and hummocks of sand and gravel in such areas form the parent materials of the Hinckley soils which are somewhat more loamy. Both the Merrimac and the Hinckley soils are lighter and less productive than the upland soils previously described.

(2) Peat Soils. In the Harvard Forest area, as elsewhere in New England, peat bogs are a notable feature. The soils of these bogs were formed largely from organic materials, and are highly acidic. The peat layer may be from a few feet to many tens of feet deep and may or may not lie on a layer of fine soft lime (marl) deposited on the old lake or pond bottom which the bog occupies. In most places the marl is underlain by sand and gravel.

4. Climate.

New England has a continental climate despite its proximity to the Atlantic Ocean. Summers are warm to hot, and winters are cold. The region is in the heart of the westerly wind belt of the northern hemisphere, in which the upper air currents

"follow their regular course from west to east with remarkable persistence. The control of weather types and hence more or less directly of climate is largely in the hands of passing cyclones and anticyclones" (Ward, Brooks, and Connor, 1936, p. 16).

In winter the prevailing wind is from the northwest in most parts of New England, and in summer the prevailing wind is from the south or southwest. Because the prevailing wind blows offshore much of the year, the Atlantic Ocean has only a slight influence upon temperatures.

"Thus it follows that the coastal belt, except when the wind blows onshore under general cyclonic or anti-cyclonic controls, or when in summer local sea breezes occur, does not differ very much from the interior. The large temperature ranges of the interior are carried eastward to the coast, and even over the ocean for some distance offshore. Nevertheless, regions bordering immediately on the Atlantic coast, and especially islands and promontories, have milder winter climates than those commonly experienced farther inland" (op. cit. p. J177).

The onshore winds bring abundant moisture from the Atlantic to supplement that brought from elsewhere, and precipitation is abundant at all seasons.

a. Temperature.

In winter the temperature gradient from south to north in New England is very steep. The mean January temperature at New Haven, Connecticut, is about 28°F, at Harvard Forest it is about 21°F, and at First Connecticut Lake, New Hampshire, near the Canadian border, it is about 10°F. In summer, when almost the whole continent is warm, the temperature gradient is much less steep. The mean July temperature at New Haven is 72°F, at Harvard Forest, 69°F, and at First Connecticut Lake, 63°F. Similarly, the variability of winter from year to year is greater than that of summer. Mean departures of mean monthly temperatures in New England are from about 3F degrees to 5F degrees in January, but only about half that much in July. The actual departures, from year to year, however, are much greater. At Burlington, Vermont, one January (31°F) averaged 25F degrees warmer than another January (6°F). The warmest July, however, averaged only 9F degrees warmer than the coolest (75°F and 66°F). At Harvard Forest, during the period 1938-1947, the highest and lowest January averages (derived from means of weekly maximum and minimum temperatures) were 24.75°F (1942) and 12.8°F (1945) respectively. The highest July average (1936-1947), similarly derived, was 68.6°F (1937), and the lowest was 66.3°F (1939). As is characteristic of regions with continental climate, New England has experienced some particularly unusual seasons. In 1816 summer was phenomenally cold, and the year was remembered as "the year without a summer." Winter of 1917-1918 was remarkably cold, with heavy snowfall. That of 1920-1921, by contrast, was one of persistent mildness. The winter of 1933-1934 was especially severe. Certain kinds of temperature conditions tend to repeat, however, in successive years and have become traditional. The most notable of these are the January thaw, the May freeze, and Indian summer (Ward, Brooks, and Connor, 1936, p. J103 and 104).

The length of the frost-free season differs considerably in New England, and varies significantly from year to year. At Harvard Forest from 1936 to 1947 inclusive, this period between the last killing frost (32°F or lower) in spring and the first killing frost in autumn was as short as 103 days (1944) and as long as 154 days (1940 and 1942). The average was 137 days (Spurr, 1950, p. 169 ff). In most years the length of the frost-free season has been within 10 percent plus or minus of this average. The last spring frosts usually have occurred by mid-May. First autumn frosts usually have occurred by the end of September.

b. Precipitation.

New England precipitation has a more uniform monthly distribution through the year than is found anywhere else in the country except possibly in the Pacific Northwest. The climate is humid at all seasons, and only in the driest years is a drouth condition even approached. The autumn of 1947, however, was exceptionally dry, with a rainless period of 29 days. The driest years may have only two-thirds of the mean annual precipitation and the wettest year one-third more than the mean, but in general the hazards to agriculture, from too little or too much rainfall at any given time, are less than in other parts of the country. Most months average at least 10 days with precipitation; and the spring months average more. The precipitation at Harvard Forest during the driest year of record (1913-1948) was 27.3 inches (1941); and during the wettest year it was 60.1 inches (1938). The 36-year average of annual precipitation was 42.36 inches (op. cit.).

Most of the rainfall comes from the passing cyclonic storms or "lows." Some of it comes from thunderstorms, which average about 25 each year; of these, two-thirds occur in summer (June-August). Hail storms are rare in New England, and few places average one per year.

c. Snow-Cover.

Most interior portions and many coastal areas of New England have a several-months-long period of continuous snow-cover in most winters. The length of the season with snow-cover varies greatly from place to place and is influenced by differences in elevation, topographic form, vegetative cover, land-water relationships, exposure to sunlight and prevailing winds, and by other factors. Although the season is generally longest in those areas which receive the heaviest total snowfall, it is equally long in many sections with lighter snow-cover but which come under the influence of large nearby lakes or the ocean. The actual depth of snow-cover at its annual maximum increases northward and with altitude (Stone, 1940, p. 676.).

Table I shows the average length of season with snow-cover of various depths at selected New England stations in representative type locations cited by Stone (op. cit., pp. 676, 683-687; also Stone, 1944, pp. 877-880). It will be seen from this table that although differences in latitude are significant in determining differences in the depth of snow-cover and the length of the season of snow-cover, other factors, particularly elevation, are of even greater significance. In general, stations in northern New England, both coastal and inland, have somewhat deeper and longer lasting snow-cover than do stations in comparable topographic situations in southern New England.

In most years at upland stations in central Massachusetts, snow usually falls by early November, but the first snows quite commonly melt away. A continuous snow-cover is common from late November to about mid-March. One or more heavy, but sometimes fast-disappearing, snowfalls may occur later in March or in April. On the average, three or more ice and sleet storms occur every year.

TABLE I

AVERAGE LENGTH OF SEASON OF SNOW-COVER OF VARIOUS DEPTHS IN NEW ENGLAND

General ranges estimated from isopleth maps in Stone, 1944, pp. 877-880.
Station data adapted from Stone, 1940, pp. 683-687.

SOUTHERN NEW ENGLAND	Elev. in ft.	Depth of Snow-Cover 2 in.	5 in.	10 in.	15 in.	20 in.	30 in.
		Weeks of Duration (Usually Consecutive)					
Coastal and Lowland							
General Range		5-10	0-5	0	0	0	0
Haverhill, Mass.	50	12	2	0	0	0	0
Brockton, Mass.	110	4	0	0	0	0	0
Springfield, Mass.	199	8	4	0	0	0	0
Amherst, Mass.	217	10	6	0	0	0	0
Eastern Upland							
General Range		10-15	5-10	0-5	0	0	0
Worcester, Mass.	625	14	6	0	0	0	0
Ashburnham, Mass.	1008	14	8	4	0	0	0
Rutland, Mass.	1160	14	6	0	0	0	0
E. Templeton, Mass.	1200	16	6	2	0	0	0
Western Upland							
General Range		10-20	5-15	5-15	0-10	0-10	0
Hoosac Tunnel, Mass.	800	14	12	8	4	0	0
Pittsfield, Mass.	1037	8	2	0	0	0	0
Whitingham, Vt.	1450	18	12	10	4	0	0
Searsburg Mt., Vt.	2360	20+	16	14	12	10	0
NORTHERN NEW ENGLAND							
Coastal and Lowland							
General Range		10-15	5-15	0-10	0	0	0
Bar Harbor, Me.	20	15	10	4	0	0	0
Old Town, Me.	108	14	12	2	0	0	0
Belfast, Me.	165	15	12	8	0	0	0
Cornwall, Vt.	504	14	8	2	0	0	0
Intermediate Uplands							
General Range		15-25	10-20	10-15	5-15	0-10	0-5
Ashland, Me.	605	20	16	14	10	6	6
Grafton, N.H.	863	16	13	9	4	0	0
Ripogenus, Me.	965	22+	17	16	14	12	8
Chelsea, Vt.	1070	20	16	12	6	6	0
Highlands							
General Range		20-30	15-25	10-20	10-15	5-15	0-5
Garfield, Vt.	1300	20	18	16	12	6	0
Middle Dam, Me.	1430	20	18	16	14	10	0
Pittsburg, N.H.	1660	24+	20	16	14	12	6
Mt. Washington, N.H.	6280	24+	20	14	10	4	0

At Harvard Forest the average yearly snowfall totals about 50 inches, although it may vary from less than half to more than twice this amount. Local differences in depth of snow-cover as observed during the period of the study, and the significance of snow-cover to forest growth at Harvard Forest, will be discussed in Chapter IV.

d. Sunshine and Cloudiness.

New England is one of the cloudiest parts of the United States. The mean annual cloudiness for the greater part of central New England averages between 45 percent and 55 percent. Cloudiness is somewhat greater than this over northern New England, especially in highland areas, also over the easternmost part of the Maine coast and over the industrial region of eastern Massachusetts. At most stations in New England, April is often the cloudiest month and October is the least cloudy. The average difference between the two months at each station is less than 20 percent. In the Harvard Forest area, during the period 1935-1939, cloudiness in January averaged slightly more than 50 percent, in April almost 60 percent, in July about 45 percent, and in October about 40 percent. In April about 8 days were clear and 14 or more were cloudy. In October about 14 days were clear and 10 or less were cloudy (Liverance and Brooks, 1943, pp. 263-273).

Maps by Visher (1944, pp. 73-75) show that in the Harvard Forest area, on the average, about one-third of the days each year are cloudless, about one-third are partly cloudly, and one-third are cloudy. The average number of hours of sunshine per summer day is almost 9 hours, and per winter day hardly 5 hours.

Despite the great number of cloudy or partly cloudy days, New England has much sunshiny weather. In the interior the annual percentage of total possible sunshine is 45 to 50 percent. Many coastal stations in southern New England have a somewhat higher percentage of sunshine (Liverance and Brooks, 1943, pp. 272-274). Even during months when cloudiness is most common, and in winter, when the percentage of possible sunshine is greatly reduced, many days are bright and sunny, and are followed by clear, crisp, starlit nights.

e. Weather Changes.

It is proverbial that New England weather is subject to frequent and marked changes from day to day. Such changes are consequent upon the passage of the cyclones and anticyclones moving eastward across the region. These "lows" and "highs" are more numerous, larger, more active, and move faster in winter than in summer. This accounts for the more frequent and more marked changes of wind and weather in winter than in summer. The winds blowing outward from the highs and toward the centers of lows differ greatly in temperature and in moisture content, according to differences in places of origin, direction in which they blow, and the speed at which they blow.

In winter, northwest winds are likely to be dry and very cold, since they come from the continental interior. Such winds may cause the temperature to fall as much as 30F degrees in 24 hours, and may reduce the temperature to -15°F or lower. These clearing and cooling winds are associated with cold-front conditions; often they set in suddenly after a period of rain or snow associated with damper and relatively warmer winds blowing inland from the ocean on the south and east. Summer cool spells are similarly caused by northwest winds.

Both in winter and summer the warmest weather is usually brought by southwesterly and westerly winds, blowing out of high-pressure areas centered over lower latitudes or over the warmer interior of the continent. These unseasonably warm conditions break the severe cold spells of winter, but in summer they cause the weather to be hot, muggy, and uncomfortable. Every summer has such heat spells, but many summers have relatively few.

Northeast winds blowing onshore from an anticyclone centered over the ocean also bring rain. In winter and spring their effect is to make the weather damp and chilly or even cold. Some of the heaviest rains and snowstorms are caused by these northeast winds (Ward, Brooks, and Connor, 1936, p. J179).

In summer the highs and lows are poorly developed and move more slowly. In general they are much weaker, except when modified by West Indian hurricanes moving northward and northeastward over the ocean in late summer or autumn. The changes induced by the eastward movement of summer cyclones are less emphatic than those of winter. Winds may be quite variable, but the prevailing south and southwest wind, though light, blows quite steadily for long periods. Temperature changes, too, are of a smaller order than in winter. On the whole, summer weather is calm and peaceful, though broken occasionally by squall winds which come out of thunderstorms and cause sharp drops in temperature.

Spring and autumn are seasons of transition. They differ considerably in detail from year to year, but in general have much changeable weather. March often has much gusty and unpleasant weather alternating with fine spells. April tends to be milder but wetter. During September, which is very changeable, summer gives way to fall, but October often has a long, fine golden spell of "Indian Summer" before another changeable period sets in and winter approaches.

f. Summary of Weather Conditions during Period of Study.

A brief summary of weather conditions from August, 1947 through July, 1948, the period during which the study here reported was made, will be found in Section 3 of Chapter IV, Findings and Analysis.

5. Vegetation.

The Harvard Forest is in the transition zone between the northern forest and the central forest of eastern United States. The dominant trees of the northern forest are white pine, spruce, fir, beech, yellow and paper birch, and sugar maple. The central forest originally consisted of many species of oak, hickory, and other hardwoods, notably chestnut. The chestnut has been practically eliminated by blight. The transition zone in New England includes most of the species common in each of the two bordering forest types. In addition, the transition zone includes much more white pine, hemlock, red maple, and red oak than is common in the northern forest, although these are essentially northern species, and much more white ash than is common in the central forest, of which ash is an important component.

In the transition zone, the northern-forest species are common in the cool, shaded, or otherwise less favored situations, and the central forest species are most common on the warmer southern and western slopes.

"For example: mixed stands of white pine, hemlock, beech, birch, and maple on cool northern sites contrast with oak and hickory on sunny upper slopes, with pitch pine on light outwash soils (sand plains), with spruce and larch in sphagnum bogs, and red maple and white ash growing in swales. It is on the intermediate sites, middle elevations, and moderate exposures that intermingling of the northern and central species occurs to the maximum degree; in such places it is not uncommon to find as many as twenty different species, softwoods and hardwoods, growing together" (Lutz and Cline, 1947, p. 15).

In the pre-colonial forest many of these general relationships of stand-type to site characteristics were essentially the same as today, although the common species probably were not represented in the same proportions at all times. Fisher (1933, p. 215-216) has described the kinds of changes which took place in this pre-colonial forest as follows:

"... we find evidence, even with no human factors in operation but the aboriginal Indian, that there must have been over long periods important changes in the distribution of species and the character of the forests within each of our climatic regions. Undoubtedly forest fires are more prevalent und destructive today than when the Pilgrims landed; but there is convincing evidence that everywhere fires were of periodic occurrence both from the practice of the Indians and occasionally from lightning.... In addition to fires it is only necessary to consider longer stretches of time, such as centuries or more, to find unmistakable signs of other destructive agencies: wind-throw, generally occurring on uplands of exposed ridges and often prostrating large areas of trees; lightning, which sometimes kills a dozen or fifteen trees with one bolt; ice storms, shattering many acres of tree tops; and, probably in the wake of these, fluctuating attacks from injurious forest insects or disease. It is likely, especially on drier and more exposed sites, that such periodic calamities as these, upsetting for a time and sometimes over large areas the equilibrium of tree species, were collectively the most powerful influence governing pre-colonial forest history. Without the recurrences of fires we should not have had the heavy forests of pine in central New England reported in some localities by the early settlers. It is likely also that, without these periodic upsets providing breaks and exposures in the ancient forests, many of our short-lived, light-seeded species such as gray birch, pin cherry, and aspen would have been even more rare and restricted in distribution than they actually were in the original forest. Thus, while areas of big timber certainly predominated in the early forests as traversed by the pioneers, there must also have occurred many areas where reversions to younger woods or shorter-lived species were in progress."

Careful field study at Harvard Forest, combined with study of early descriptive writings and of land titles dating back to the original white settlement of the Petersham area, gives abundant evidence that many of the present forest types characteristic of particular kinds of natural sites are essentially the same types that were common on those kinds of sites in the pre-colonial period (Raup and Carlson, 1941). Field analysis of present-day, old-growth forests known to have been left undisturbed by man since pre-colonial times gives added confirmation to such conclusions (Cline and Spurr, 1942).

5. Land-Use History.

The Eastern Upland was settled relatively late in the Colonial period, well after a considerable development had taken place in the coastal regions to the east and in the Connecticut Valley and other lowlands to the west.

"Settlement was begun in Petersham in 1733, and thereafter the land was parceled out in five different divisions, from 1733 to 1770. Certain portions of the Harvard Forest properties were among those in the first division, and were cleared for farming at an early date; others were in the later divisions, and clearing was delayed or never made. The process of land clearing did not proceed at a rapid pace in the beginning, because the community was isolated and an exchange of produce with other communities was impossible Only enough food and other essentials were produced to satisfy local needs. Not until the early part of the 19th century, when neighboring towns had become more heavily populated and industrialized and intercommunal roads had been built, did the clearing of the land for cultivation gain impetus" (Lutz and Cline, 1947, p. 15-16, summarizing Raup and Carlson, 1941, p. 17-28).

In the 1840's, agriculture reached its greatest development. Even then not more than 15 percent of the land was tilled, although much more was cleared for pasture and upland mowing (Raup and Carlson, 1941, p. 26). Actual woodland may have been reduced to as little as 20 percent or less of the total; this period of maximum agricultural land-use continued for about ten years.

"Many factors contributed to the next stage in land history — farm abandonment. The lure of higher wages in the growing industrial centers, the declining fertility of the local soils, the opening up of the Middle West with its vast stretches of highly fertile land, and the discovery of gold in California all had their effect. Farm abandonment started on a large scale about 1850, and has proceeded at a variable rate up to the present time...

"The natural seeding in of white pine on the thousands of abandoned fields and pastures throughout the region ushered in the old-field white pine era, one of the most unexpected and productive in land-use history. This gratuity of nature completely reversed the downward trend in lumber production. Large-scale logging operations in old-field white pine started about 1890, and reached a peak in 1909. This twenty-year period probably witnessed the most intensive lumbering operations in the history of the region. Pine-using industries sprang up in many of the larger centers, and portable sawmills dotted the landscape. Clear-cutting was universally practiced" (Lutz and Cline, 1947, p. 17).

During this period, some farming continued, especially on better lands accessible to roads. Many farms, however, were bought by city residents to be used only as "summer places". On a few such places some farming was done by owners or caretakers, but on many places the land reverted to forest. Petersham became the center of a quiet but substantial summer colony. Later, as auto tourism developed, resorts of the Petersham type experienced partial decline. But the automobile also made it possible for people to live farther from their work; in recent years many permanent residents of Petersham have found it possible to commute daily to work in nearby industrial and commercial centers, particularly Athol and Worcester; newcomers also, who work in the cities, have settled in the village and in the surrounding country.

Both agriculture and logging declined during the first third of this century and became subordinate to urban manufacturing and commerce and to recreation employment as sources of income for residents of Petersham Township. Forest and woodland increased steadily in extent. For the most part, however, these stands received little or no silvicultural treatment, and their quality deteriorated steadily.

"The stands following the clear-cutting of old-field pine on the better soils were composed largely of a mixture of hardwoods of advance growth origin together with hardwoods which seeded in after logging. Thus, the next stage in local forest history, predominant to the present time, is characterized by mixed hardwoods, even-aged in form and mostly single-stemmed.

"When the stands following old-field pine are clear-cut for fuel wood, as has often been the case in recent years, the next stage is hardwood coppice composed of coarse stump sprouts, markedly inferior in quality to the preceding generation and comparatively unsusceptible to improvement by silvicultural measures. In some places a second regeneration of coppice now occupies the land and deterioration of the growing stock has reached a new low. Over a period of slightly more than 200 years, since the first settlement and the beginning of land clearing, virgin sawtimber of fine composition and quality has been replaced by rank-growing stump sprouts and weed species suitable only for fuel wood and similar products" (Lutz and Cline, 1947, p. 17).

The managed lands in the Harvard Forest were developed in differing ways, depending upon the silvicultural practices employed. When the Forest was established, much of the land was in old-field pine, but most of this has since been logged off and now has young growth in various stages of development. Many idle fields and pastures which were open land in 1908 were planted with conifers, particularly in the Prospect Hill Tract. Some parts of the Forest, particularly in the Slab City Tract, today have a fine growth of timber. The hurricane of September 21, 1938, wrought great havoc on exposed slopes. On almost all forest lands which it devastated, hardwood species are now in the ascendancy.

7. Present Status, Major Problems, and Potentialities.

On the upland ridges of Petersham today, as well as on the ridges and broad valley plains of bordering townships, some large farms and a considerable number of smaller farms are operated. Some of these are productive enough to provide the full support of the families occupying them. In Petersham Township, however, full-time farmers are the exception. Many of the operating farms are part-time enterprises. The owners or tenants of these supplement their farm income with wages earned in nearby cities, to which they commute daily. Others work part-time for one or the other of numerous families who own summer property in or near Petersham. Still others operate small businesses serving tourists or resorters, or work for the township or other government agencies. The larger farms are primarily dairy farms, with general mixed farming providing feed crops for livestock and partial subsistence for the family. On many farms a secondary cash product, such as poultry, or vegetables, or fruit is produced in significant amounts, but the emphasis is chiefly upon dairying. Hay and silage corn are the chief field crops, and permanent pasture occupies a large portion of the cleared land. Few farms are without large blocks of woodlot. The forest provides fuel for the family and additional firewood to sell in town or city. Only a few stands of forest undergo any cutting for lumber purposes in a given year.

Less than half the township is included in farms actually in operation as a farm, and less than half the land on these farms is cleared. Less than 20 percent of the land in farms is in harvested crops, including hay. About the same amount or slightly more is pasture. The rest is woodland. All told, 75 percent or more of the Town of Petersham is woodland. Although the Town of Petersham may be considered unusual because the Harvard Forest lands compose about ten percent of the total town area, the figures given are representative of many townships in this part of New England (Davis, 1933, pp. 118-167, esp. pp. 142, 143, 146, 147, 150, and 151)

Actually, the rural economy of much of southern New England is being strengthened by the present-day development of part-time farming, and at least a slight increase in land in farms might reasonably be expected. It is hardly likely, however, that very much of the present woodland will be cleared for agricultural use under present conditions. These woodlands now represent the most extensive type of land use in many townships; but at present they are one of the least remunerative resources. The problem of increasing their quality as sources of timber for local industry, and their beauty as forests, to be appreciated by visitors and local residents alike, is obviously of primary importance.

CHAPTER III - METHODOLOGY

1. Establishment and Expansion of Station Network.

a. Summer, 1947.

The study was begun as a summer research project in July of 1947. Stations were established at that time in a line extending from Petersham Center westward into the Tom Swamp Tract. These stations were all of the small-shelter type. Most of the shelters were fastened on tree trunks, on the north side. In order from east to west these stations were (Figure 6): Petersham (Nichewaug), East Hill, Trail Fork, Stream Crossing, Hemlock Base, Harvard Hill, Gravel Hill, Mill Point, and Tom Swamp. Weekly maximum- and minimum-temperature readings were taken at each station. In addition, a continuous thermograph record was obtained at Harvard Hill and Tom Swamp. Owing to the contrasted nature of the sites of these stations, the readings obtained were strikingly different.

In order to supplement the data gathered at the stations, a few rapid traverses were made on clear, relatively windless afternoons, to obtain maximum-temperature readings at other points. Similarly, several rapid traverses were made on calm, clear nights, during the three-hour period preceding sunrise, to obtain minimum-temperature readings. These minimum-temperature traverses were more extended, with check readings taken at several crossing points in the course of each traverse. Most of the day traverses and all the night traverses were made by automobile. Readings were taken about fifty feet ahead of the car at each stopping point, and were taken at least twice to verify the value obtained.

The results obtained from this summer project were sufficiently interesting to make it appear worthwhile to increase the number of stations to form a network in contrasted parts of each of the three main tracts at Harvard Forest, and to continue the project for a full year.

b. Autumn, 1947.

During the autumn of 1947, some fifteen minimum-thermometer stations were established, including one at the highest point in the Forest (Prospect Hill, 1383 feet), one at a point lower than any in the Forest (Swift River Power Line Crossing, 590 feet), and others on hilltops and in representative swales at intermediate elevations. At these stations the thermometers were wired between branches of trees or otherwise suspended in the open. Such stations are designated in this report as unsheltered, or nonsheltered, stations, to indicate that the instruments were not placed in instrument shelters. The sites of some of these stations, however, are partially sheltered by vegetation or by topography.

c. Winter, 1947-1948.

In late autumn the University received 10 war-surplus shelters of the standard Weather-Bureau type, which were made available for use at Harvard Forest. Permanent supports were constructed for these, and stations were established at selected points, many of them where particularly interesting long-time silvicultural studies are being made. In addition, 15 standard shelters and supports, of the Army Signal Corps knockdown type, were provided by The Quartermaster General, United States Army, for the period of the study. These were assembled at the Forest Headquarters and were set up in various contrasted locations. By mid-December a network of 31 sheltered stations and 14 nonsheltered stations was in operation. The Harvard Forest woods crew gave invaluable help on numerous occasions in establishing this network and in dismantling stations upon completion of the project. In a few places standard shelters were set up where smaller shelters were already in use. After a few weeks during which readings were taken for check purposes from instruments in both shelters, the smaller shelters were moved to new locations (Harvard Hill to Chestnut Grove; Petersham to Trailside Swale).

As the network increased in size it became necessary to use two days a week to obtain readings. After the heavy snows had set in, in late December, it became necessary to devote three days per week to taking readings, a separate day for each main tract. This introduced an element of non-simultaneity into the data, but, as will be justified later, it was considered desirable to obtain the greatest number of records.

During some weeks in winter it was not possible to reach all stations in the Tom Swamp Tract in the course of the day; and several stations near others from which an interpolative value could be taken, if desired, were skipped. No interpolative data are given in the tables, however, for those stations (chiefly East Hill, Gravel Hill, and Red Pine Ridge). A few non-sheltered minimum thermometer stations in isolated locations in all three tracts were read only once a month in winter (Choate Farm Hill, Pierce Road Swale).

d. Spring and Summer, 1948.

For some less accessible places, it had not been possible during winter to establish stations as had been planned. In spring these stations were added, chiefly in the Prospect Hill Tract. At two of these (Northwest Midslope, Lower Spruce-Hardwood) the instruments were housed in Weather-Bureau type shelters. In addition, five more shelters were built to fasten to trees. Although smaller than the standard shelters, they are of considerable size and will house several kinds of instruments and still be amply ventilated. Some of these were placed in new locations (Little Prospect Hill, Big Spruce Swamp, Nelson Brook Flat). Two were placed at stations where particularly small shelters were already in use, housing only a Six-type max-min thermometer (East Hill and Mill Point). The larger shelters were installed in order to obtain checks as to instrumental and shelter comparability.

In the course of the project as a whole, a few stations were discontinued in order to make instruments available for use at other places with unusual characteristics. The period of reliable operation of each station can be determined by reference to the tables of basic data in Appendixes B and C.

Readings were taken from August 1947 through July 1948, to get a full twelve-months' record including a coldest and a hottest month.

2. Instrumentation for Temperature Measurements.

All instruments, except the exposed minimum thermometer at bush height at Tom Swamp, were placed at heights of five to seven feet from the ground. Thermometers in shelters were at a height of five to six feet.

In winter, at every station where any likelihood existed of the snowcover becoming exceptionally deep, the snow within a radius of 15 feet of the shelter was tramped down each week. Where necessary, broad exits also were tramped out leading to lower ground, in order to facilitate cold-air drainage and thereby minimize the probability of abnormally low temperatures within the artificially created shallow basin occupied by the shelter. At no station were any instruments in the shelter ever less than 40 inches from the surface of the snow-cover, and very few instruments were ever less than four feet. All readings may therefore be considered to be "standard-height readings." The general effect of snow-cover upon temperatures will be discussed in Chapter IV.

a. Weather Bureau and Six-Type Max-Min Thermometers for Weekly Readings.

In most shelters a standard Weather-Bureau-type maximum thermometer (mercury), and standard minimum thermometer (spirit) were used. At five stations in the original string, small shelters were used, each housing a Six-type maximum-minimum thermometer.

b. Thermographs Used for Detailed Records.

Three Friez-type thermographs were employed from the start of the project and were used continuously for the year period. Four additional thermographs of the same type were put into use in December and January, and four more were put into use in March. All 11 of these thermographs used an identical type of chart.

It will be noted from the tables in Appendix C that the Harvard Hill and Tom Swamp thermograph record is essentially complete for the whole year. At Prospect Hill and White Pine Bottoms a continuous record was obtained from January to the end of the study. At first the other thermographs were used for sampling purposes at various stations for a week or two at a time. In March and April a continuous thermograph record for seven weeks or more was obtained at six stations in the Slab City Tract, to provide detailed spring records for places on south-facing slopes as contrasted to places on north-facing slopes. In May these thermographs were moved to the Prospect Hill Tract to get a full-month's record; some of these thermographs were placed in stations which had been established in early winter, others in stations which had not been established until spring. In July these thermographs were moved to various scattered points in the Prospect Hill and Tom Swamp Tracts to get detailed information about contrasts among canopied and noncanopied stations, also to obtain comparative readings where only Six-type thermometers had been used.

c. Nonsheltered Minimum Thermometers.

The minimum thermometers used at nonsheltered stations were the standard Weather-Bureau type (spirit) but were not, except in a few cases, mounted on a protecting metal frame. They were suspended on copper wires between horizontal branches of trees; most of the trees were coniferous. Wherever possible the trees chosen were in places reasonably protected from strong wind.

At the Harvard Forest Headquarters station, operated by members of the Forest staff, a daily reading is taken at noon on Weather-Bureau-type maximum and minimum thermometers, and a continuous record is obtained in addition from a hygrothermograph. Instrumental difficulties developed simultaneously on several instruments during October 1947 at the Headquarters Station. The instruments were adjusted shortly thereafter.

The daily record for Harvard Forest Headquarters is given separately in Appendix C-II. Weekly maximum and minimum readings are included in Appendix B.

d. Calibrations and Inter-Station Checks.

All instruments used were calibrated by field methods before use. The Harvard Forest instruments had been calibrated for previous temperature studies conducted by S. H. Spurr. The thermographs furnished by the Blue Hill Meteorological Observatory at the beginning of the project were adjusted at the time they were made available and were again checked against instruments of known local reliability by simultaneous operation in a shelter set up at Harvard Forest Headquarters. All thermometers and thermographs furnished later by the Army were checked similarly. During warm weather some instruments, including thermographs were checked against each other by so placing them in a refrigerator that all sensitive elements were near the same point. The instruments were taken out of the refrigerator after about a half-hour, placed on a stand in the shade for a half-hour, then returned to the refrigerator, and so on. The correspondence of minimum and maximum readings with those of check instruments was sufficiently close to justify the conclusion that, for the degree of accuracy required, the method furnished a useful and quick check.

In the field, check readings were taken with a sling thermometer at each shelter almost every week. All thermograph records had an additional weekly maximum check and minimum check from the thermometers installed in the same shelters. Agreement of readings was generally very high during periods of cloudy or rainy weather. Slight differences between instruments at other times were caused by differences in position within the shelter. The thermographs were a foot lower than the thermometers in the shelters, hence recorded slightly lower minimums than the thermometers during inversions, and occasional higher maximums at times of superadiabatic lapse rates. Some of these slight differences will be apparent from comparison of tables of weekly readings from thermometers, and of daily readings from thermographs.

On numerous occasions additional thermometers were placed in shelters for a few weeks at a time, some on the shelter floor, some lying across the top of the thermograph (with bulbs just above the Bourdon element), and some on the shelter bracket. On a few occasions a minimum thermometer would be placed with the bulb extending outside the shelter to obtain an inside-outside comparison. From these various prechecks and in-use checks it was determined that the thermometers in general were accurate to one-tenth of a degree or better at all temperatures. The few thermometers which gave unusual readings during calibration were not used in the field.

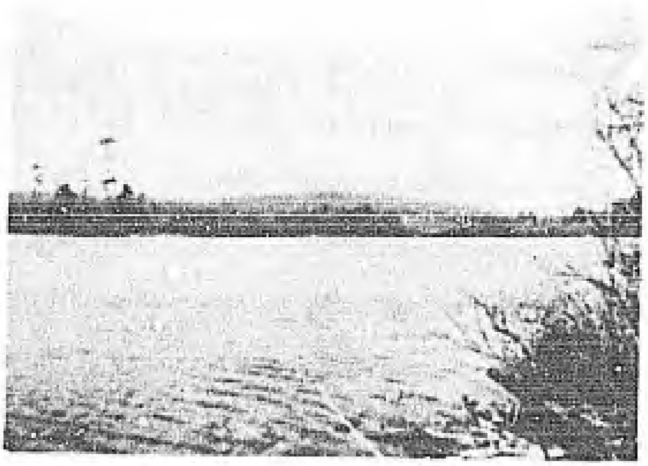
The thermograph pens required very little resetting from week to week. The chief problem with the thermographs was expansion of charts during humid periods and shrinkage away from the drum flange during succeeding dry periods. This resulted in the lower edges of some charts being up from the flange a distance equivalent to as much as two degrees at the end of the week. Such discrepancy was unavoidable when instruments were not checked daily. Comparison with the shelter-thermometer and hand-thermometer readinge generally made it possible to verify that the pen setting was still correct, and to make reasonably satisfactory adjustments of a degree or two in the daily maximum and minimum temperature figures for those parts of the week which had experienced unusual humidity conditions.

The nonsheltered minimum thermometers installed near shelters on hills, such as Prospect Hill, gave readings which corresponded closely to those in the shelter. In concave areas, as at Shelf Swamp, if the non-sheltered thermometer was installed at a point slightly higher or lower than the sheltered thermometer the readings would differ slightly, owing to air layering, but in the expected direction. The higher instrument gave the higher reading, whether it was the one in the shelter or in the open.

3. Snow-Depth and Water-Temperature Measurements.

In the course of the middle and late winter, snow depths were measured at more than a hundred different points along the regular station-traverse routes. At each place ten separate readings were taken with a snow-stick, and the average was then recorded. Although readings were taken on different days the total body of data gathered provided useful information, not only about rates of snow accumulation and settling and melting but also about the interrelationships between temperature and snow-cover.

In the spring and early summer seasons, water temperatures were read at selected points along the traverse route, chiefly in the Tom Swamp Tract (Figures 11 and 12). Temperatures were read at different times. At the pond outlets the thermometer was held in the swiftest flowing water below the dam for several minutes for each of three readings, which were then averaged. At pond shores and at Tom Swamp the procedure consisted of swirling the thermometer around in foot-deep water for a minute for each of three readings and taking an average. The readings were almost always identical at any one place, and when not identical differed less than a degree. These water-temperature readings proved to be of some use, but did not provide the basis for reaching positive conclusions such as would have been possible had readings been taken more frequently on a regular schedule throughout the period of the study.



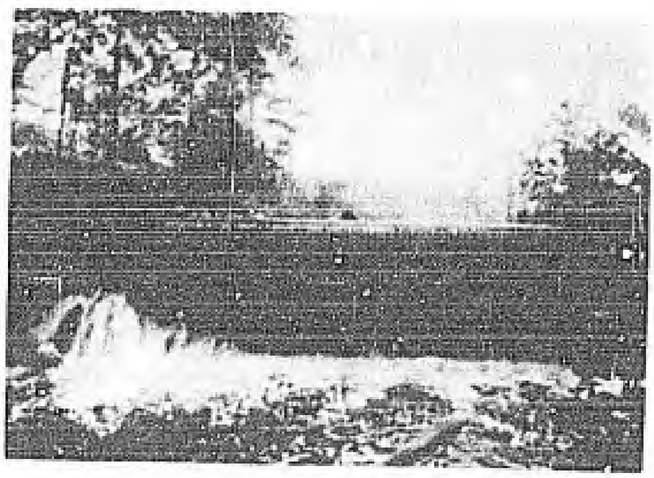


Figure 11 (left) - Water-temperature station, Harvard Pond east shore. Looking northwestward from reading point toward Tom Swamp and West Boundary Hill. April, 1948.
Figure 12 (right) - Water-temperature station, Harvard Pond outlet. Water temperatures were measured in waterfall and in stream in foreground. Looking east. June, 1948.

4. Description of Station Situations, Sites, and Instrumentation.

In this section summary descriptions are given for all stations, both sheltered and non-sheltered, for which data are cited. These summary descriptions treat the stations in sequence for each of the three main tracts, and indicate each station's elevation, topographic situation, surrounding vegetation, type of instrument shelter or installation, instruments installed, and general period of operation. Station locations are shown in Figure 6. Photographic figures which accompany this section show many of the stations, and for some of them illustrate seasonal contrasts (Figures 13-71).

a. PROSPECT HILL TRACT (Figure 6).

In this section the sheltered stations are listed first, followed by the nonsheltered stations.

SHELTERED STATIONS.

PROSPECT HILL. Elevation 1383 ft. (Figures 13 and 14).
Situation: Highest point in Harvard Forest area. At southern edge of extensive upland divide. Gentle slope to north. Steep descents to east, south, and west.
Vegetation: Open summit with bare rock and grass. Scrubby growth of pin cherry and birch in bordering fields. Completely open to winds from any direction.
Shelter type: Weather Bureau Standard type. Permanent installation.
Instruments: W. B. Maximum and Minimum thermometers, thermograph, December through July.

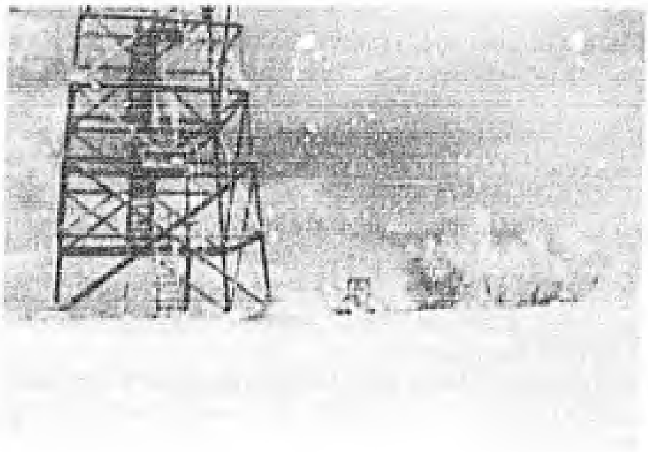
HIGH SWAMP. Elevation 1280 ft. (Figures 15, 16, and 17).
Situation: Highest upland swale in Harvard Forest. Occupies a slight depression at head of long valley draining south to swamp at east base of Prospect Hill.
Vegetation: Station in open blowdown area of mixed hardwood swale. Old-field pine on slope to east. Hemlock and pine to northwest. Heavy fern growth in summer.
Shelter type: Weather Bureau Standard, portable type.
Instruments: W. B. Maximum and Minimum thermometers, December through July. Thermograph during June.

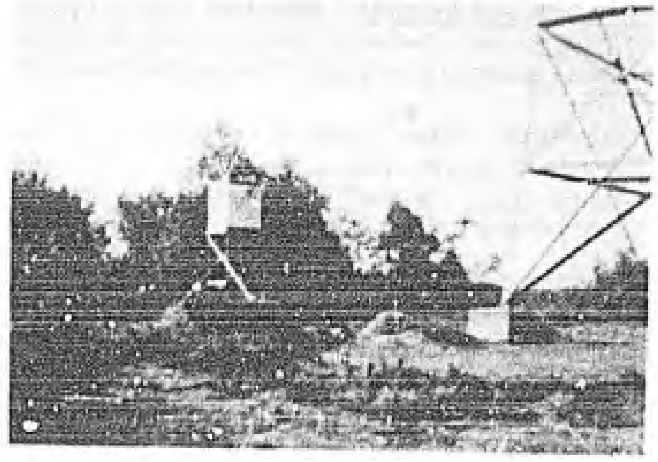
TOWN LINE SWAMP. Elevation 1125 ft. (Figure 18).
Situation: A wide swampy area at south and west base of Prospect Hill. Bordered by till-covered terraces.
Vegetation: A mature and submature mixed hardwood stand, mostly of northern-forest species with abundant red maple, yellow birch, and hemlock. Open blowdown to east. Red oak and paper birch on higher ground to west.
Shelter type: Weather Bureau Standard type. Permanent installation.
Instruments: W. B. Maximum and Minimum thermometers, December through July. Thermograph during June.

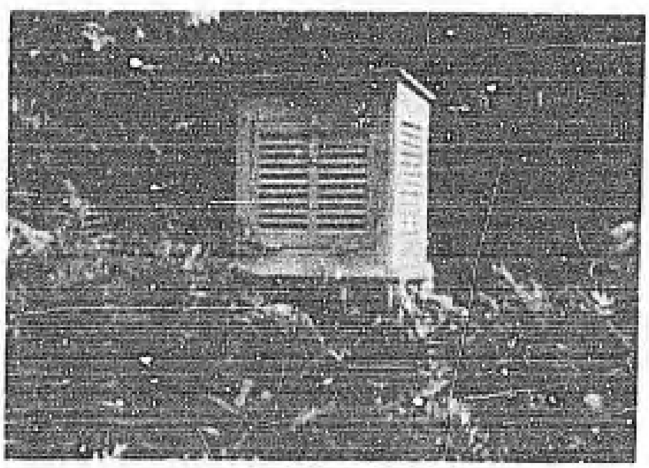
LITTLE PROSPECT HILL. Elevation 1300 ft. (Figure 19).
Situation: On summit of rounded secondary summit southwest of Prospect Hill, with moderately steep descents to northwest and southeast and terraced descent beyond a slightly lower summit to the southwest.
Vegetation: Twenty-two-year-old red pine plantation, lower branches pruned, moderately dense canopy, except above summit trail.
Shelter type: Harvard Forest shelter, wide type, large. Nailed and braced on tree trunk.
Instruments: W. B. Maximum and Minimum type, June and July. Thermograph during June.

NORTHWEST MIDSLOPE. Elevation 1210 ft.
Situation: At approximate midpoint (within Harvard Forest limits) in long rocky northwest slope of Little Prospect Hill.
Vegetation: Young stand of vigorous sprout growth of transition-forest hardwood species, closing in station but not forming canopy.
Shelter type: Weather Bureau Standard, portable type.
Instruments: W. B. Maximum and Minimum thermometers, June and July. Thermograph during June.

LOWER SPRUCE HARDWOOD. Elevation 1150 ft.
Situation: At lower edge of rocky slope of Little Prospect Hill and just above narrow, steep-edged kame terrace.
Vegetation: Thirty-five-year-old suppressed spruce stand overtopped by mixed transition hardwoods which form dense summer canopy. Hardwoods in north half of stand felled in 1947 to release spruce.
Shelter type: Weather Bureau Standard type. Permanent installation.
Instruments: W. B. Maximum and Minimum thermometers, June and July. Thermograph during June.







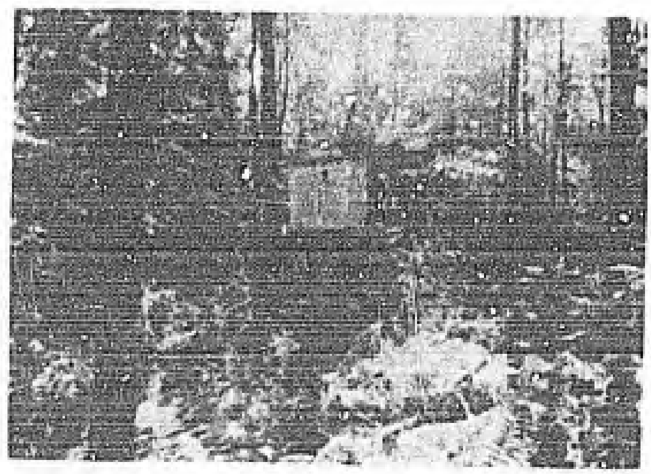


Figure 13 (upper left) - Prospect Hill Station. January, 1948.
Figure 14 (upper right) - Prospect Hill Station. June, 1948.
Figure 15 (left center) - High Swamp Station. Looking southeast. Oldfield pine in left background, mixed hardwoods in swale to right. January, 1948.
Figure 16 (right center) - High Swamp Station. Looking northwest, Late March, 1948.
Figure 17 (lower left) - High Swamp Station, showing heavy growth of cinnamon fern around shelter. Late June, 1948.
Figure 18 (lower right) - Town Line Swamp Station. Looking southeast toward shelter. June, 1948.

BIG SPRUCE SWAMP. Elevation 1180 ft. (Figures 19 and 20).
Situation: At southeast base of Little Prospect Hill. Occupies lowest part of broad Brooks Hill platform. Drains eastward to Swift River and westward via Nelson Brook to Riceville Pond and Brook, and Miller's River.
Vegetation: Mixed stand of red spruce, hemlock, and numerous hardwood species, including black gum. Shelter is in open, near edge of one of several blow-down areas.
Shelter type: Harvard Forest shelter, wide type, large. Nailed and braced on tree.
Instruments: W. B. Maximum and Minimum thermometers and thermograph, July only.

LOCUST OPENING. Elevation 1200 ft. (Figure 21).
Situation: Near eastern edge of a broad, undulating-to-flat platform which grades northward into Big Spruce Swamp and eastward by a series of terraces into Town Line Swamp.
Vegetation: Near station a dense growth of black locust (not native) and elm. On slopes to east are young stands of mixed transition hardwoods. To west, weed-tree species in old fields. No canopy over station.
Shelter type: Weather Bureau Standard type. Permanent installation.
Instruments: W. B. Maximum and Minimum thermometers, December through July. Thermograph during June.

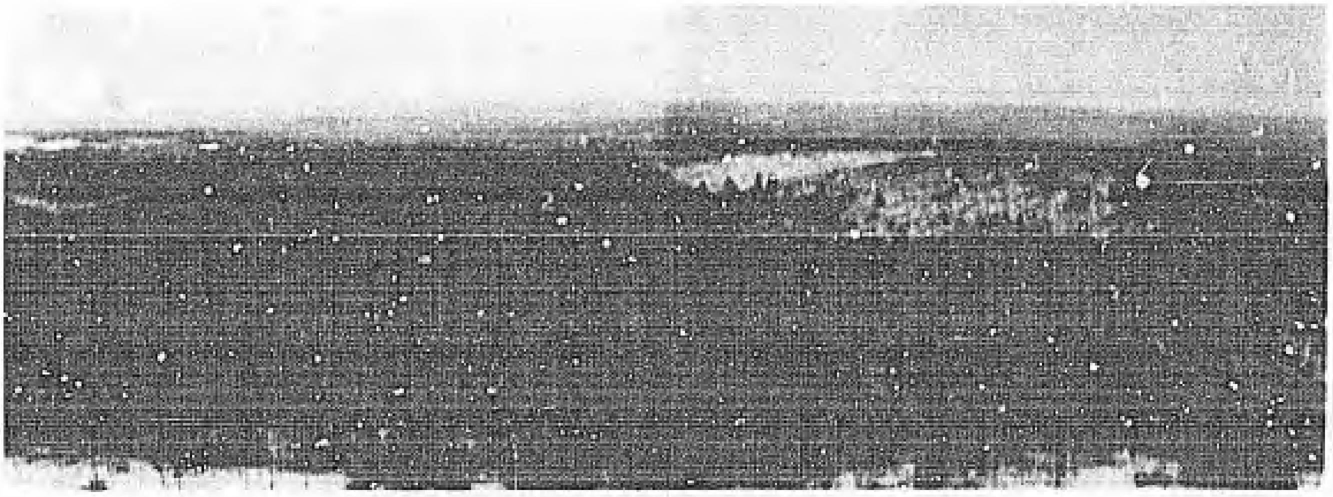
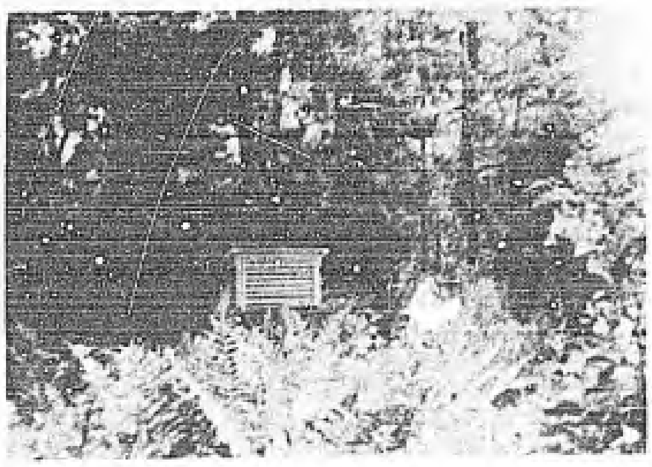


Figure 19 - View westward toward Little Prospect Hill (1) and Big Spruce Swamp (2). Little Prospect Station is in center of plantation on summit. November, 1947.



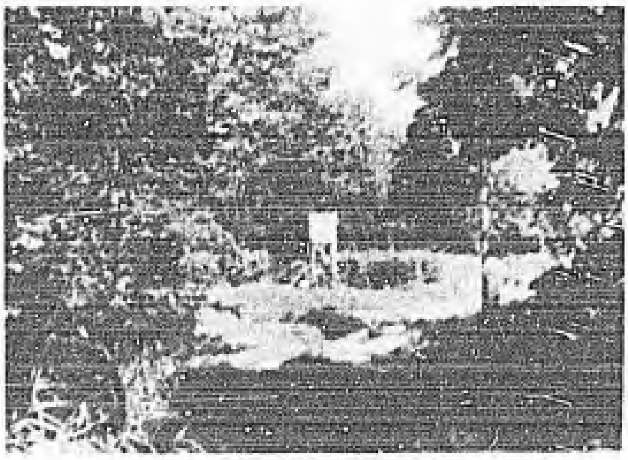


Figure 20 (left) - Big Spruce Swamp Station. Looking southeast toward shelter from open blowdown area in center of swamp. July, 1948.
Figure 21 (right) - Locust Opening Station. Looking north toward road junction and shelter. June, 1948.

LAKE SWAMP. Elevation 1125 ft. (Figures 22 and 23).
Situation: A long swamp occupying a slight trough on a broad platform west of Brooks Hill. Grades southward into an open, marshy millpond which also receives streams draining a higher terrace to the east and south.
Vegetation: Mixed hardwood swale, with much swamp-brush growth to north and open marsh to south. Heavy canopy.
Shelter type: Weather Bureau Standard, portable type.
Instruments: W. B. Maximum and Minimum thermometers, end of December through July. Thermograph during June.

HARVARD FOREST HEADQUARTERS. Elevation 1100 ft. (Figure 24).
Situation: On a south-trending spur which descends gently eastward and southward into hardwood swale of upper Nelson Brook and drops away sharply westward to Riceville Pond lowland.
Vegetation: On open grassy north slope of low knoll. Red maple swale to east. Red pine plantation to south.
Shelter type: Weather Bureau Standard shelter on permanent timber support 3' high, weighted with heavy stones.
Instruments: W. B. Maximum and Minimum thermometers. Hygro-thermograph. Also anemometer and recording rain gauge nearby.

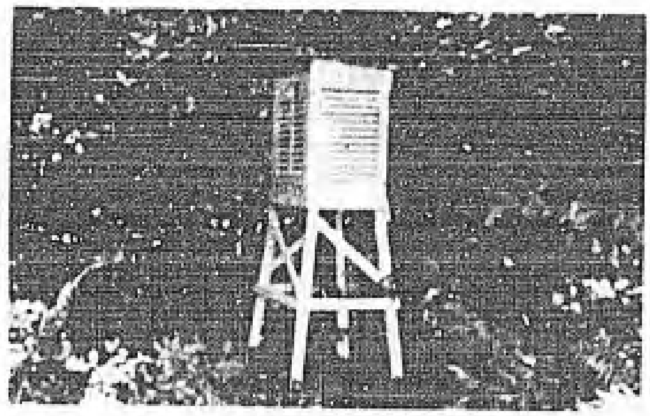


Figure 22 (left) - Lake Swamp Station. Looking east. Winter view showing typical swale hardwood growth. March, 1948.
Figure 23 (right) - Lake Swamp Station. Looking east. Summer view, showing heavy canopy and abundant undergrowth. Late June, 1948.

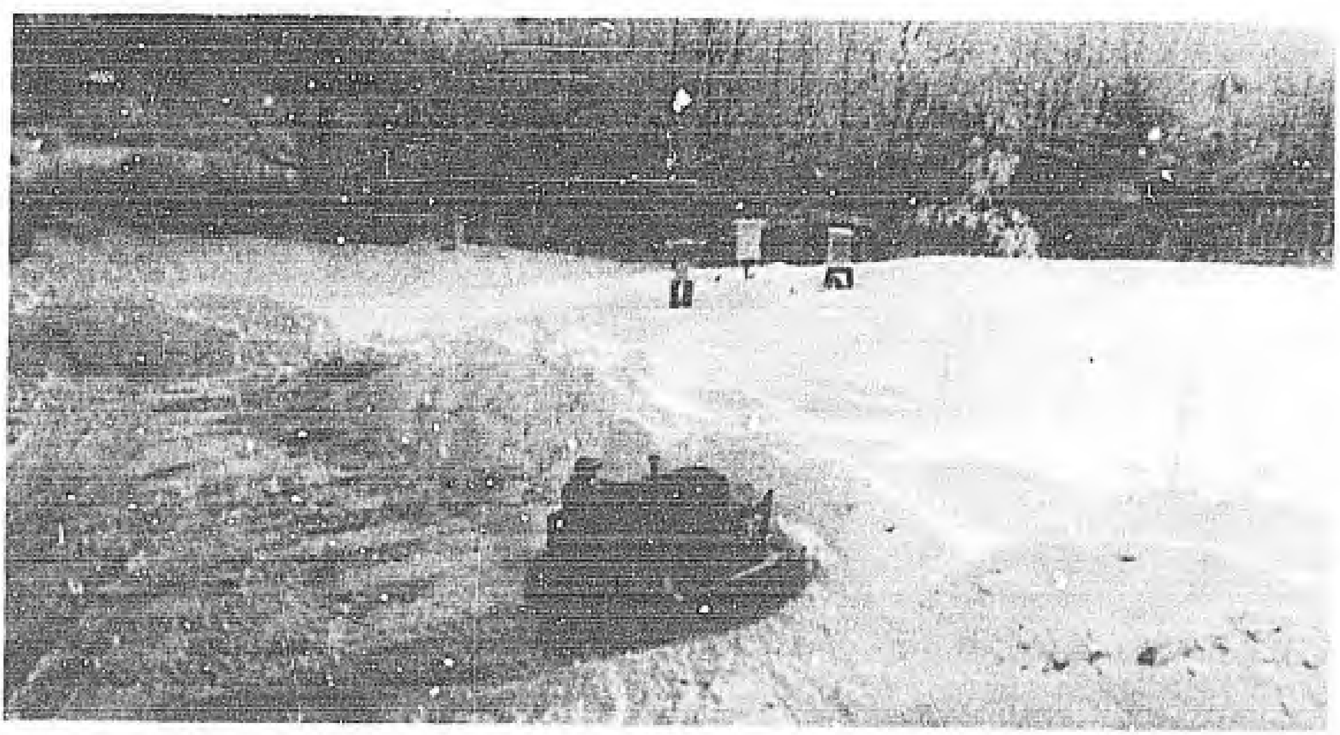


Figure 24 - Harvard Forest Headquarters Station. Looking east from Shaler Hall, past station and toward hardwood swale. January, 1948.

NELSON BROOK FLAT. Elevation 930 ft. (Figure 25).
Situation: On high, moist, stony terrace at base of steep, rocky western slope of Prospect Hill-Petersham Ridge. Westward a succession of lower terraces leads down to a broad kame terrace bordering Riceville Pond and Tom Swamp.
Vegetation: Mixed stand of widely spaced mature and submature mixed transition-hardwood species. Moderately open summer canopy.
Shelter type: Harvard Forest shelter, wide type, large. Nailed and braced on tree.
Instruments: W. B. Maximum and Minimum thermometers, July only.

NONSHELTERED STATIONS.

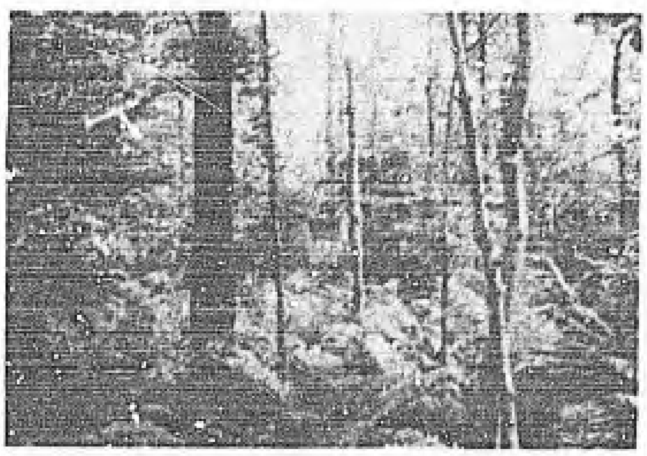
PROSPECT HILL. Elevation 1383 ft.
Situation and Vegetation: See description (above) for Prospect Hill sheltered station.
Instrument: Nonsheltered. W. B. Minimum thermometer without guard, wired to power-line pole. October through July.

BROOKS HILL. Elevation 1250 ft. (Figure 26).
Situation: On summit of high, smooth, oval hill bordered by successively lower platforms or terraces, till-surfaced.
Vegetation: Twelve-year-old white pine plantation being overtopped by red oak, forming a partially open canopy.
Instrument: Nonsheltered. W. B. Minimum thermometer without guard wired between branches of white pine tree. November through July.

LOCUST OPENING. Elevation 1200 ft.
Situation: See description (above) for Locust Opening sheltered station.
Instrument: Nonsheltered. W. B. Minimum thermometer without guard, wired between branches of elm tree. November through July.

SWAMP KNOLL. Elevation 1140 ft.
Situation: A small terrace fragment in the center of Town Line Swamp. Has undulating surface about 15 feet above swamp level.
Vegetation: Mixed stand of transition and northern hardwoods, submature. Bordered to east by pure hemlock stand. Medium-dense summer canopy.
Instrument: Nonsheltered. W. B. Minimum thermometer without guard tied across fork of branch on beech tree, April through July.

PIERCE ROAD SWALE. Elevation 1100 ft.
Situation: At lower exit of Town Line Swamp, between terraced slopes of Brooks Hill platform to west and a long, narrow, low, north - south ridge to east.
Vegetation: Mixed stand of submature hardwoods, both transition and northern species, with brushy growth near stream. Medium-dense canopy near instrument. Semi-open blowdown area to northeast.
Instrument: Nonsheltered. W. B. Minimum thermometer without guard wired between branches of small hemlock, November through July.



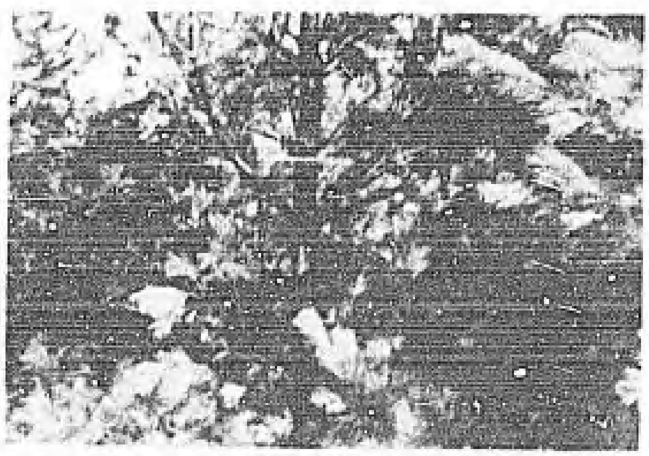


Figure 25 (left) - Nelson Brook Flat Station. Looking south toward shelter, opened to show thermometers. July, 1948.
Figure 26 (right) - Brooks Hill Station. Looking north. Minimum thermometer is wired between branches of young white pine tree. June, 1948.

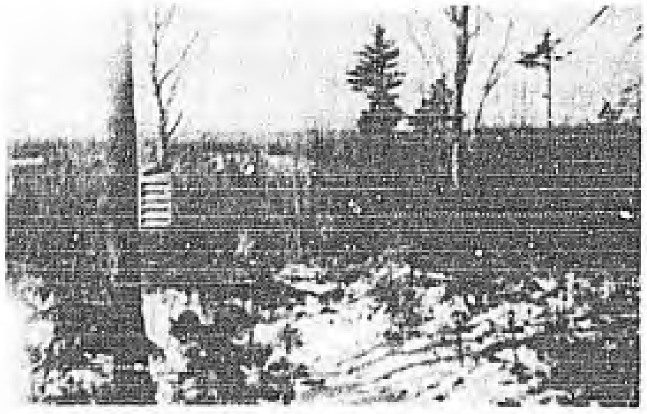
b. TOM SWAMP TRACT. (Figure 6).

The sheltered stations are listed first, followed by the nonsheltered stations.

SHELTERED STATIONS.

EAST HILL. Elevation 950 ft. (Figure 27).
Situation: At east boundary of Tom Swamp Compartment III, on west-facing slope overlooking Compartment V Swale. At exit of shallow ridge-side valley which channels cold air drainage from higher slopes and flats of Petersham Ridge.
Vegetation: Station is at upper edge of cutover area with scattered large trees. General cover of young mixed hardwood and coniferous growth averages less than 10 feet high. East of station, upslope, is stand of 60-foot-high mixed hardwoods, including central- and transition-forest species. Much blowdown timber remains from 1938 hurricane. No canopy, but morning shade.
Shelter type: Harvard Forest shelter, narrow, vertical type, nailed to pignut hickory. In late spring an additional shelter, Harvard Forest wide type, large, was nailed and braced on a white pine 20 feet to west.
Instruments: Six's type thermometer, August through July. W. B. Maximum and Minimum thermometers, and thermograph, July only.

FISHER STAND. Elevation 860 ft. (Figures 28 and 29).
Situation: On gently sloping terrace overlooking slightly lower terrace to south and west, which in turn overlooks broad flat floor of former millpond. To the north and east is a slightly higher terrace above which rises the long slope of East Hill. Surface of the entire stand area is covered with subangular boulders. A small intermittent stream has cut a shallow southwest-trending valley across the area.
Vegetation: Thirty-five-year-old mixed hardwood stand consisting chiefly of white ash, red oak, and paper birch. Thinned in early summer, 1947. Dense summer canopy. The oldest continuously managed stand in Harvard Forest. Named in honor of the Forest's founder and first director, Richard Thornton Fisher.
Shelter type: Weather Bureau Standard shelter. Permanent installation.
Instruments: W. B. Maximum and Minimum thermometers, December to July. Thermograph, part of March and all of July.



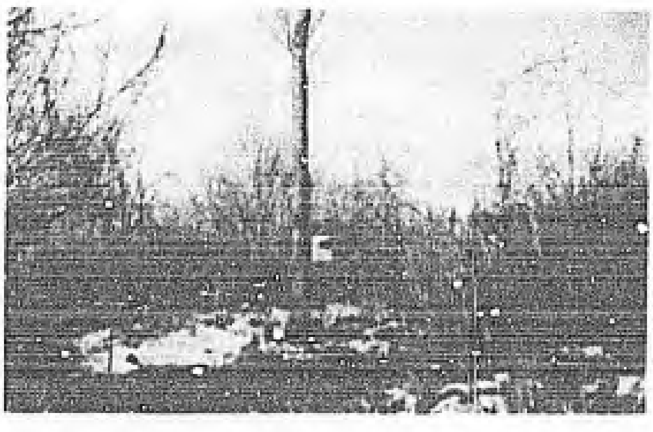


Figure 27 (upper left) - East Hill Station. Looking west from east boundary of Tom Swamp Tract, past station and toward Harvard Hill (1, left center, below skyline). December, 1947.
Figure 28 (upper right) - Fisher Stand Station. Looking east-southeast. March, 1948.
Figure 29 (lower left) - Fisher Stand Station. Looking northeast. Late March, 1948.
Figure 30 (lower right) - Stream Crossing Station. Looking northwest, across stream, toward station. December, 1947.

TRAIL FORK. Elevation 860 ft.
Situation: At east edge of Compartment V Swale and near base of long west down-slope from East Hill. Near edge of small stream valley cut into low terrace. Several knobs of eroded bedrock rise above general terrace level.
Vegetation: Open cutover area with low growth of mixed hardwoods and conifers. Widely scattered large trees. Dense young hardwood swale growth, 40 feet high, to north. Little or no canopy in station vicinity.
Shelter type: Harvard Forest shelter, narrow vertical type, nailed to large white oak.
Instruments: Six's type thermometer, August through July.

STREAM CROSSING. Elevation 840 ft. (Figure 30).
Situation: At stream edge on lowest terrace level near south end of Compartment V Swale. Terrace grades southward into flat bottomland of former millpond.
Vegetation: Mixed hardwood and coniferous volunteer growth, averaging less than 10 feet high, on cutover land. 100 yards to north is an open grove of hardwoods 30 feet high, with thick undergrowth near stream. South of station is an extensive grove of swale maple sprout growth, 30 feet high. Almost no canopy, but late afternon shade at station.
Shelter type: Harvard Forest shelter, wide type, nailed to large elm.
Instruments: W. B. Maximum and Minimum thermometers, October to July. Nonsheltered Minimum thermometer, September only. Thermograph, part of February and all of July.

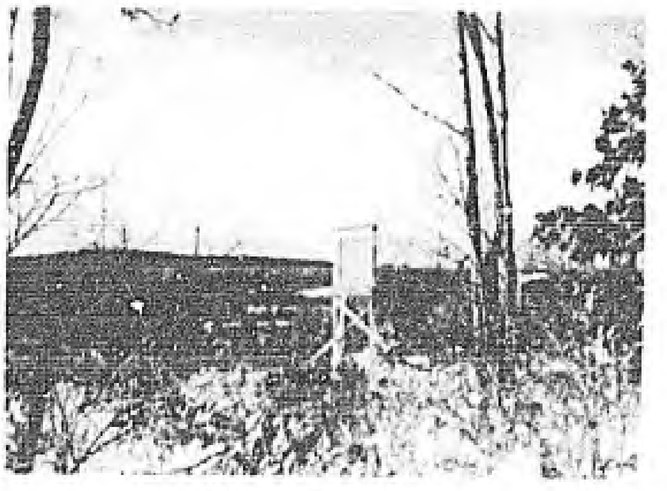
HEMLOCK BASE. Elevation 850 ft. (Figure 31).
Situation: At east base of Harvard Hill and west edge of Compartment V Swale.
Vegetation: Mixed young hardwood, coniferous, and berry-bush growth, averaging four feet high, on cutover land. Slight canopy from hemlock itself. Open to winds from north, east, and south.
Shelter type: Arnold Arboretum shelter, narrow vertical type, with wire mesh sides and front, August until May. Arnold Arboretum cubical type, with alternating overlapping slat inner and outer walls, May until July. Shelters nailed to 30-foot-high, lone hemlock.
Instruments: Six's type thermometer, August until May. W. B. Maximum and Minimum thermometers, May until July.

HARVARD HILL. Elevation 900 ft. (Figure 32).
Situation: On almost flat summit of isolated oval hill of bedrock, covered with glacial drift except for exposed, rounded rock surfaces on summit and steep 15-foot-high joint face at east edge. Summit is approximately 60 feet above general level of Compartment V Swale to east and about 150 feet above Harvard (Brooks) Pond to west.
Vegetation: Low mixed hardwood and coniferous volunteer growth on cutover land. Some large hurricane blowdown logs on east face. Heavier stands of 60-foot-high hardwoods and hemlocks on lower north and west slopes of hill. No canopy at station.
Shelter type: Harvard Forest shelter, wide type nailed to sprout maples, August to November. Weather Bureau Standard type, permanent installation, November to July.
Instruments: W. B. Maximum and Minimum thermometers, and thermograph, August to July.

CHESTNUT GROVE. Elevation 820 ft.
Situation: On top of terrace spur extending northward from north base of Harvard Hill. Slight drop on east and north to valley of stream draining north end of Compartment V Swale. Long terraced drop westward to Harvard (Brooks) Pond.
Vegetation: Moderately thick grove of 50-foot-high hemlock, chestnut, yellow birch, and beech. Immediately to west of station is a clearing 50 feet in diameter, with very young growth of hemlock and hardwoods. Heavy canopy above station. None in clearing. Shelter is in shade until noon, in sun in afternoon.
Shelter type: Harvard Forest shelter, wide type, nailed to hemlock.
Instruments: W. B. Maximum and Minimum thermometers, December to July. Thermograph, part of March.

GRAVEL HILL. Elevation 800 ft. (Figure 33).
Situation: On summit of knobby terminus of esker ridge trending northwest, down-slope, toward southeast corner of Harvard (Brooks) Pond. Most of ridge has been dug away.
Vegetation: On north face of hill and on summit east of station is a moderately dense stand of 50-foot-high hemlock, together with some paper birch, red oak, and other hardwoods. To west is bare excavated new face of gravel pit.
Shelter type: Harvard Forest shelter, narrow vertical type, nailed to red oak.
Instruments: Six's type thermometer, August to July.

MILL POINT. Elevation 760 ft. (Figure 34).
Situation: Low flat peninsula, consisting of terrace remnant extending out into artificially created shallow pond (Harvard Pond) occupying wide flat floor of stream valley.
Vegetation: Moderately open stand of second growth mixed hardwood forest averaging 50 feet high. White oak a common species. Included are scattered taller white pines. Little canopy in winter. Almost complete canopy in summer.
Shelter type: Harvard Forest shelter, narrow vertical type, nailed to red oak, August to July. Harvard Forest shelter, wide, large type, nailed and braced on white pine, July only.
Instruments: Six's type thermometer, August to July. W. B. Maximum and Minimum thermometers and thermograph, July only.



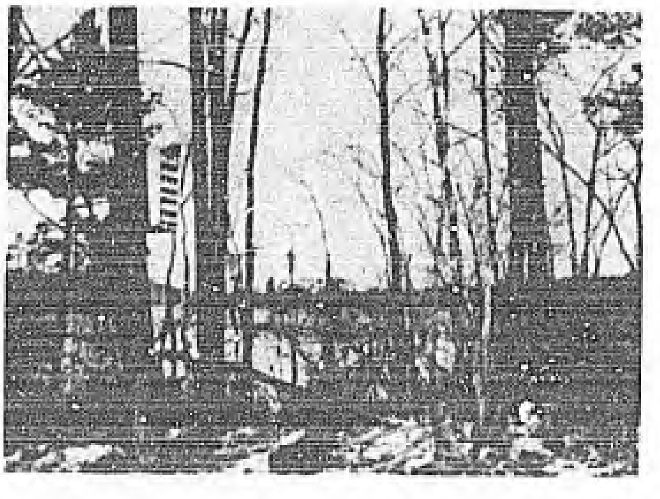
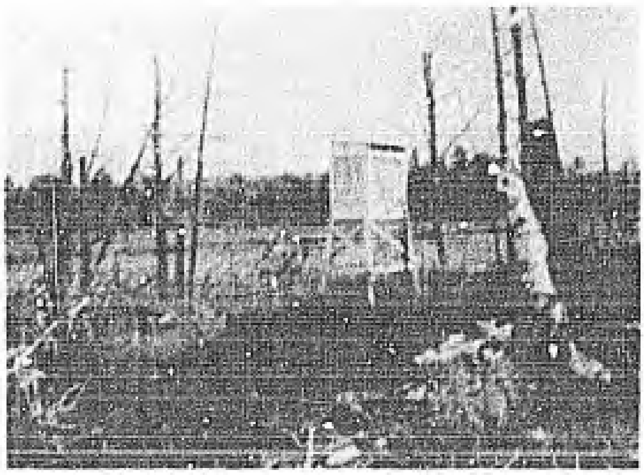


Figure 31 (upper left) - Hemlock Base Station. Looking east, from Harvard Hill past Hemlock Base station (1) and across Compartment V Swale (2) toward East Hill (3). Late November, 1947.
Figure 32 (upper right) - Harvard Hill Station. Looking west, past station, across Harvard Pond lowland toward Bald Hill. Old shelter in right foreground. November, 1947.
Figure 33 (lower left) - Gravel Hill Station. Looking east. Shelter is on small red oak to right of summit. Large hemlock, undermined by excavation of gravel, has fallen into pit. November, 1947.
Figure 34 (lower right) - Mill Point Station. Looking north across Harvard Pond. Late November, 1947.

RICEVILLE POND. Elevation 755 ft. (Figures 35 and 36).
Situation: On sandy west shore of Riceville Pond at tip of broad curving point. Exposed to winds blowing across water from west, north, east, and southeast.
Vegetation: Station is surrounded by dead conifers killed by flooding during high water. Back of station on steep bank which marks the edge of Fay Lot Terrace is a narrow band of mature white pines and hemlocks. No canopy but part-time shade during winter.
Shelter type: Weather Bureau Standard, portable type.
Instruments: W. B. Maximum and Minimum thermometers, December to July. Thermograph, part of February.

FAY LOT TERRACE. Elevation 785 ft. (Figures 37 and 38).
Situation: On broad, flat platform surface of pitted kame terrace bordering the west shore of Riceville Pond. Station is near logging road and midway between pond shore and edge of a long narrow northward extension of Tom Swamp separating Fay Lot peninsula from West Boundary Hill.
Vegetation: Low growth of mixed white pine and hemlock with some mixed hardwoods. Area was logged off, and slash cleaned up, after 1938 hurricane. Station open and exposed in winter. Partially closed in by hardwoods in leaf in summer. No canopy.
Shelter type: Weather Bureau Standard, portable type.
Instruments: W. B. Maximum and Minimum thermometers, December to July. Thermograph, part of March and all of July.



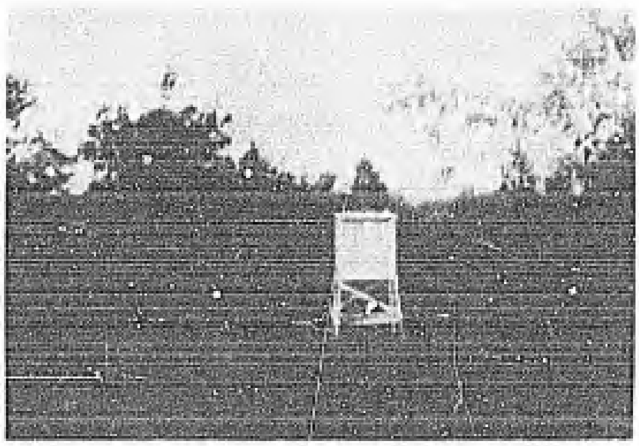


Figure 35 (upper left) - Riceville Pond Station. Winter view, looking southwest. March, 1948.
Figure 36 (upper right) - Riceville Pond Station. Summer view, looking northeast. July, 1948.
Figure 37 (lower left) - Fay Lot Terrace Station. Looking southeast into Riceville Pond - Tom Swamp lowland. March, 1948.
Figure 38 (lower right) - Fay Lot Terrace Station. Looking north. July, 1948.

WEST BOUNDARY. Elevation 900 ft. (Figure 39).
Situation: On gently sloping southwest face of West Boundary Hill at a point 20 feet lower than and 200 yards from broad summit area. Station is across road from and 40 feet above floor of broad, wooded, partially swampy terraced valley which drains southeastward to Harvard (Brooks) Pond.
Vegetation: In young, moderately dense stand, 20 feet high, of mixed hardwoods, with little undergrowth. Closed canopy during leaf season only.
Shelter type: Weather Bureau Standard, portable type.
Instruments: W. B. Maximum and Minimum thermometers, December to July. Thermograph, part of March and all of July.

WEST TERRACE. Elevation 770 ft. (Figure 40).
Situation: On broad gravel and sand terrace bordering west side of Tom Swamp.
Vegetation: In open grassy yard of abandoned farmstead. To north is a grove of 10-foot-high young cottonwoods. To southeast is a clump of tall white pines. To west is plantation of 15-year-old white pines. To south, across road, are a small abandoned orchard, a small clump of white pine, and an extensive cutover area.
Shelter type: Weather Bureau Standard, portable type.
Instruments: W. B. Maximum and Minimum thermometers, December to July.

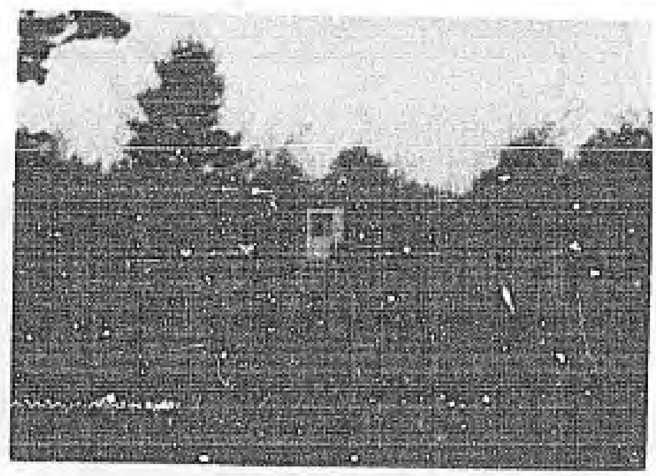


Figure 39 (left) - West Boundary Station. Looking northeast from road. Early December, 1947.
Figure 40 (right) - West Terrace Station. Looking south-southeast. May, 1948.

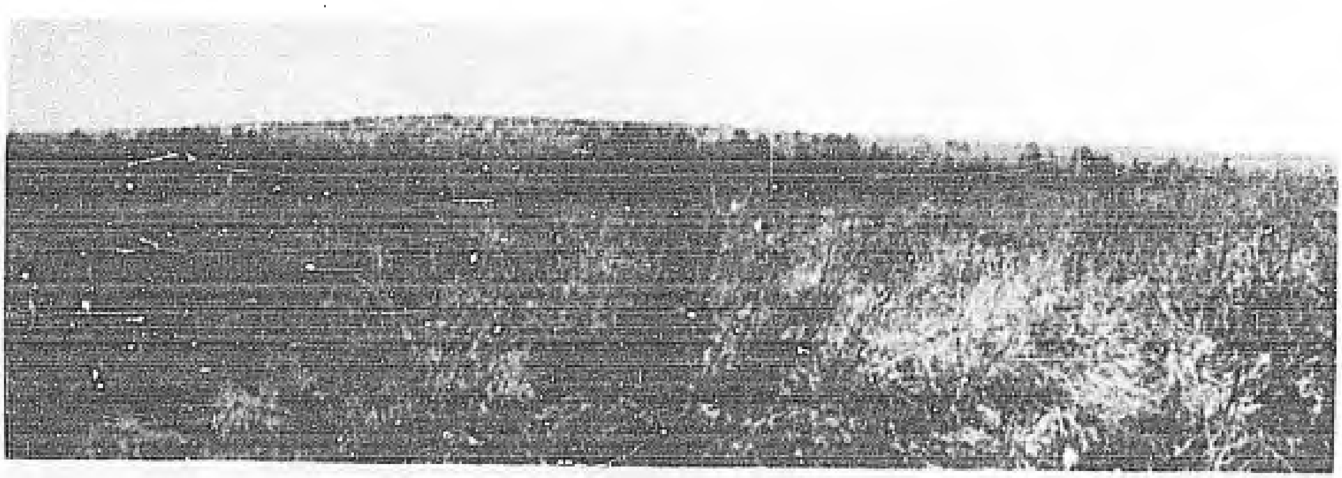


Figure 41 - Tom Swamp. Panorama, looking northeastward and eastward toward Petersham Ridge. Original station is to far left; new station to right. Causeway road, not visible, runs between shelters. Late March, 1948.

TOM SWAMP. Elevation 756 ft. (Figures 41, 42 and 43).
Situation: On broad, open floor of Tom Swamp valley. Water-level of swamp is at or above moss surface, except in late summer and early autumn. Causeway for road is one to two feet above water level.
Vegetation: Swamp-shrub vegetation two to four feet high, with deep underlayer of sphagnum moss. Elsewhere in swamp are stands of larch and black spruce, and plantations of red pine. Station is in the open, with no canopy, and is exposed to all winds.
Shelter type: Department of Agriculture shelter, on 2x4 support frame, north of road, August to December. Weather Bureau Standard, portable type, south of road, with shelter support standing on stretchers laid across top of sphagnum moss growth, December to July.
Instruments: W. B. Maximum and Minimum thermometers and thermograph, August to December. W. B. Maximum and Minimum thermometers and thermograph, December to July. Additional Maximum and Minimum thermometers used for control purposes, December to July.

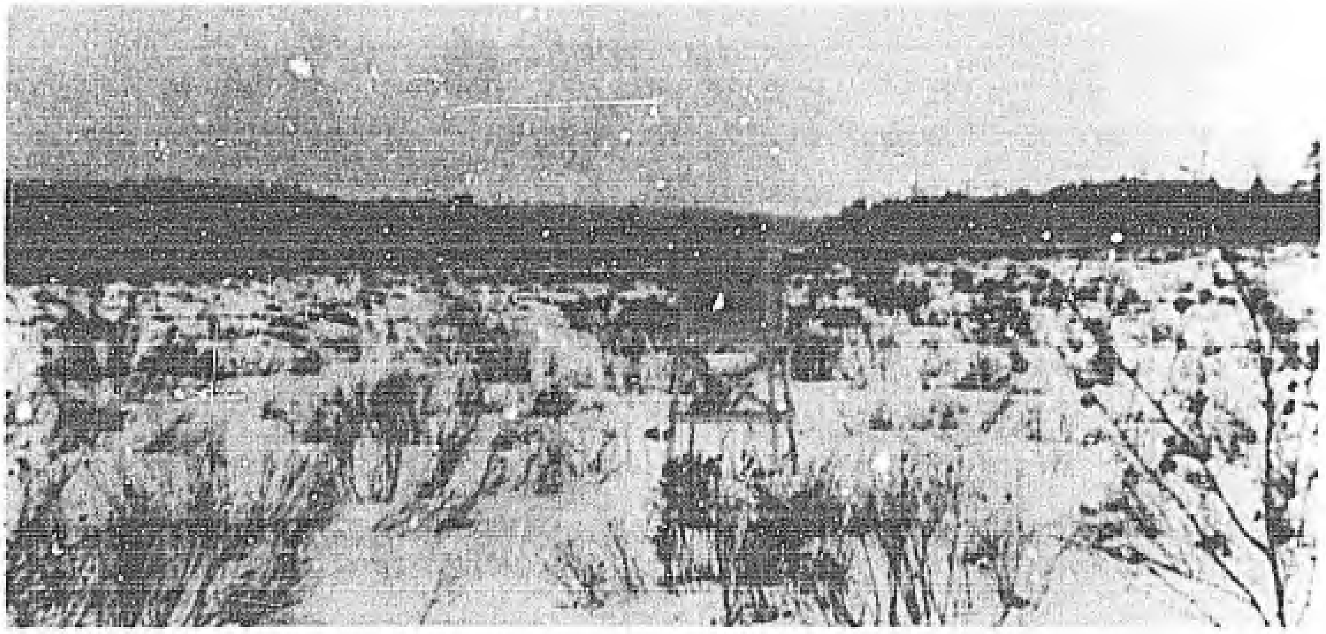


Figure 42 - Tom Swamp Station. Winter view, looking south toward Harvard Pond. Late February, 1948.

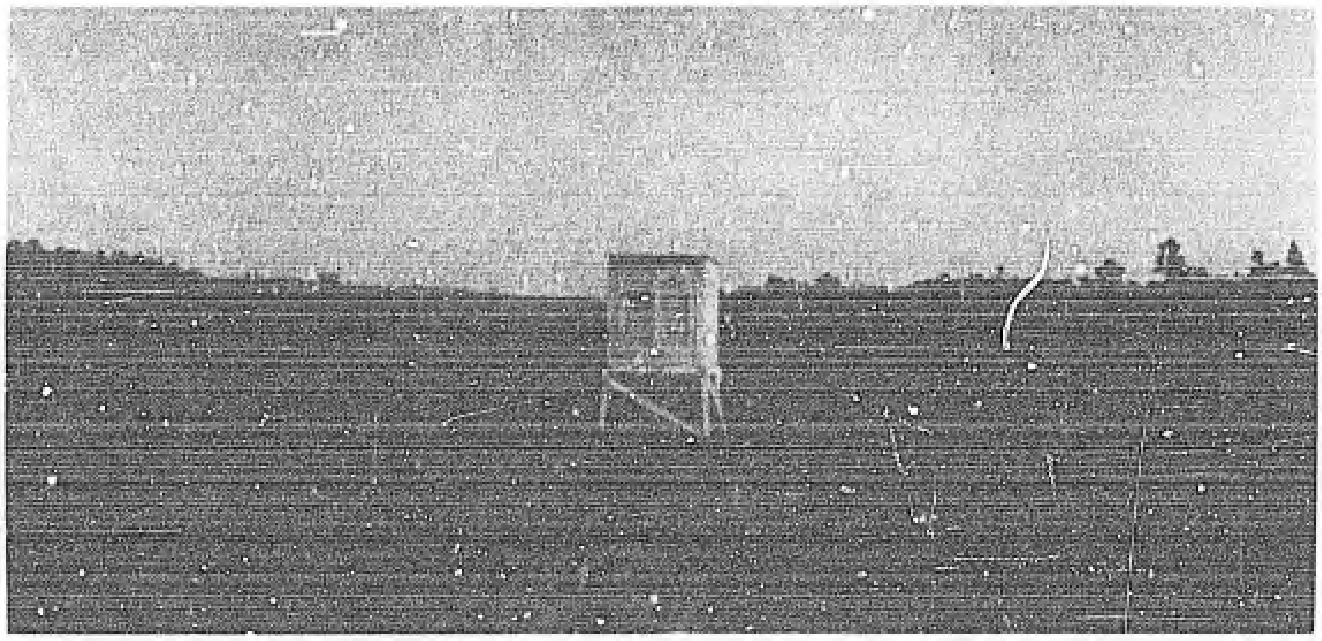


Figure 43 - Tom Swamp Station. Summer view, looking south. Late June, 1948.

NONSHELTERED STATIONS.

RED PINE RIDGE. Elevation 925 ft.
Situation: On flat top of south-trending spur of low ridge. To east is shallow upper valley of White Ash Swale. To west is long slope leading down to Compartment V Swale.
Vegetation: Station is about 25 feet east of woods road and in a grove of red pines and white pines 20 feet high. Almost complete canopy at all seasons.
Instrument: Nonsheltered W. B. Minimum thermometer without guard, wired into dead lower branches of a white pine, September to July.

HEMLOCK GROVE. Elevation 840 ft.
Situation: On gentle slope, at east edge of Compartment V Swale.
Vegetation: Grove of widely spaced large hemlocks, 80-100 feet high. No undergrowth. Complete canopy. Dense low growth in stream valley to west.
Instrument: Nonsheltered W. B. Minimum thermometer without guard, wired between lower branches of large hemlock, September and October.

BLOWDOWN. Elevation 840 ft.
Situation: On gentle slope at east edge of Compartment IV-V Swale and about 100 yards north of Hemlock Grove.
Vegetation: Open blowdown and cutover area, mostly in low brush. Widely scattered tall trees. No canopy.
Instrument: Nonsheltered W. B. Minimum thermometer, without guard, wired to small hemlock, September to January.

WHITE ASH SWALE. Elevation 885 ft.
Situation: Flat bottomed shelf valley east of and fifty feet higher than Compartment V Swale.
Vegetation: Open cutover area with scattered large trees and abundant growth of mixed hardwoods, including much white ash.
Instrument: Nonsheltered W. B. Minimum thermometer without guard, wired below branch of young red maple, April to July.

FISHER STAND. Elevation 860 ft.
Situation: See description (above) of sheltered station at this stand.
Instrument: Nonsheltered W. B. Minimum thermometer without guard, wired into branches of young basswood, 30 feet north of sheltered station, September to January.

MILL POND FLAT. Elevation 835 ft.
Situation: On broad stream flat, the bottom of a former millpond.
Vegetation: Bushy growth, about 7 to 10 feet high, including much alder. Tufted grass understory, flooded at high water. Scattered growth of small red maples. No canopy. To north, between this and Stream Crossing Station, is dense older growth of swale hardwoods.
Instrument: Nonsheltered W. B. Minimum thermometer without guard, wired to branch of young maple, April and May.

FAY TERRACE EDGE. Elevation 780 ft.
Situation: At east edge of Fay Lot, about 10 feet from edge of steep slope leading down 25 feet to shore of Riceville Pond.
Vegetation: Blowdown and cutover area. Low growth of mixed conifers and mixed hardwoods. No canopy.
Instrument: Nonsheltered W. B. Minimum thermometer without guard, wired between large roots on weathered stump of large, blown-down tree, July only.

TOM SWAMP BUSH. Elevation 753 ft.
Situation: See description (above) of sheltered station at Tom Swamp.
Instrument: Nonsheltered W. B. Minimum thermometer without guard, laid among upper branches of bushes August to December; wired to leg of shelter thereafter, January to July.

c. SLAB CITY TRACT. (Figure 6).

The stations listed below include several that are outside the limits of the Slab City Tract. Figure 6 shows the location of all such stations, which include the following: Sheltered stations at (1) Petersham Center, operated first near the Nichewaug Hotel and later near the High School; (2) Shelf Swamp; and (3) River Meadow. Unsheltered stations include (1) Hickory Hill; (2) Shelf Swamp; (3) Choate Farm Hill, and (4) Power Line Crossing. Together these stations provide additional reference points on ridges and in valleys for comparison with nearby stations within the Harvard Forest.

SHELTERED STATIONS.

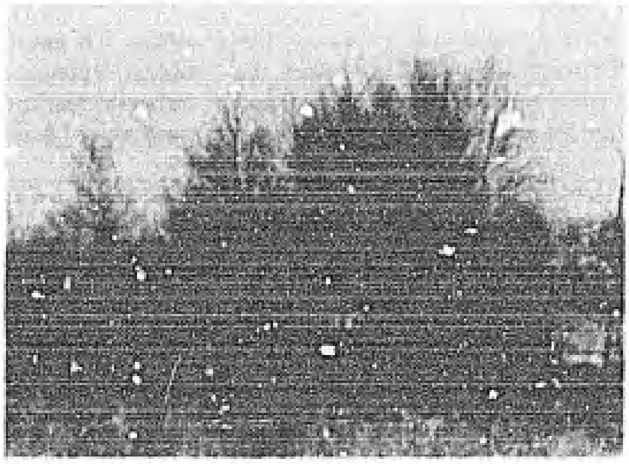
PETERSHAM, NICHEWAUG. Elevation 1100 ft. (Figure 44).
Situation: On very slightly concave part of summit of Petersham Ridge, northwest of Nichewaug Hotel.
Vegetation: In small grove of paper birch and cottonwood, standing in open field of grass and low shrub growth. Partial canopy, summer and autumn.
Shelter type: Harvard Forest shelter, wide type, nailed to tree.
Instruments: W. B. Maximum and Minimum thermometers, August to January.

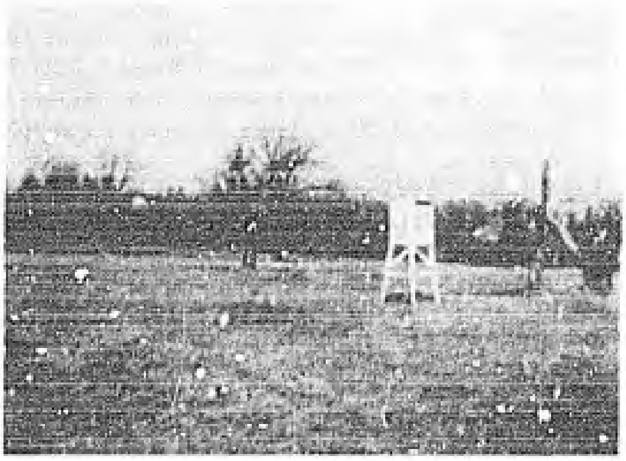
PETERSHAM, HIGH SCHOOL. Elevation 1055 ft. (Figure 45).
Situation: On very gentle southeast slope of Petersham Ridge, southeast of school building.
Vegetation: On grassy lawn, near stump of dead orchard tree.
Shelter type: Weather Bureau Standard, portable type.
Instruments: W. B. Maximum and Minimum thermometers, including additional control thermometers much of time, January to July.

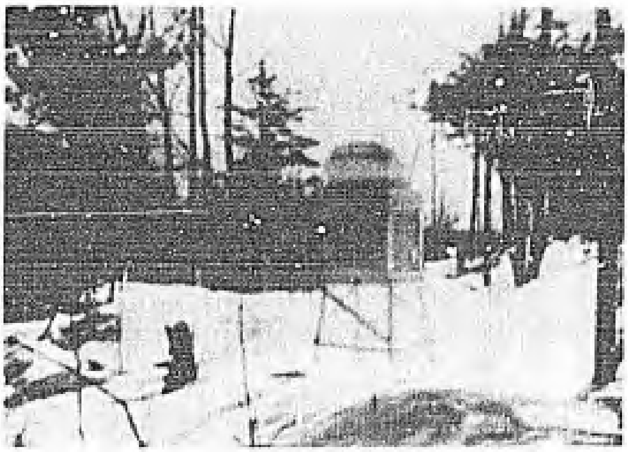
HICKORY HILL JUNCTION. Elevation 1000 ft. (Figure 46).
Situation: On flat upper terrace, which forms a saddle between the main ridge and an eastern lower outlier of Hickory Hill. Saddle also forms the head of Coach Road valley. Station is just north of junction of Coach Road and Cave Swamp-Wildcat Hill Road.
Vegetation: Moderately dense stand of old field white pine and mixed hardwoods, including much hickory. Surfaces of woods roads are grassy.
Shelter type: Weather Bureau Standard, portable type.
Instruments: W. B. Maximum and Minimum thermometers, December to July. Thermograph, most of April and all of May.

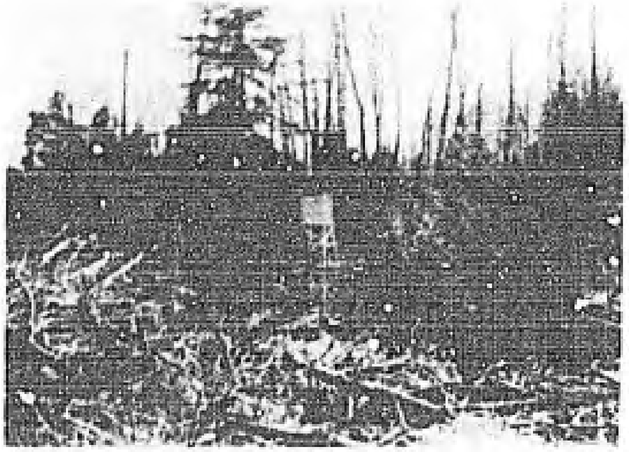
SHELF SWAMP. Elevation 990 ft. (Figure 47).
Situation: In upland swale at south base of highest summit of Hickory Hill, and on rock shelf near edge of steep rocky face forming west side of Coach Road valley. Station is a few yards outside Harvard Forest boundary.
Vegetation: At north edge of forest of 50-foot high mixed hardwoods with some hemlock, all much damaged by hurricane. Area to east, north and west recently cut over. Volunteer growth of mixed hardwoods, including hickory, and of conifers, especially white pine, on cutover area.
Shelter type: Weather Bureau Standard, portable type.
Instruments: W. B. Maximum and Minimum thermometers, December to July. Thermograph most of April and all of May.

WILDCAT HILL. Elevation 995 ft. (Figures 48 and 49).
Situation: On summit of hill, separated from, but near to, ridge extending south from Hickory Hill. Summit has thin soil cover over crystalline bedrock. Steep face to east overlooks Hidden Swamp. Moderately steep slopes to north, west, and south.
Vegetation: Summit near cliff edge is bare, but just to west, in slight hollow and on back slopes, is a moderately dense stand of large hemlocks, yellow birches, and other northern-forest species, 50 to 70 feet high.
Shelter type: Weather Bureau Standard, portable type.
Instruments: W. B. Maximum and Minimum thermometers, December to July. Thermograph, most of April and all of May.









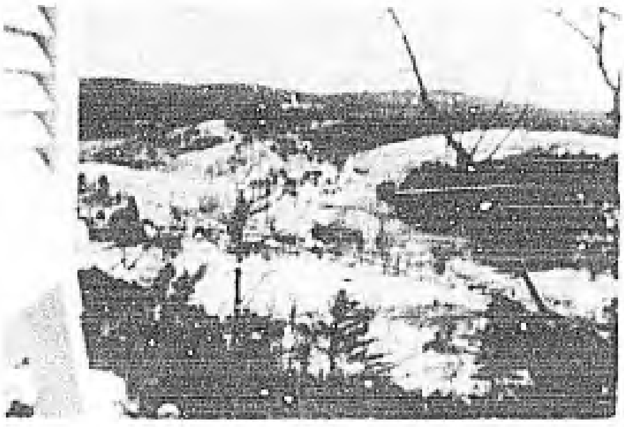


Figure 44 (upper left) - Petersham (Nichewaug) Station. Looking northwest, past shelter in grove of small birches, toward Sunset Lane. December, 1947.
Figure 45 (upper right) - Petersham (High School) Station. Looking northeast, toward Petersham Center. Late March, 1948.
Figure 46 (left center) - Hickory Hill Junction Station. Looking southeast, down Coach Road. February, 1948.
Figure 47 (right center) - Shelf Swamp Station. Looking southeast. High water is from spring melt. Late March, 1948.
Figure 48 (lower left) - Wildcat Hill. Looking west-northwestward from Highway 122 and across terraces bordering Swift River. Temperature station shelter is barely visible on hill summit. December, 1947.
Figure 49 (lower right) - View from Wildcat Hill. Looking east from station into Swift River valley and toward Loring Hill. Arrow points to River Meadow Station. February, 1948.

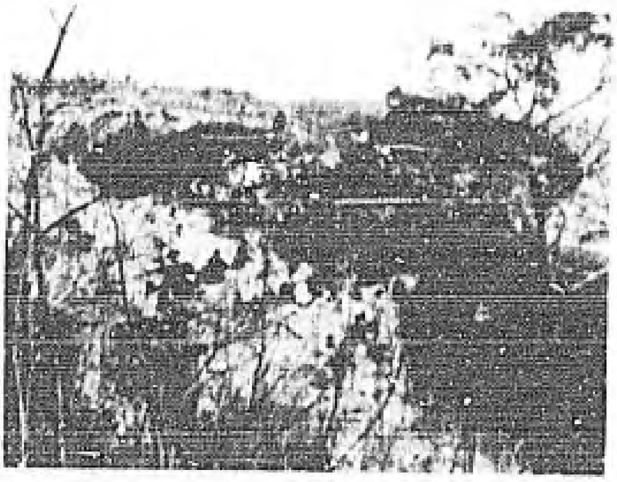
COACH ROAD. Elevation 850 ft. (Figures 50, 51, 52, and 53).

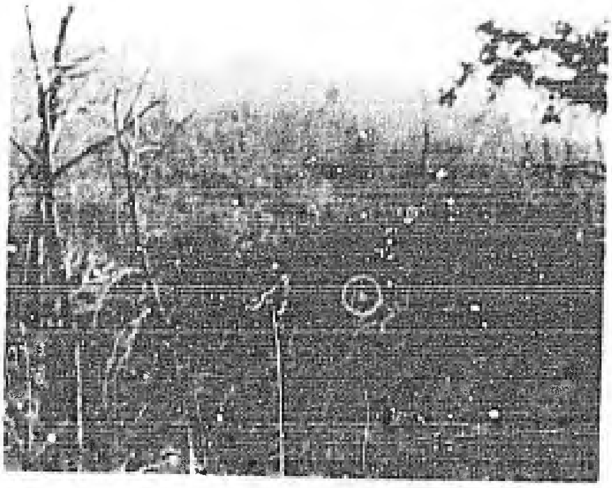
Situation: On southwest face of long terraced ridge, which forms east side of Coach Road valley. To southwest, on valley floor at base of Wildcat Hill, is Hidden Swamp, about 30 feet lower than station. Station is beside road on moderately steep grade leading down from wide terrace, and is at midpoint between Hickory Hill summit and Swift River. Locally the slope of the ridge face is steeper, both east (up) and west (down) from station.

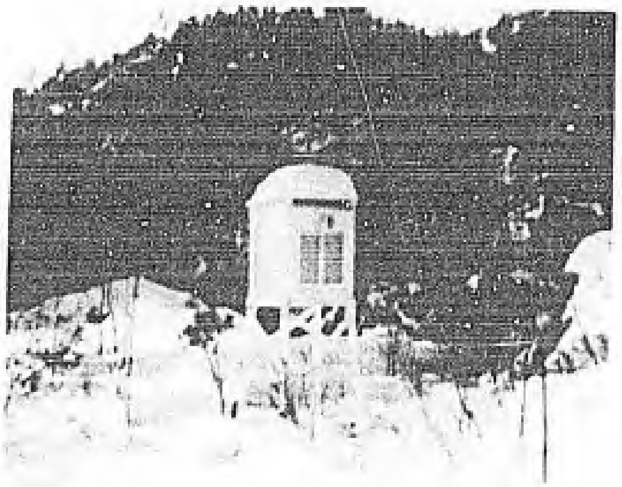
Vegetation: Station is in open but is sheltered on northwest by scattered low hemlocks. General forest cover in area is mixed hardwood, including much hickory, 50 feet and more high, much of which was damaged by hurricane.

Shelter type: Weather Bureau Standard, portable type.

Instruments: W. B. Maximum and Minimum thermometers, December to July. Thermograph, most of April and all of May.







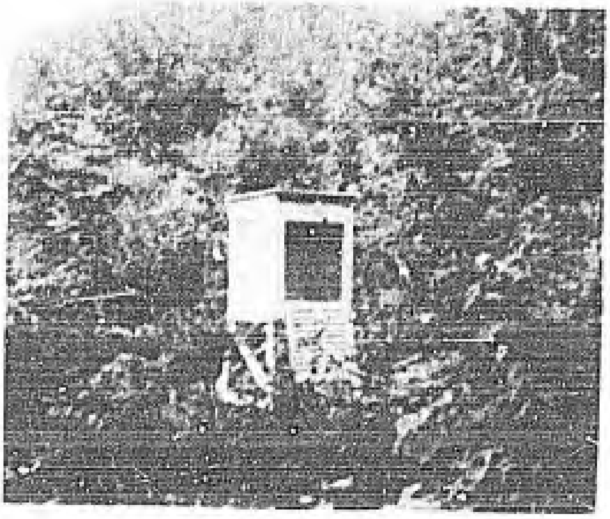


Figure 50 (upper left) - Coach Road valley. Looking northeast from Wildcat Hill, across Hidden Swamp to Coach Road and eastern spurs of Hickory Hill. February, 1948.

Figure 51 (upper right) - Coach Road valley. Approximately same view as in Figure 50, showing Coach Road Station. April, 1948.

Figure 52 (lower left) - Coach Road Station. Looking southwest, across Hidden Swamp toward Wildcat Hill. Late December, 1947.

Figure 53 (lower right) - Coach Road Station. Approximately same view as in Figure 52, but showing full summer foliage. July, 1948

BURNS BRIDGE. Elevation 750 ft. (Figures 54 and 55).

Situation: On floor of Swift River valley near junction with Moccasin Brook. Area widely but shallowly excavated for gravel.

Vegetation: Station stands in open, on gravel surface partially overgrown with low herbaceous growth and shrubbery, especially berry bushes.

Shelter type: Weather Bureau Standard type. Permanent installation.

Instruments: W. B. Maximum and Minimum thermometers, December to July. Thermograph, part of February.

RIVER MEADOW. Elevation 725 ft. (Figures 56 and 57).

Situation: On flat floor of Swift River valley, below Connor Pond, and southeast of mouth of Coach Road valley.

Vegetation: Open grassy meadow, formerly the "lower mowing" of Choate Farm.

Shelter type: Weather Bureau Standard, portable type.

Instruments: W. B. Maximum and Minimum thermometers, December to July. Thermograph, all of April and May.

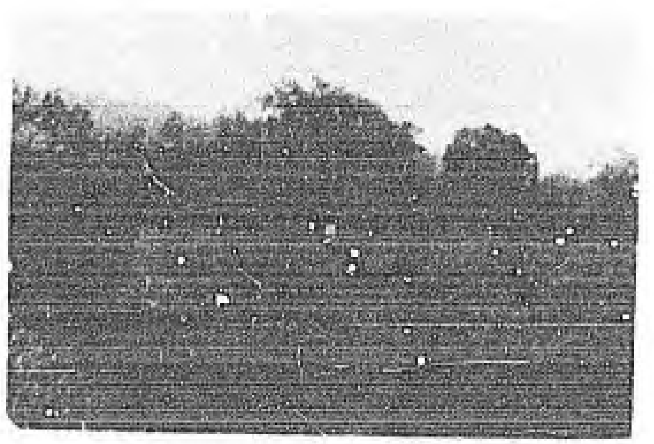


Figure 54 (upper left) - Burns Bridge Station. Looking southwestward past station and across Highway 122 to eastern spurs of Hickory Hill. March 9, 1948.

Figure 55 (upper right) - Burns Bridge Station. Looking north-northwest toward Petersham Center. Shelter is in right middle ground (1). Nonsheltered minimum thermometer is wired into hemlock in left center (2). March, 1948.

Figure 56 (lower left) - River Meadow Station. Looking west- southwest toward Wildcat Hill (right background). Linden Terrace is seen in left background above roof of shelter. Bare grass shows under shelter. Late February, 1948.

Figure 57 (lower right) - River Meadow Station. Looking south. Large elms in background border Swift River. June, 1948.

SOUTH BOUNDARY. Elevation 850 ft. (Figures 58, 59, and 60)

Situation: On gently sloping grade of abandoned portion of highway, in narrow, steep-walled valley leading down from Barre Upland to Swift River.

Vegetation: Valley upstream (south) from station is partially wooded, but is largely cutover or in old fields, pasture, and cultivation. Near station and downstream (north) from it, valley is heavily wooded with old hemlocks and some mixed hardwoods, 50 to 70 feet high. The highway provides an air channel through the forest. No canopy, but early morning and late afternoon shade. Actual station site is grassy, with dense growth of hemlock less than one foot high.

Shelter type: Weather Bureau Standard, portable type.

Instruments: W. B. Maximum and Minimum thermometers, December to July. Thermograph, part of April and all of May.

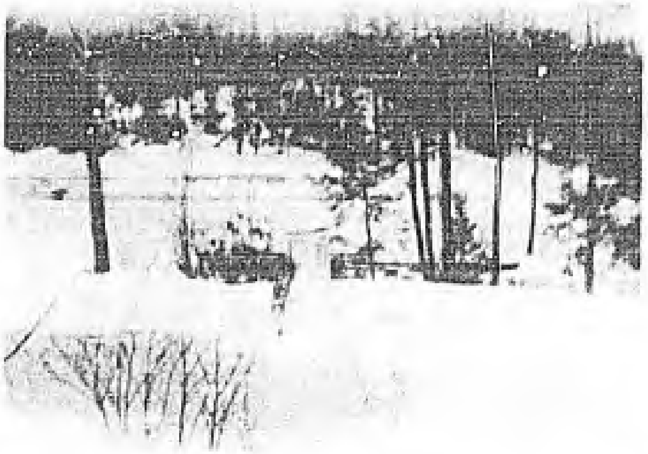
HEMLOCK KNOLL. Elevation 795 ft. (Figure 61).

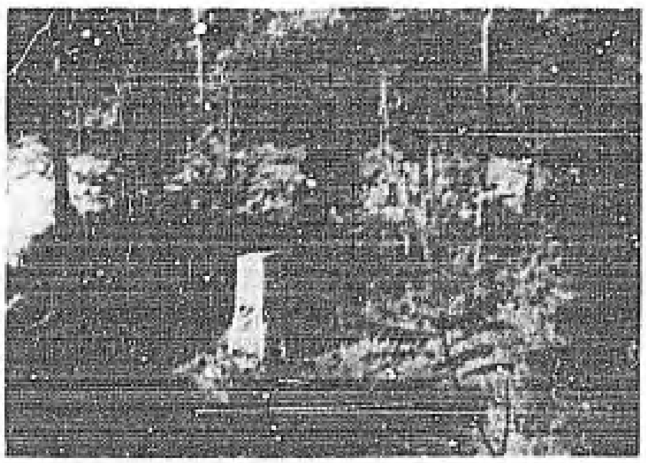
Situation: On summit of isolated oval hill, of moulinkame type, rising 50 feet above gently sloping terrace to west, and 40 to 50 feet above swales which separate this knoll from similar knolls to north, east, and south. Terrace ends abruptly at steep bank which drops 20 to 30 feet to Swift River. To east, at the heads of the swales, is a higher terrace, from which the easternmost knolls rise only 10 to 30 feet.

Vegetation: Moderately dense stand of 40- to 50-foot-high hemlock and mixed northern hardwoods. Heavy but not complete canopy in summer. Much shade at all seasons. Little undergrowth. Vegetation on knoll to north and on steep opposite bank of Swift River forms air-drainage dam upstream between River Meadow and this station.

Shelter type: Weather Bureau Standard type. Permanent installation.

Instruments: W. B. Maximum and Minimum thermometers, December to July.





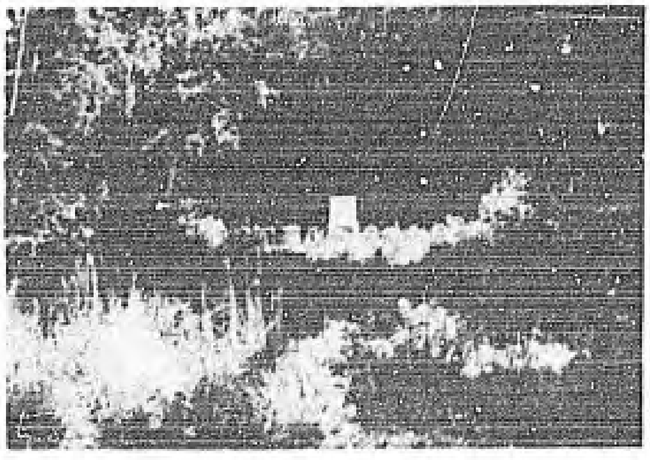


Figure 58 (upper left) - South Boundary Station. Looking west-southwest across stream and highway toward gravel hill on north slope of South Hill. February, 1948.

Figure 59 (upper right) - South Boundary Station. Approximately same view as Figure 58. August, 1948.

Figure 60 (lower left) - South Boundary Station. Looking north, down right-of-way of old road. Stand of old-growth hemlock in right background. August, 1948.

Figure 61 (lower right) - Hemlock Knoll Station. Looking north toward shelter on crest of knoll. February, 1948.

TRAILSIDE SWALE. Elevation 750 ft. (Figure 62).
Situation: In swale separating Hemlock Knoll from terrace and knolls to east.
Vegetation: Dense stand of 50- to 70-foot-high hemlocks and mixed northern hardwoods with considerable understory of shorter trees, 20 to 50 feet high. Morning shade. Afternoon sunshine in winter. Dense canopy in summer.
Shelter type: Harverd Forest type, wide, nailed to tree.
Instruments: W. B. Maximum and Minimum thermometers, March to July.

TRANSECT SWALE. Elevation 748 ft. (Figures 63 and 64).
Situation: In swale at northwest base of South Hill and almost 300 feet below its summit. On west side of swale is a string of knolls which form a knobby low ridge 10 to 30 feet higher than swale but dropping away on far side 40 to 70 feet to Swift River. The swale itself is part of a long narrow terrace which terminates in a 10-foot bank at its northeast end, and in a 50-foot river-cut bank at its southwest end.
Vegetation: Near station the forest is a fairly open stand of 40- to 60-foot high mixed hardwoods, with a few hemlocks. Northeast end of swale is closed by similar forest but with much greater proportion of hemlock. Southwest of station an almost pure stand of young hemlock closes swale. Beyond is a mature stand of old-field white pine. Station has morning shade, little winter canopy, and dense summer canopy.
Shelter type: Weather Bureau Standard type. Permanent installation.
Instruments: W. B. Maximum and Minimum thermometers, December to July. Thermograph, parts of March and April, all of May.

Figure 62 (upper left) - Trailside Swale Station. Looking southwest, down drainage. Hemlock Knoll is to right. March, 1948.
Figure 63 (lower left) - Transect Swale Station. Looking southeast across swale and up slope of South Boundary Hill. Early spring, 1948.
Figure 64 (right) - Transect Swale Station. Looking southwest. Late July, 1948.

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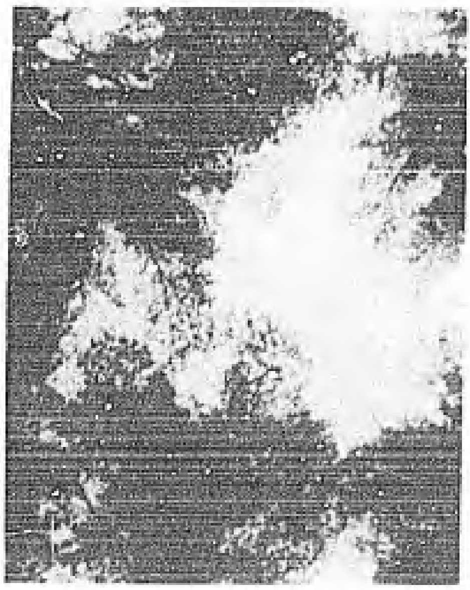
WHITE PINE BOTTOMS. Elevation 680 ft. (Figures 65, 66, 67, and 68).

Situation: On relatively wide, flat surface of bottomland just below junction of Swift River and small south-flowing creek, and just north of great river bend at southwest corner of Harvard Forest. To east of station is the knoll and terrace area described above. Beyond this, to southeast, is South Hill. Other high, steep hills border the bottomland, but are separated from each other by valleys of Swift River and tributary streams that join the Swift in this vicinity.

Vegetation: Dense old-field stand of 70-year-old white pines, some of which are more than 100 feet high. Partially open canopy. Understory of 20- to 40-foot-high mixed hardwoods, including hornbeam. The hardwoods form a dense summer canopy but themselves receive sunlight through openings among the pines.

Shelter type: Weather Bureau Standard type. Permanent installation.

Instruments: W. B. Maximum and Minimum thermometers and thermograph, December to July.



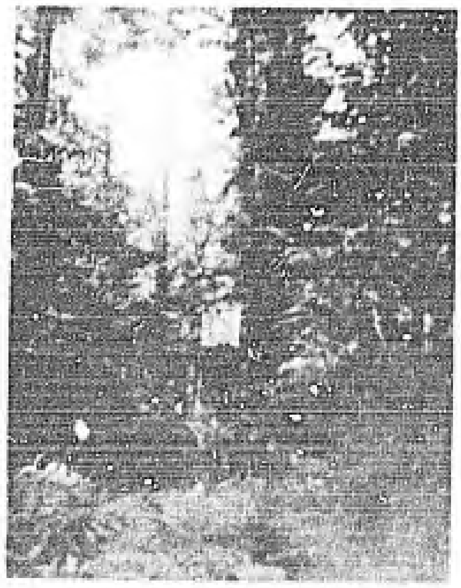


Figure 65 (upper left) - White Pine Bottoms. Looking southwest into 70-year-old white pine stand from west edge of bordering outwash terrace. March, 1948.

Figure 66 (upper right) - White Pine Bottoms Station. Looking north toward shelter. March, 1948.

Figure 67 (lower left) - White Pine Bottoms. Looking upward from a point near shelter, showing partially open canopy. March, 1948.

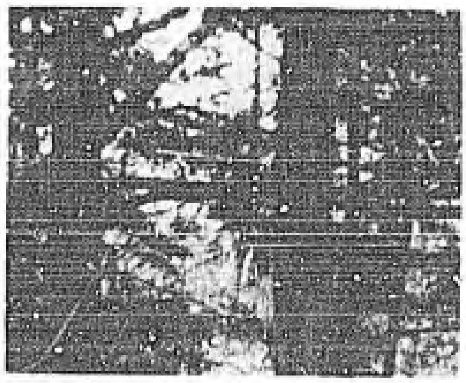
Figure 68 (lower right) - White Pine Bottoms Station. Looking north-northwest toward station, through dense foliage of young hardwood understory. Late July, 1948.

NONSHELTERED STATIONS.

HICKORY HILL. Elevation 1070 ft. (Figure 69).
Situation: On wide, almost flat, crest of Hickory Hill. Gentle slope to west. Steeper slope with several stepdown faces of bedrock to east. Scattered areas of exposed bedrock on crest, including several huge perched boulders near Coach Road, north of station.
Vegetation: Scattered white pine and hickory, 40 feet high. Wide intervening areas with low shrub cover or grass.
Instrument: Nonsheltered W. B. Minimum thermometer without guard, wired between open lower branches of a white pine, October to June.

SHELF SWAMP. Elevation 990 ft. (Figure 70).
Situation: In upland swale at south base of highest summit of Hickory Hill, and on rock shelf near edge of steep rocky face forming west side of Coach Road valley.
Vegetation: In small group of hemlocks at north edge of wooded area and about 40 feet southeast of sheltered station. Heavy canopy but open to air drainage from north.
Instrument: Nonsheltered W. B. Minimum thermometer without guard, wired between open lower branches of a large hemlock, November to June.

CAVE ROAD SWAMP. Elevation 930 ft. (Figure 71).
Situation: Small swamp in narrow windgap valley between Wildcat Hill (to east) and long, low ridge (to north and west).
Vegetation: Open standing water or wet gound with much swamp shrub around station. A mixed hardwood forest of 50- to 70-foot-high trees to north, west, and south, partially damaged by hurricane. Considerable hemlock to east and northeast, on and near slopes of Wildcat Hill. Little canopy. Morning shade.
Instrument: Nonsheltered W. B. Minimum thermometer, without guard, wired between branches of small hemlock at edge of swamp, April to June.



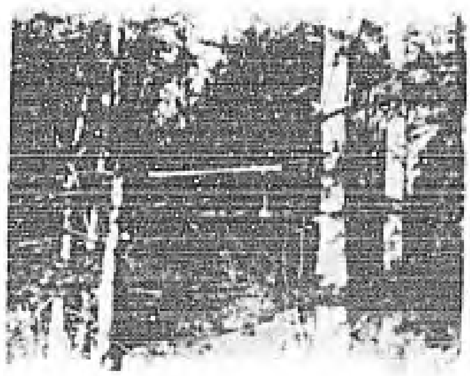


Figure 69 (left) - Hickory Hill Station. Nonsheltered minimum thermometer is wired between branches of white pine in left foreground. Late December, 1947.
Figure 70 (upper right) - Shelf Swamp Station. Looking south-southwest. Early spring, 1948.
Figure 71 (lower right) - Cave Road Swamp Station. Looking northwest into mixed stand of central- and transition-forest species. Thermometer is wired into branches of small hemlock growing in swamp. February, 1948.

PORTAL SWAMP. Elevation 920 ft.
Situation: Small swamp north of Wildcat Hill, on shelf above cliffs which form west side of Coach Road valley. Swamp is at northeast portal to windgap forming Cave Road valley.
Vegetation: Scattered 20-foot-high hardwood and hemlock trees. Extensive areas of swamp shrub. Tufts of sedge, sphagnum, and grass on swamp floor. Little canopy. Afternoon shade.
Instrument: Nonsheltered W. B. Minimum thermometer without guard, wired to small red maple, April to June.

LINDEN TERRACE. Elevation 860 ft.
Situation: Lower of two rock-floored, drift-covered terraces south of Wildcat Hill. On west and northwest is a moderately steep slope, leading up to the higher terrace and Cave Road valley. On east is moderately steep slope down to Swift River.
Vegetation: Mixed hardwoods, 40 to 60 feet high, including much hickory, together with older white pine. The stand was greatly damaged by the 1938 hurricane and was subsequently logged. Little undergrowth, and no canopy near station.
Instrument: Nonsheltered W. B. Minimum thermometer without guard, wired between nails on high dead stump of small white pine, April to July.

CHOATE FARM HILL. Elevation 930 ft.
Situation: Broad gently rounded crest of long, oval, drift-covered bedrock hill, with short slope to saddle on north; long, steep, partly cliffed slope east and south to Swift River; and long, very steep slope west to valley of small creek flowing southward to join Swift River near White Pine Bottoms.
Vegetation: Open farm fields on gentle upper slopes, except for trees and shrubs forming field boundaries. The "upper mowing" of the Choate Farm. Dense woods on lower slopes to east, south, and west.
Instrument: Nonsheltered W. B. Minimum thermometer without guard, wired between lower branches of small white pine, October to April.

SOUTH HILL. Elevation 1030 ft.
Situation: At highest point of this hill inside Harvard Forest boundary, slightly downslope from and north of hill summit (1041 ft). Land slopes gently near station but at a slight distance from it drops steeply to east, north, and west.
Vegetation: Once-dense growth of mature mixed hardwoods and white pine, now much opened with huge deadfalls from hurricane. Very little undergrowth near station, and almost no canopy.
Instrument: Nonsheltered W. B. Minimum thermometer without guard, wired between branches of dead white pine stub, November only.

TRANSECT KNOLL. Elevation 760 ft.
Situation: Narrow, long, north - south-trending knobby ridge, with short slope east to Transect Swale (described above), and with long, steep slope to Swift River. On the southwest, midway between summit level and river, is a broad terrace. This is lower than Transect Swale and ends abruptly at bank forming edge of White Pine Bottoms.
Vegetation: East slope and summit predominently mixed hardwoods, 30 to 40 feet high, together with some white pine. White oak is common. North and northwest slopes predominantly large hemlock with some northern hardwoods. Considerable canopy, but open to sides.
Instrument: Nonsheltered W. B. Minimum thermometer, with metal guard, wired between branches of moderately large hemlock, May to July.

BURNS BRIDGE. Elevation 750 ft. (Figure 55).
Situation: On floor of Swift River valley, just south of junction with Moccasin Brook. Area widely but shallowly excavated for gravel.
Vegetation: Relatively isolated hemlock at south edge of extensive area of bare gravel. Heavy canopy but open sides. Considerable low shrubbery, especially berry bushes, near station.
Instrument: Nonsheltered W. B. Minimum thermometer without guard, wired into lower branches of small hemlock, September to June.

POWER LINE CROSSING. Elevation 600 ft.
Situation: On broad, flat valley floor near river bank. The river plain is bordered in places by wide, flat terraces, about 20 feet higher than main valley floor. Lowest station in project, 1 1/2 miles downstream from Harvard Forest boundary, and nearest station to Quabbin Reservoir.
Vegetation: Meadow to north, with open plantation of very young white pine. Larger growth, including alder and hornbeam near stream. Large hickories near road on north terrace.
Instrument: Nonsheltered W. B. Minimum thermometer without guard, wired to nails on trunk of small sprout red maple amid low shrubs, October to February.

CHAPTER IV - FINDINGS AND ANALYSIS

In this chapter the following topics are discussed, in the order listed: (1) Relative reliability of various types of data; (2) reliability of comparative data gathered for only one year; (3) weather conditions at Harvard Forest during the period of study; (4) comparison of Harvard Forest temperature patterns with those of other New England stations; (5) discussion of local factors that help to explain the diversity of temperature at Harvard Forest, with examples shown by copies of thermograph traces and by other graphic materials; (6) description of temperature-rank scales, both maximum and minimum, as a means of classifying stations within Harvard Forest, together with an explanation of how scales were constructed and some comments on their usefulness and their shortcomings; (7) presentation and analysis of frequency distributions of daily maximum and minimum temperatures, by seasons, for selected stations; and (8) discussion of special temperature conditions affecting plant growth, including: length of vegetative season, number of frost days and ice days, number of hours per month having freezing temperatures, and number of vegetative days, summer days, and tropical days. The supporting data for these discussions are contained in Appendixes A through F.

1. Relative Reliability of Various Types of Data.

Because the gathered data are the chief source upon which the findings, analyses, and conclusions presented in this chapter and in Chapter V are based, it is desirable at this point to indicate the relative reliability of the data gathered by each of the methods previously described. Figure 72 shows how selected stations compare with each other each month according to three types of data: (1) average maximums and minimums compiled from daily readings, (2) average maximums and minimums compiled from weekly readings, and (3) monthly absolute maximums and absolute minimums. It should be noted that the diagrams composing Figure 72 do not show actual temperatures; rather they show deviations, for stations used, from the temperature conditions at Harvard Hill Station. The three diagrams in the left column show the selected stations compared according to deviations of average daily, weekly, and monthly maximum temperatures; the three diagrams in the right column show comparisons according to deviations of average daily, weekly, and monthly minimum temperatures. The comparisons are discussed below.

a. Daily Readings of Extremes.

Obviously, in this study, the greatest amount of information and the most accurate differentiation among stations is that derived from continuous thermograph records, which not only give a daily maximum and minimum but also make it possible to determine total number of hours below or above critical temperature thresholds, comparative hour and rate of warming or cooling, and small but important details of temperature change throughout the day. When check thermometers are used with the thermograph, and careful regular adjustment is made, as needed, considerable confidence can be placed in the records obtained.

b. Weekly Readings of Extremes.

Figure 72 shows that, in general, stations compared on the basis of extreme minimum readings taken once a week have essentially the same arrangement in order of rank as to coldness as when compared on the basis of daily minimum readings. The weekly minimums are good random samples. It is apparent at once, however, that the relative position of a few very similar stations differs on the two charts. Also, some stations, although in the same order, are indicated as slightly warmer, or colder, on the weekly chart than on the daily chart. It may be concluded that except when very precise differentation is desired, a mean of the weekly minimum temperatures gives a satisfactory approximation of a station's minimum-temperature rank or relative coldness for a month.

For comparisons of maximum temperatures, the weekly readings also are useful, but much less so than the weekly readings for minimum temperatures. Several factors help to account for this. Differences in maximum temperature from place to place are much smaller than those of minimum temperature. Hence a difference of only one degree in maximum temperatures can change a station's relative temperature rank much more than does one degree of difference in minimum temperatures. Then too, the extreme minimum temperatures occur at night, at times when the air is comparatively still, and layering is general. Differentiation from station to

HARVARD FOREST - PETERSHAM, MASSACHUSETTS

DEVIATIONS OF TEMPERATURES AT SELECTED STATIONS ACCORDING TO TYPES OF READING

IN EACH DIAGRAM THE RECORD FOR HARVARD HILL (HH) IS THE BASE. DEVIATIONS FROM THIS BASE ARE SHOWN IN F° FOR PROSPECT HILL (PH), TOM SWAMP (TS), AND WHITE PINE BOTTOMS (WPB). COMPARISONS FOR MAXIMUM TEMPERATURES ARE MADE IN THE LEFT-HAND COLUMN, WHERE DEVIATIONS ARE SHOWN ACCORDING TO MEAN DAILY MAXIMUM, APPROXIMATE MEAN WEEKLY MAXIMUM, AND ABSOLUTE MAXIMUM TEMPERATURES FOR EACH MONTH; IN THE RIGHT-HAND COLUMN, THE DEVIATIONS FOR MINIMUM TEMPERATURES ARE COMPARED.

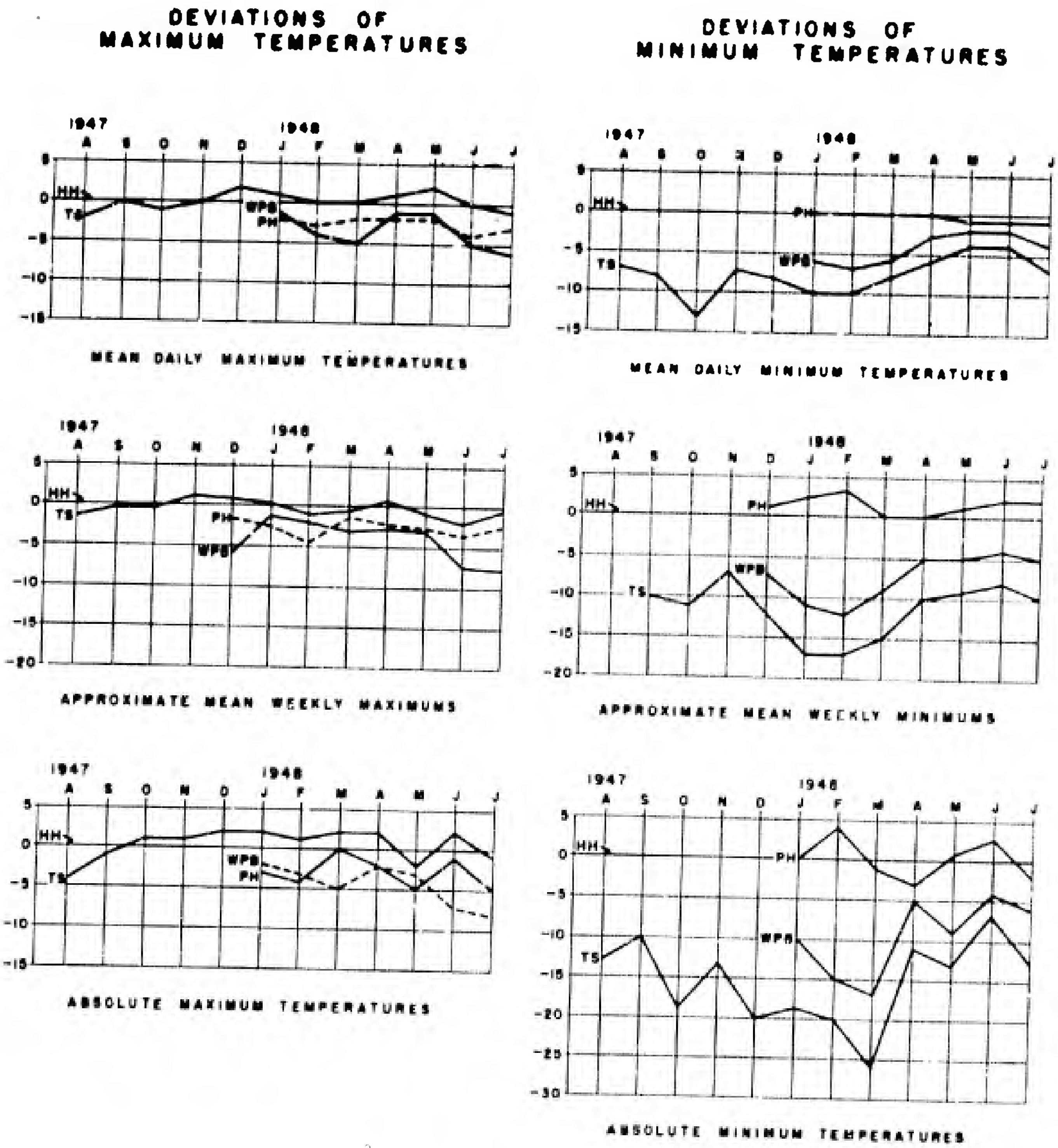


Figure 72

station is likely to be very nearly the same on most cold nights (Geiger 1950, p. 253), and the one coldest night is fairly representative of the other cold nights during the week. Maximum temperatures, by contrast, occur usually on sunny afternoons, at which times gradients are superadiabatic and the air is frequently unstable. One station may be slightly warmer than another on the first hot day, and be cooler than the other on the next, or may be warmer on all of several hot days, but, because of wind or some other factor, be a few degrees cooler on the hottest day, which is the only one recorded for the weekly reading. It must be recognized, then, that means derived from weekly maximums are a much less useful index of relative maximum-temperature rank than the means of weekly minimums are of relative minimum-temperature rank. Even so, the variabilities of given weeks tend to be cancelled out when averaged for a month or a season, and means of maximum temperature so derived can be considered useful for approximate ranking purposes.

c. Monthly or Seasonal Extremes.

It will be noted in Figure 72 that, although slight changes in the order of similar stations result when the monthly minimum rather than the mean of weekly minimums is used, the general arrangement still prevails for the stations with the greater contrasts. It is evident, however, that the range, month by month, is more variable than on the daily or weekly charts. One exceptionally strong inversion on an unseasonably cool night gives a great range for a given month, whereas the average range for that month as shown by the mean of weekly, or daily readings, is much smaller than for several other months. For determining a general pattern of coldness among various stations, a single set of readings is almost as useful as a monthly mean of weekly readings; but precise placement of stations on a graduated degree scale is not warranted.

Extreme monthly maximums, by contrast, show so little correlation with monthly means of weekly maximums that one must conclude they have little value. If all the maximums occurred simultaneously at all stations the pattern would be more distinct and useful, but such is seldom the case.

d. Rapid Traverse Surveys.

As indicated in the preceding section, a single minimum-temperature reading each month is useful for comparing places as to relative coldness. It follows then that a series of rapid-traverse readings taken carefully on a well-chosen night will give useful results, and, moreover, will make it possible to compare many additional places where stations have not been established (Brooks, 1931, p. 493 ff; and Geiger, 1950, pp. 264-265, citing Kraus, 1911 and others).

Rapid afternoon traverses for differentiating places as to maximum temperatures are less useful than traverses for minimum temperatures, for reasons already given, but probably yield data of more value than those in a set of once-monthly maximums, for the reason that the readings are all for the same day. If the day is selected with some care, significant differences will be revealed from place to place, especially when some places are wooded and others are in the open. Actually, the readings taken from a sling thermometer on such a traverse will probably be slightly more accurate than if the readings had been obtained from sheltered instruments at the same places. Because conditions usually vary slightly from minute to minute even on a quiet afternoon, however, the differentiation of maximum temperature obtained during, say, a two-hour period cannot be considered accurate to within less than two degrees, unless it can be determined from thermograph records from two or more contrasted places that conditions were exceptionally uniform during the traverse period. The various thermograph traces shown later in this chapter indicate that such periods do occur, but usually not on sunny days when the greatest differences in maximum temperatures from place to place are most likely to be found.

e. Seasonal Samplings with Thermographs.

A thermograph record kept for only a short period at one place has great value for showing local conditions, and for comparing stations. Unfortunately, such a record cannot be used for determining normal means, extremes, or frequency distributions. As obtained at Harvard Forest, where records were being made simultaneously by several thermographs operating the year round and by the hygrothermograph at the Headquarters stations, such short-time records were found to give only a general indication of the normal temperature characteristics of the station where taken. When used for at least a month at any one place, however, the thermographs provided valuable information about extremes of maximum and minimum temperature, and number of days having temperatures above or below critical thresholds.

Such data, even for a single month, give added value to tables of frost days, ice days, summer days, and the like, and emphasize differences which might not be apparent from tables of weekly extremes alone. It will be readily apparent, however, that statistical analyses of greater significance could have been made in this study had more thermographs been used from the start, and if each had been placed in a distinctively different location and operated there continuously for the full-year period. Not all the distinctive differences were known at the beginning of the study, however, and the various procedures used, and the large network of stations operated, made it possible to differentiate the temperatures of many more places than if more detailed records had been sought.

The study, as conducted, produced a large body of daily readings from a few stations, sufficient to provide an accurate basis for comparison. In addition it produced a large body of weekly readings from many stations — readings which are extremely useful for differentiations of minimum temperature, and fairly useful for differentiation of maximum temperature. Later studies, intended to be more precise and to provide more detailed information, could well be concentrated at the sites already discovered to be of greatest interest. At such sites it would be most valuable then to obtain a continuous and more comprehensive record not only of temperature at various heights, but of humidity, precipitation, and wind, and of soil temperatures at the surface and at various depths, to mention a few (Bacsó and Zolyómi, 1935; Geiger, Woelfle, and Seip, 1933 and 1934; Kunkele, 1933; Schmidt, 1930 and 1934; Tinn, 1938; and Wolfe, Wareham, and Scofield, 1949).

2. Reliability of Comparative Data Gathered for Only One Year.

Admittedly, the data gathered during only one year, and that a year with several unusual seasons, are not likely to be so reliable for studying the climatic relations of the Harvard Forest as data gathered for longer periods. It will be seen, however, from Figure 73, which shows comparative temperature data for Boston, Mass. and Concord, N.H. plotted for a 30-year period, that although temperature conditions may differ considerably from year to year at a given station, the comparative warmth or coolness of a particular station with respect to neighboring stations remains approximately the same in practically all years. It is only slightly less true for maximum temperatures. So long as site character does not change significantly, various stations should remain in approximately the same relationship to one another. Data of the kind plotted in Figure 73 lead one to conclude that analysis of the record for any one year within that record should give a reasonably accurate picture of the differences between the two stations. Consequently, one can place considerable confidence in the differences indicated by a single year's record for Harvard Forest obtained in this study and cited in the pages to follow. Obviously, to provide a higher degree of reliability a longer record would be more desirable.

3. Weather Conditions at Harvard Forest during Period of Study: August, 1947-July, 1948 (Figure 74, Appendix A-2, and Tracy, et al., 1947-1948).

Throughout the period of this study, climatic conditions in New England were seldom average; at times the departures from average for individual months were quite large, although for the full-year period the plus and minus departures almost balanced. Annual averages for the whole period would give little hint of the very unusual conditions which prevailed during several of the seasons. Summer of 1947 was warmer than average but came to an early close. The growing season ended about September 20 in valleys and about September 23 on the uplands. Autumn, which began early, was very warm and dry at first. During October, forest fire danger remained high for several weeks. A moist, cool November followed.

The winter of 1947-1948 was colder than average, with average or less-than-average precipitation, but with record or near-record snow. Continuous snow-cover lasted from late December to late March. Snow-cover disappeared rapidly during the third week in March. The growing season began by May 5 on the uplands; in forested parts of the lowlands it began about May 18, but in open sections of the lowlands killing frost occurred as late as June 8.

Summer of 1948 again was warmer than average. Although the one-year period of this

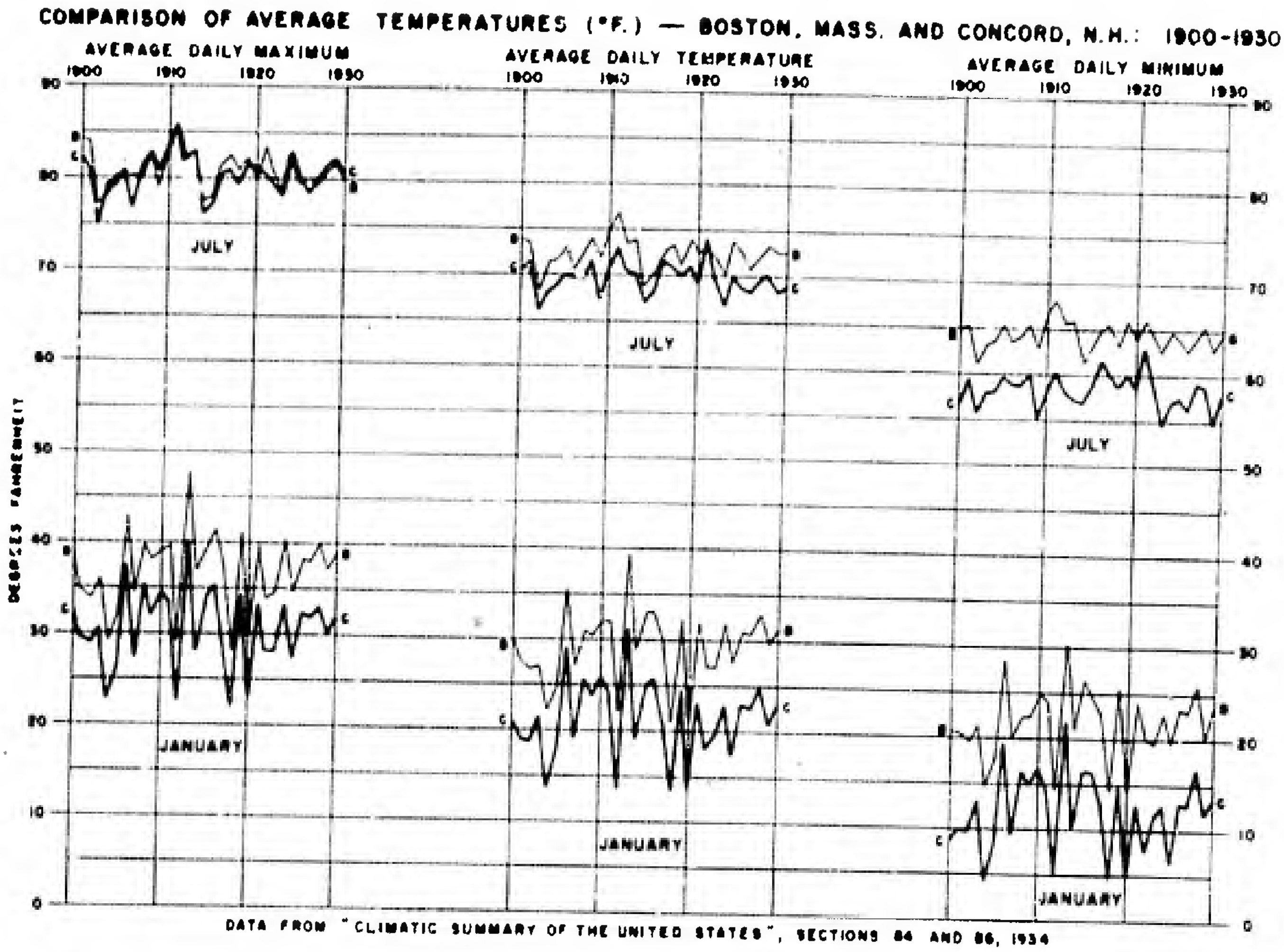


Figure 73

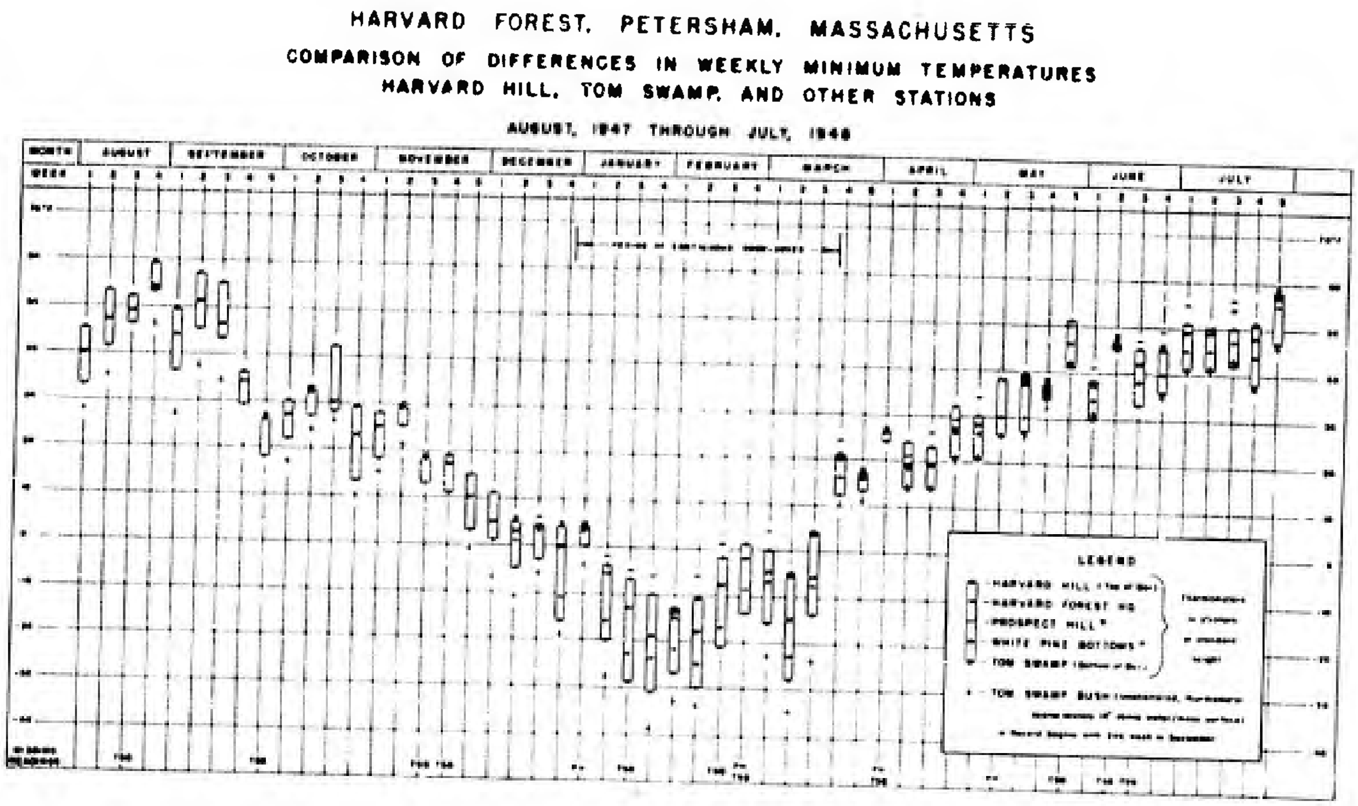


Figure 74

study ended on July 31, 1948, it is of interest to note that the 1948 summer was six weeks longer than the short summer of 1947 and three weeks longer than the long-time average. The first killing frost at the end of summer, 1948 at Harvard Forest Headquarters occurred on October 15.

To summarize: The period of the study covered part of one summer that was warmer but shorter than average and part of a second summer also warmer but much longer than average. In between occurred an autumn which first was warmer and drier and later cooler and wetter than average, a winter colder and snowier than average but with only average or less-than-average precipitation, and an early but otherwise not exceptional spring. Although unusual weather is common in New England, the period of this study probably embraced more periods of unusual weather than normally occur in any one year. Even so, the deviations were only rarely beyond moderate limits of expectancy, and the conclusions drawn from this study may be considered to be applicable to other years with less extreme conditions.

4. Proportionate Part of New England Temperature Diversity Observed at Harvard Forest.

a. Basis for Comparison.

The charts accompanying the discussion in this section are based upon the data presented in Appendix A. The data used for comparison include representative stations in a network extending from the Canadian border southward to Long Island Sound and from the Berkshires eastward to the Atlantic shore (Figure 1). These stations are compared with two Harvard Forest stations at which thermographs were operated continuously throughout the period of study and with three stations operated from December, 1947 to the end of the study. It should be noted that the network does not include any stations on high mountains or in Maine.

b. Comparisons of Mean Monthly Temperatures (Figures 75 and 76).*

In mean monthly temperatures the local differences at Harvard Forest (according to month) cover one-fourth to one-half the differences noted among the 11 other New England stations, mostly in the central part of the diversity. The succeeding diagrams will show that the monthly mean temperature diversity, although it is significant, only partially suggests the actual diversity, and, in part, by averaging out significant extremes, actually hides some of the most surprising differences.

c. Comparisons of Mean Daily Maximum Temperatures (Appendix A-3 and Figure 77).

In mean daily maximum temperatures the diversity among the Harvard Forest stations covers one-third of the diversity for New England in winter, mostly in the center, and covers almost the entire lower three-fifths of the diversity in summer. It is interesting to note how the deviations change for specific stations. Harvard Forest Headquarters has lower mean maximums than Boston (a littoral station) in autumn and winter (Oct. H. F. 69.8, B. 71.5; Jan. H. F. 26.1, B. 30.3) but has slightly higher maximums in spring (Apr. H. F. 57.3, B. 56.5), and virtually equal maximums in summer (July H.F. 83.0, B. 83.9; Aug. H. F. 81.3, B. 81.8). Harvard Forest Headquarters has lower maximums than Mount Carmel (near Long Island Sound) both in winter and in summer (Jan. H. F. 26.1, M. C. 29.0; July H. F. 83.0, M. C. 86.3), but its maximums in April and October are practically equal to those of Mount Carmel (Apr. H. F. 57.3, M. C. 57.5; Oct. H. F. 69.8, M. C. 69.2).

The Connecticut Valley stations — Springfield and Hartford — have consistently higher mean maximums than Harvard Forest Headquarters. Springfield, although farther north than Hartford is a city station, and is warmer than Hartford, which now has its station at the airport on a wide, low terrace bordering the river. Throughout the year the mean maximums at Harvard Forest Headquarters are 4 to 6F degrees lower than those at Springfield. Those at Prospect Hill are about 7F degrees lower (for the period of record at Prospect Hill) than those at Springfield.

* In Figure 75, actual mean monthly temperatures are shown in °F for each station each month. Each monthly scale is so placed that the means for Harvard Forest Headquarters form a horizontal base. Figure 76, by contrast, shows deviations in F degrees from the mean of 11 non-Harvard Forest stations. In both figures the diversity among the Harvard Forest stations is shown by a shaded band.

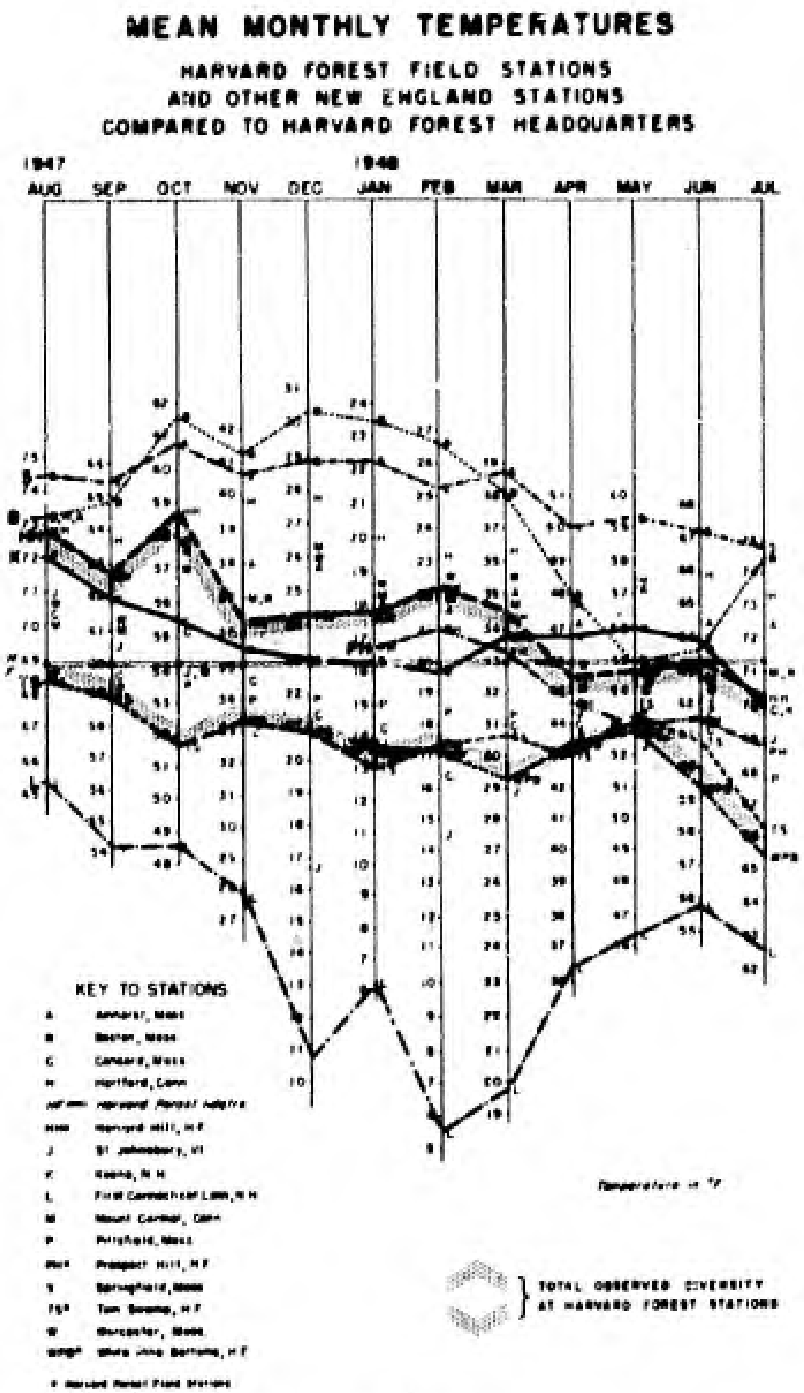


Figure 75

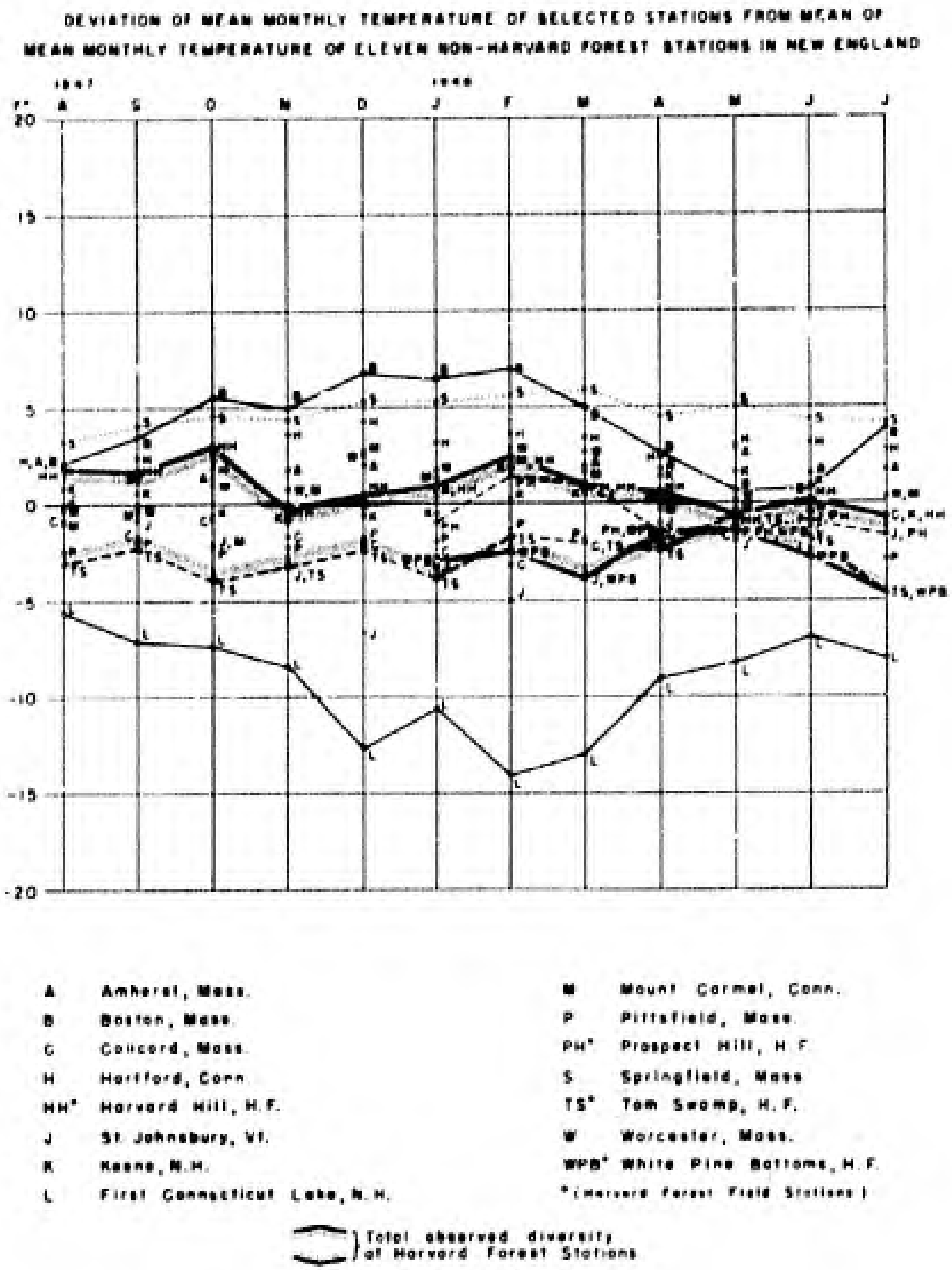


Figure 76

DEVIATION OF MEAN DAILY MAXIMUM TEMPERATURE OF SELECTED STATIONS FROM MEAN OF MEAN DAILY MAXIMUM TEMPERATURE OF ELEVEN NON-HARVARD FOREST STATIONS IN NEW ENGLAND

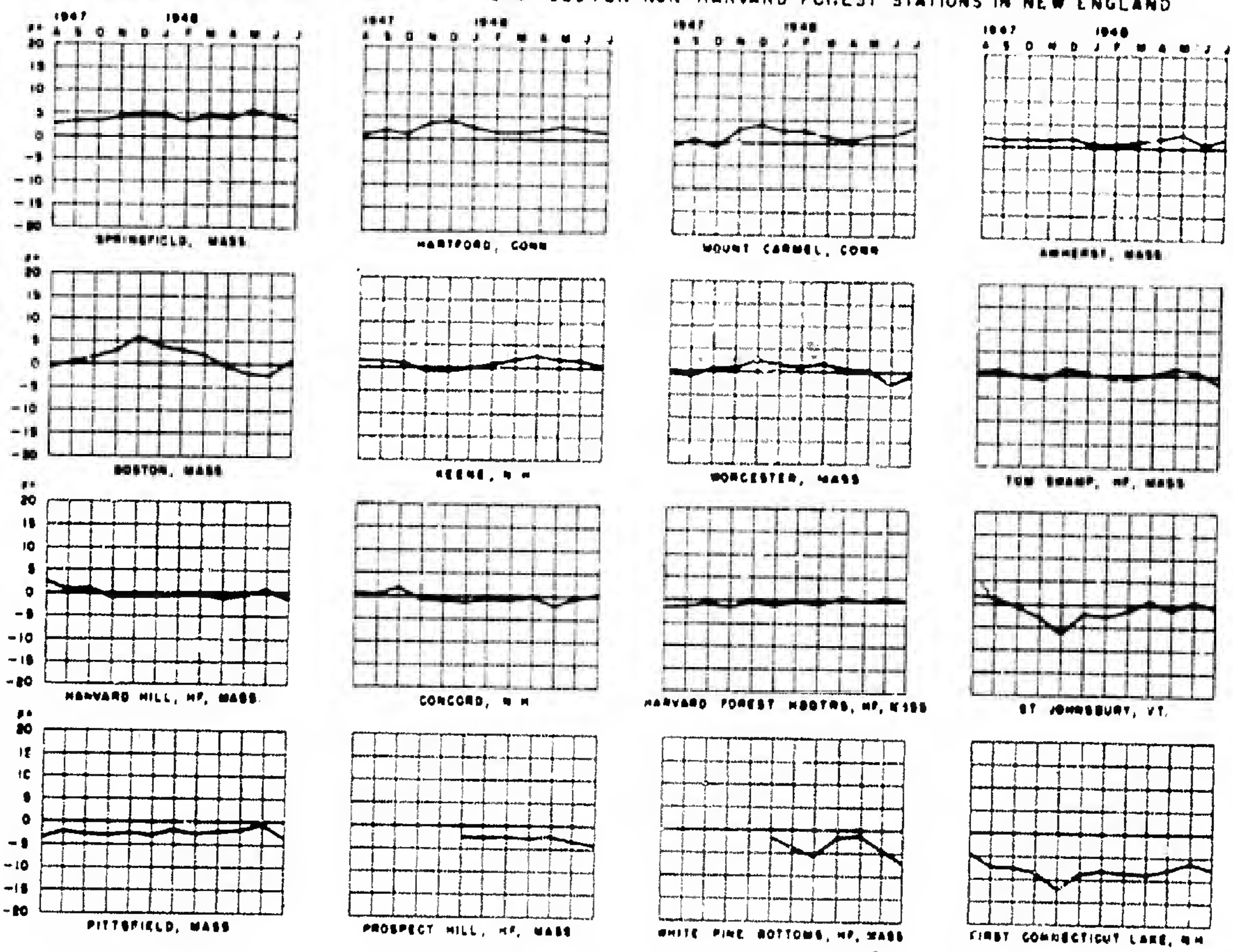


Figure 77

No station in Harvard Forest has maximums as low as those at First Connecticut Lake, New Hampshire, near the Canadian line. In summer, however, the heavily wooded White Pine Bottoms station has mean maximums almost as low as at First Connecticut Lake (July H. F. 83.0, W.P.B. 76, F. C. L. 74.9). Summer maximums at Harvard Forest stations in the open are higher. In winter the Harvard Forest stations have maximums considerably higher than those at First Connecticut Lake (Jan. H. F. 26.1, F. C. L. 17.8).

d. Comparisons of Absolute Maximum Temperatures (Appendix A-2, Figure 78).

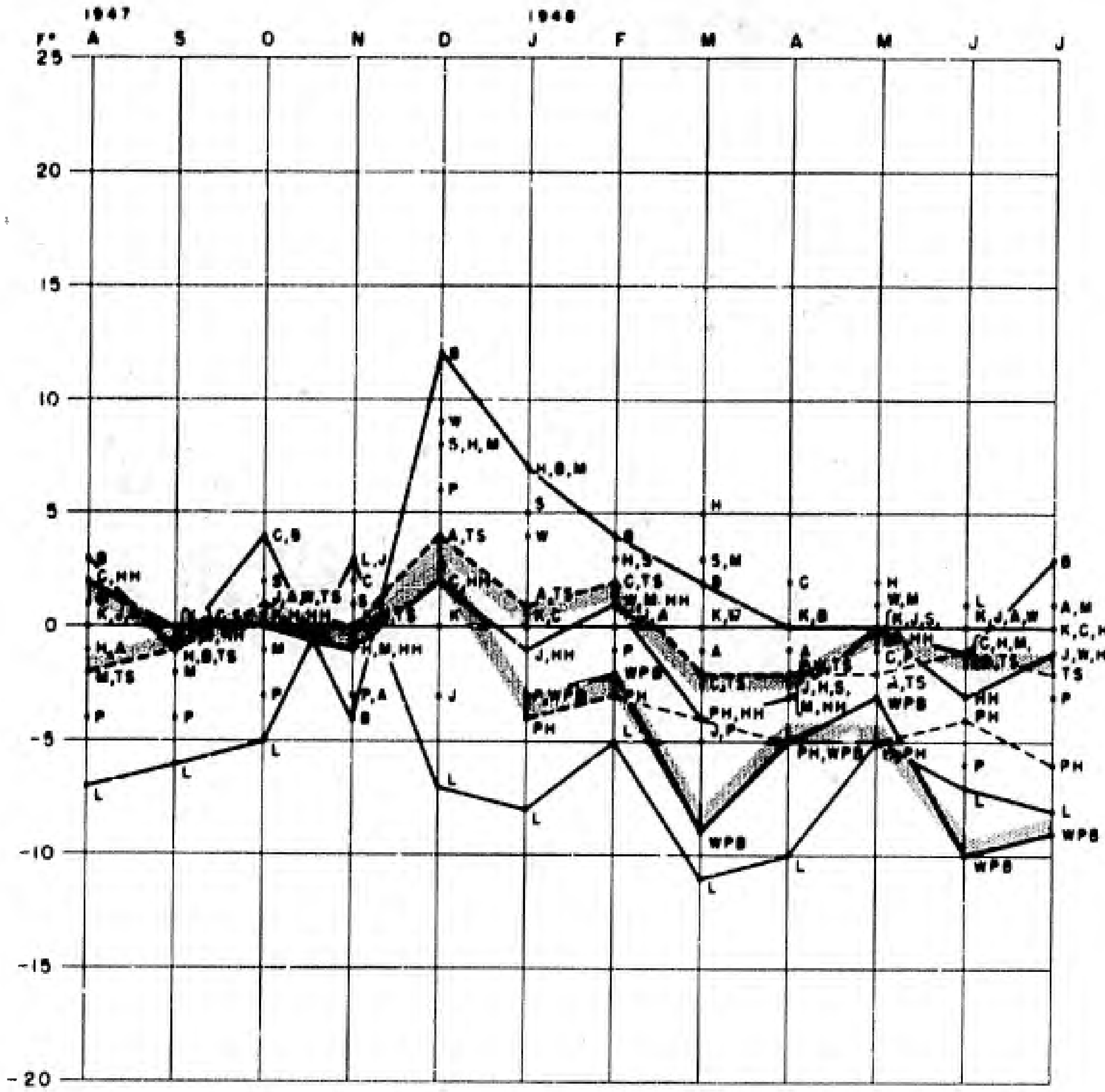
In absolute maximum temperatures the diversity at Harvard Forest (shown by a shaded band on Figure 78) covers one-third to two-thirds of the diversity for New England, mostly in the center part. An exceptional month is June, when the diversity for Harvard Forest actually exceeds that of the group of other New England stations, though at slightly lower temperatures. Although the absolute maximum temperatures have less significance for purposes of comparison than the daily mean maximums, they are not without value, as was shown in Figure 72.

e. Comparisons of Mean Daily Minimum Temperatures (Appendix A-4, Figures 79, 80, and 81*).

In mean daily minimum temperatures the diversity for the Harvard Forest stations (indicated by a shaded band on Figures 79 and 80) covers one-half or more of the diversity of the group of other New England stations in summer and autumn, slightly less in early winter, but

* In Figure 79, actual mean daily minimum temperatures in °F are shown for each station for each month. Each monthly scale is so placed as to show the Harvard Forest Headquarters mean daily minimum on a horizontal line. Figure 80, by contrast, shows deviations in F degrees from the mean of the 11 non-Harvard Forest stations, and Figure 81 shows the same deviations for each station separately.

DEVIATION OF MONTHLY ABSOLUTE MAXIMUM TEMPERATURE OF SELECTED STATIONS FROM MONTHLY ABSOLUTE MAXIMUM TEMPERATURE AT KEENE, NEW HAMPSHIRE



A Amherst, Mass.
B Boston, Mass.
C Concord, Mass.
H Hartford, Conn.
HH* Harvard Hill, H.F.
J St. Johnsbury, Vt.
K Keene, N.H.
L First Connecticut Lake, N.H.
M Mount Carmel, Conn.
P Pittsfield, Mass.
PH* Prospect Hill, H.F.
S Springfield, Mass.
TS* Tom Swamp, H. F.
W Worcester, Mass.
WPB* White Pine Bottoms, H.F.
*(Harvard Forest Field Stations)

Total observed diversity at Harvard Forest Stations

Figure 78

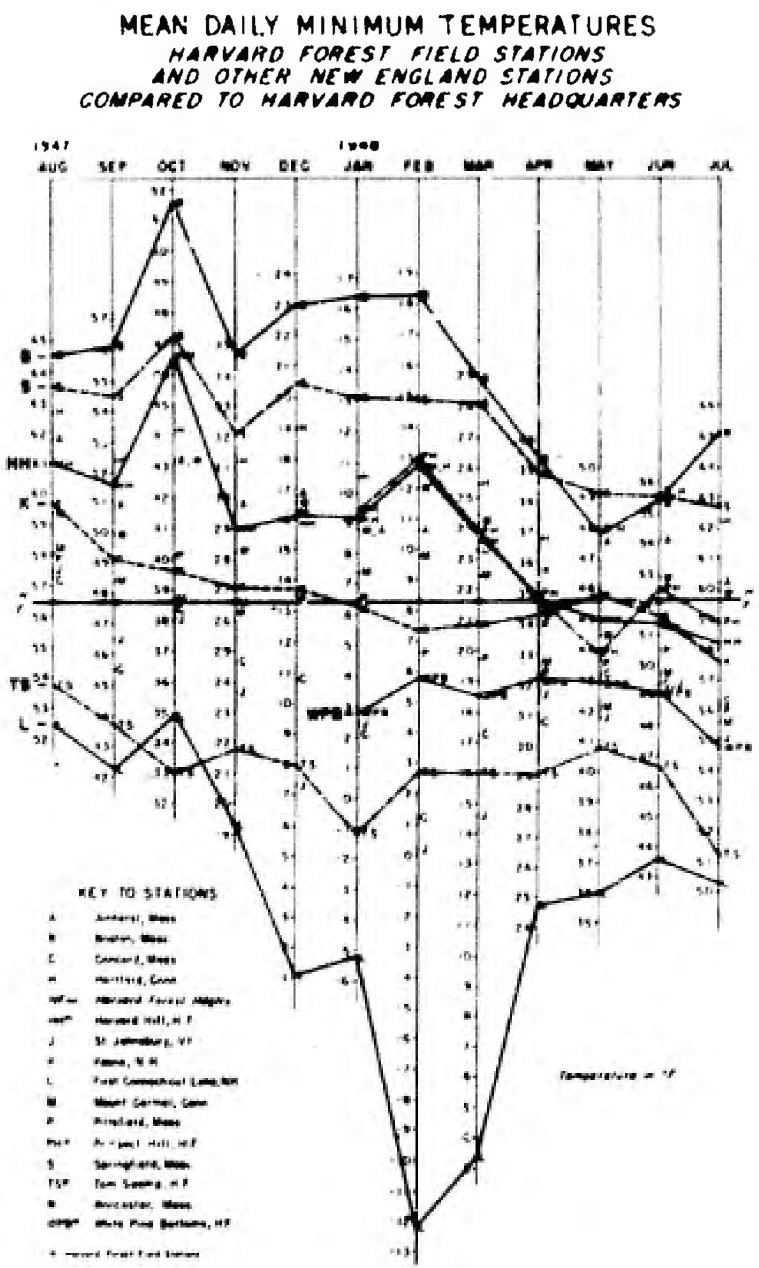


Figure 79

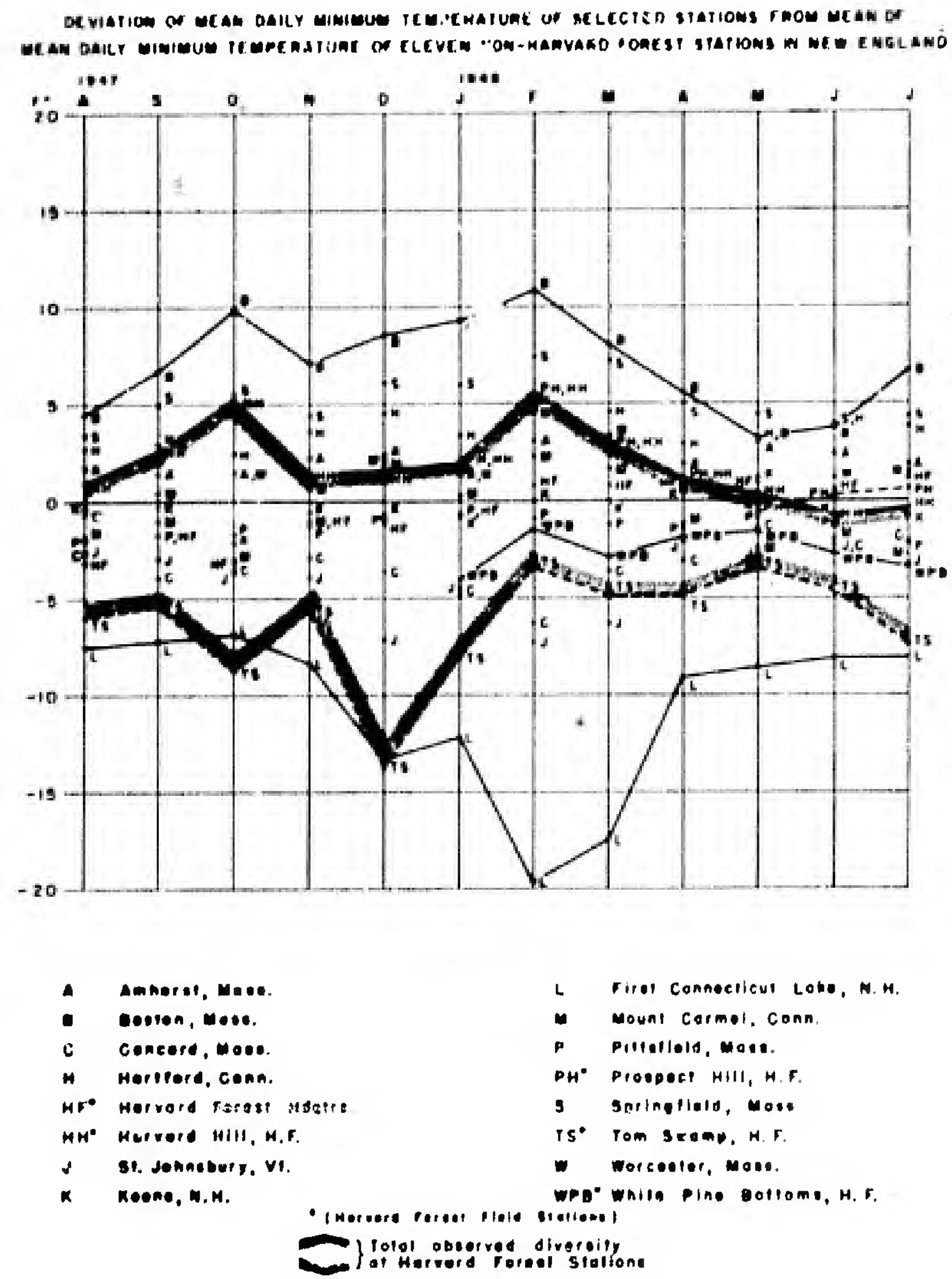


Figure 80

only one-third in late winter and spring. The total diversity for New England is greatest in winter and least in spring.

It is interesting to note (Figures 80 and 81) that hill stations in Harvard Forest have an annual deviation curve similar to Boston, Springfield, and Hartford, whereas valley stations, such as Tom Swamp and White Pine Bottoms, approximate the curve of Concord, an interior station on a sand plain in the valley of the Merrimack. Tom Swamp has lower summer minimums than St. Johnsbury, which is well to the north, and Tom Swamp has only slightly higher late winter minimums. Although minimums are higher at Tom Swamp than at First Connecticut Lake, which is much farther north, the two stations compare quite closely, except in winter, when mean minimums at First Connecticut Lake drop far below those of any other station cited for comparison.

DEVIATION OF MEAN DAILY MINIMUM TEMPERATURE OF SELECTED STATIONS FROM MEAN OF MEAN DAILY MINIMUM TEMPERATURE OF ELEVEN NON-HARVARD FOREST STATIONS IN NEW ENGLAND

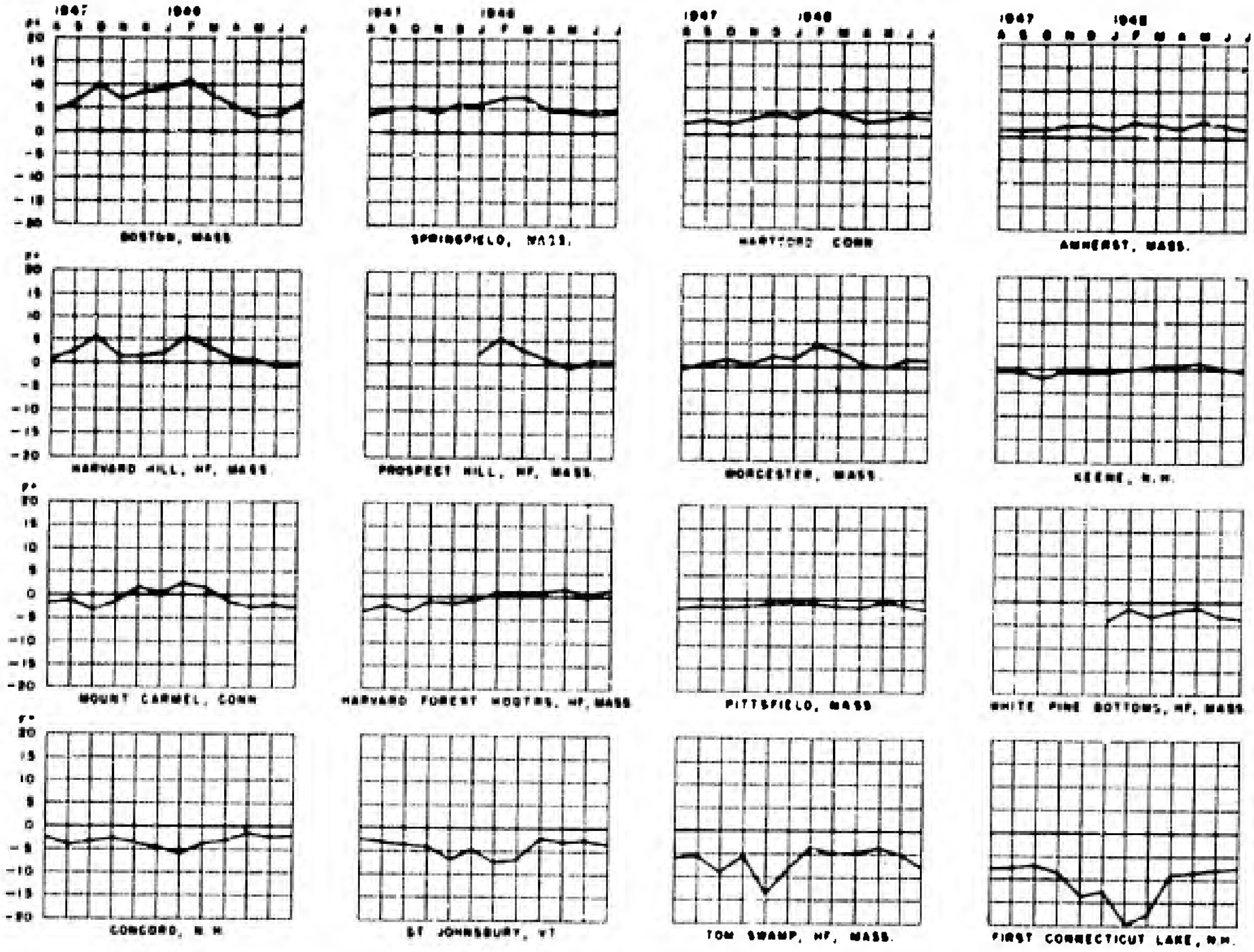
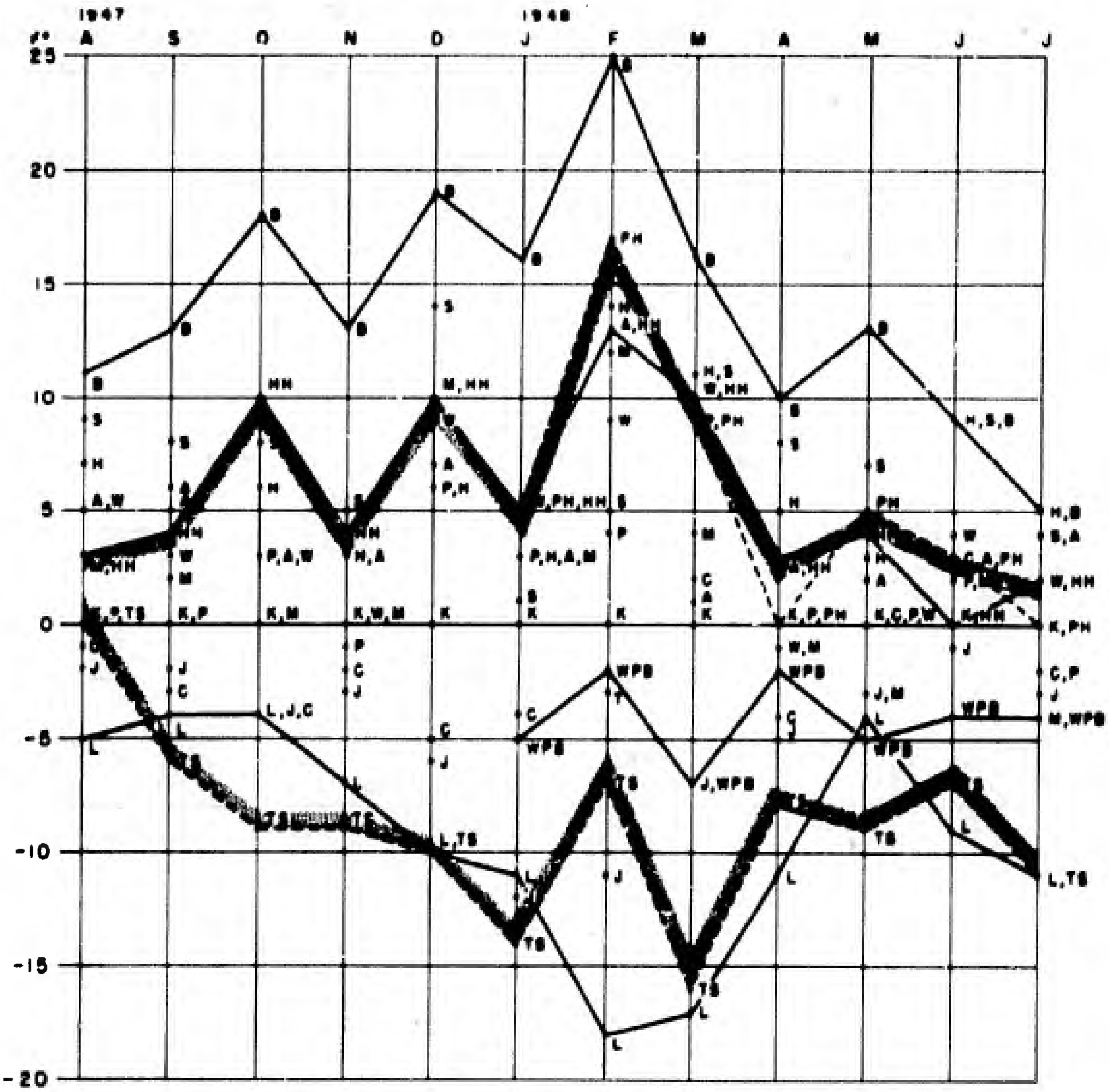


Figure 81

DEVIATION OF MONTHLY ABSOLUTE MINIMUM TEMPERATURE OF SELECTED STATIONS FROM MONTHLY ABSOLUTE MINIMUM TEMPERATURE AT KEENE, NEW HAMPSHIRE



A	Amherst, Mass.	M	Mount Carmel, Conn.
B	Boston, Mass.	P	Pittsfield, Mass.
C	Concord, Mass.	PH*	Prospect Hill, H.F.
H	Hartford, Conn.	S	Springfield, Mass.
HH*	Harvard Hill, H.F.	TS*	Tom Swamp, H.F.
J	St. Johnsbury, Vt.	W	Worcester, Mass.
K	Keene, N.H.	WPB*	White Pine Bottoms, H.F.
L	First Connecticut Lake, N.H.		*(Harvard Forest Field Stations)

Total observed diversity at Harvard Forest Stations

Figure 82

f. Comparisons of Absolute Minimum Temperatures (Appendix A-5 and Figure 82).

In absolute minimum temperatures, the diversity for Harvard Forest stations is one-half to three-fourths the New England diversity, mostly in the lower part. In many months some Harvard Forest stations have absolute minimums lower than those at any other station. Figure 82 shows that in absolute minimums the hill stations compare with Boston and are "mountain", similar to "marine", in character, whereas the valley-bottom stations compare with First Connecticut Lake in severity and are "continental" in character (Conrad, 1936 (a), pp. B160-161).

g. Summary.

From these comparisons it becomes evident that even a small area such as Harvard Forest has a great variety of temperatures, and that it displays a considerable portion of the total diversity characteristic of a much larger region. This indicates that local factors can cause significant local differences, which, though not as great as the total regional differences caused by large-scale influences, such as great differences in latitude or of location with respect to the ocean, are nevertheless equal to or greater than differences noted between stations several hundred miles apart.

In almost all months some Harvard Forest valley stations had lower minimums than any other of the compared stations. These very low temperatures occurred in types of locations characteristic of a sizeable part of New England. At the same time, several Harvard Forest stations on open hills or in forested valleys had lower mean daily maximums than any reasonably near compared station. These observations emphasize the importance of present Weather Bureau efforts to place additional stations where extreme conditions not thus far recorded, but common to large areas, are the rule. Because many of the primary network stations of New England are in river-valley cities, it is probable that many climatic estimates for the vast intermediate-height upland areas between the valleys err in the direction of indicating higher mean maximum temperatures, lower mean minimum temperatures, greater frost danger, and shorter growing seasons than are actually the case. At the same time, because many of the stations are in cities, such estimates are likely to fall short of indicating the full severity of minimum-temperature extremes in the valleys — not merely in some unusual single valley but in thousands of valleys or other depressions throughout the region.

5. Factors Causing Temperature Diversity within Harvard Forest.

In the preceding section it was shown that the temperature diversity for stations within Harvard Forest comprises from one-third to two-thirds the diversity for New England as a whole. Local factors which account for these great differences within Harvard Forest are discussed below.

a. Topographic Form.

In general, convex surfaces, such as hills and ridges, have much smaller temperature ranges than do the concave surfaces, such as stream valleys or swales (Figures 83 and 84). Broad flat terraces are similar in temperature characteristics to concave surfaces. Adjacent convex and concave areas, though differing but slightly in elevation, will have great differences in temperature patterns, especially in minimum temperatures, even at high elevations within the region (compare Prospect Hill, 1383 feet, and High Swamp, 1280 feet, Appendix B). Many of the upland basins of Harvard Forest, however, have exits at one or more points, from which streams drain to still lower points. Where these exits are not blocked by heavy vegetation, or other dams, some of the cold air that has accumulated in the upper basin can drain out and move down to still lower points. In general, the lowest basins, with the largest collecting areas from which the cold air gathers, exhibit the lowest minimum temperatures, provided the ground in such places is sufficiently exposed to the sky, and provided further that the outgoing radiation is not considerably offset by downward radiation from the trees. Thus, at all comparable elevations an appreciable temperature contrast is evident between convex and concave areas, but the amount of contrast increases as the elevation decreases within the Forest as a whole. Town Line Swamp (1150 feet) has much lower minimums than Prospect Hill (1383 feet) but, even so, is warmer than Tom Swamp at 750 feet, which, in addition to having a larger collecting area, is more open than the largely wooded Town Line Swamp. Town Line Swamp has an intermediate place on the minimum-temperature-rank scale. The contrast between Tom Swamp or Burns Bridge and Harvard Hill (910 feet), however, is relatively twice as great. Harvard Hill and Prospect Hill, although they

HARVARD FOREST, PETERSHAM, MASSACHUSETTS

TEMPERATURE RECORDS AT FIELD STATIONS

JULY 28 TO AUGUST 6, 1947

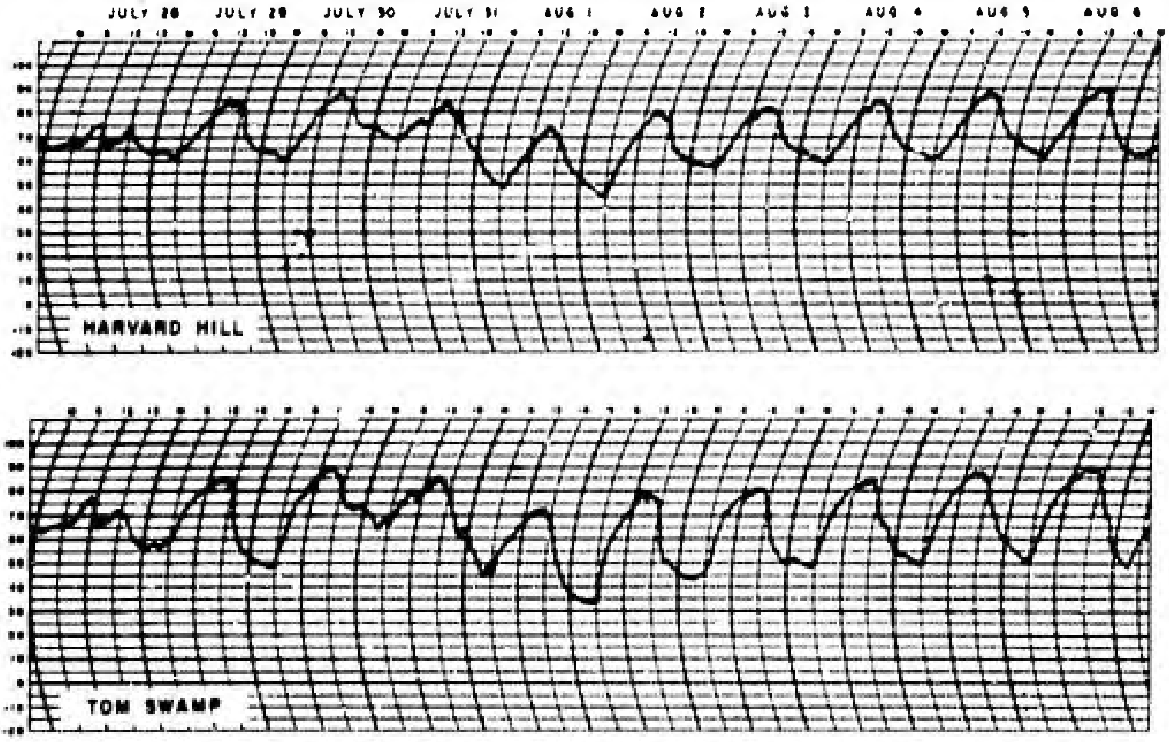


Figure 83

SEPTEMBER 15 TO 24, 1947

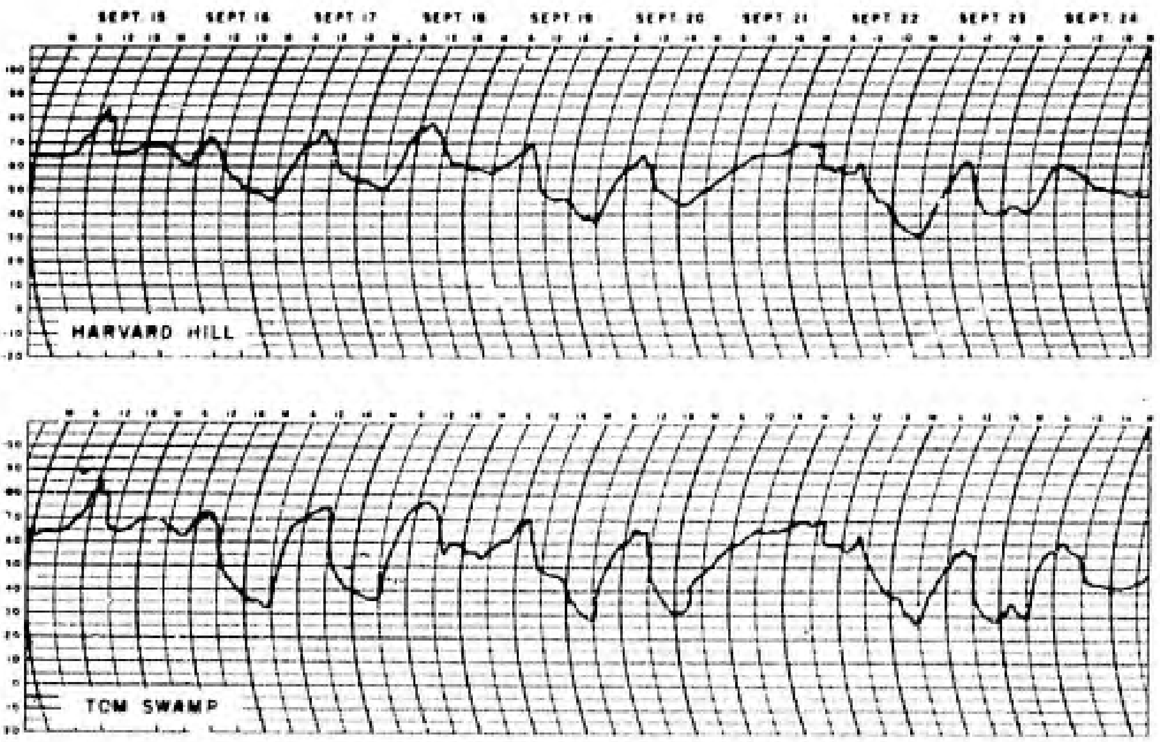


Figure 84

differ 453 feet in elevation are surprisingly similar in minimum-temperature pattern. On hill-tops the surface area and the vegetative cover have less influence on temperature than they do in basins. The basins, as has been shown, differ considerably.

"Concave slopes are known as hatching ovens, fourneux, by day, and cold holes by night". Peattie, 1936, p. 27.

These remarks apply chiefly to periods of clear weather with little or no wind, at which times inversions develop. Inversions are frequent and significant at all seasons, though particularly so during cool and cold months when trees are without leaves and the ground has a snow-cover (Figure 74). During periods of cloudy skies or moderate-to-strong winds, inversions are small or absent, and temperatures differ little from place to place. Figure 85 shows such a period continuing for a week, through January 7, 1948, followed by a period of great contrasts.

Open terraces, even though at high elevations and of limited extent, may cool rapidly by radiation and may tend to slow or stop some of the cold air draining from higher to lower points (Geiger, 1950, p. 205-206). Linden Terrace, for example, at 850 feet is frequently as cold as River Meadow at 737 feet, although intermediate points on the slope are warmer. The Locust Opening terrace exhibits this characteristic to a slight degree in the summertime, when vegetation in leaf partially blocks air drainage to lower swamps on the north and east.

The effect of topographic form on maximum temperatures is partly the reverse of its effect on minimum temperatures: tops of convex forms are cooler; basins are warmer. Differences are less striking than for minimum temperatures.

b. Elevation.

The effect of elevation upon temperature differs, and it is even reversed, according to the nature of the weather and depending upon whether it is day or night. As has been seen, on clear still nights, inversions develop, and temperatures are lower in the valleys than on the hills. In general, on clear nights, the lowest elevations at Harvard Forest have the lowest minimum temperatures. During periods of cloudy weather, by contrast, minimum temperatures in Harvard Forest are a few degrees lower on the highest points than in the deepest open valleys (Figure 85, compare Prospect Hill and open Tom Swamp, January 1-9). Maximum temperatures are almost always lower on the ridgetops than in the valleys. This is true not only on days when air movement is unrestricted, but on cloudy, windless days when ventilation is almost nil, and the lower temperatures on the ridges are a direct expression of a lapse rate. This is illustrated by the Prospect Hill - Tom Swamp comparison shown in Figure 86. Tom Swamp, though much colder than Prospect Hill at night, is warmer than the hill during the day. Figure 87 similarly illustrates this point, but brings out the much greater influence of topographic form for night temperatures. The thermograph traces for the two hill stations, although similar to each other, are very different from those of the valley stations. Figure 88 likewise shows the lower maximum temperatures at high points. It shows also the unusually extreme conditions and rapid changes that took place during the period March 4 to 6. On March 6 the minimum at Tom Swamp was -31°F, compared to -5°F at Harvard Hill and -1°F at Prospect Hill. Within eight hours the temperature rose 72F degrees at Tom Swamp and reached a maximum of 41°F, and rose 46F degrees to a temperature of 41°F at Harvard Hill. In the same eight-hour period it rose 37F degrees to reach 36°F on Prospect Hill.

c. Exposure to Direct Sunshine.

The amount of direct insolation received on the ground surface depends in part upon the angle of slope. A difference in angle of inclination of 1° toward the north or south is equivalent to a difference in latitude of 1° (Lutz and Chandler, 1942, pp. 268-269).

Several of the stations at Harvard Forest provided temperature data which documented once again the generally recognized importance of exposure in causing temperature differences. These temperature readings, taken at standard height, do not show the great contrast actually existing on the ground surface at each station, but are sufficiently different to suggest the much greater amount of heat energy available to plants growing on sunny slopes than is available to plants growing on shady slopes. The station at South Boundary, which is on a north-facing slope, has fewer hours of sunlight than Coach Road on the opposite side of the valley. Its day temperatures are slightly lower than those at Coach Road (Figure 89) although its night temperatures are higher than those at Coach Road. The Northwest Midslope of Little Prospect Hill receives the afternoon sun's rays at a high angle of incidence during the summer months when the sun

HARVARD FOREST, PETERSHAM, MASSACHUSETTS

TEMPERATURE RECORDS AT FIELD STATIONS

JAN. 1 TO 10, 1948

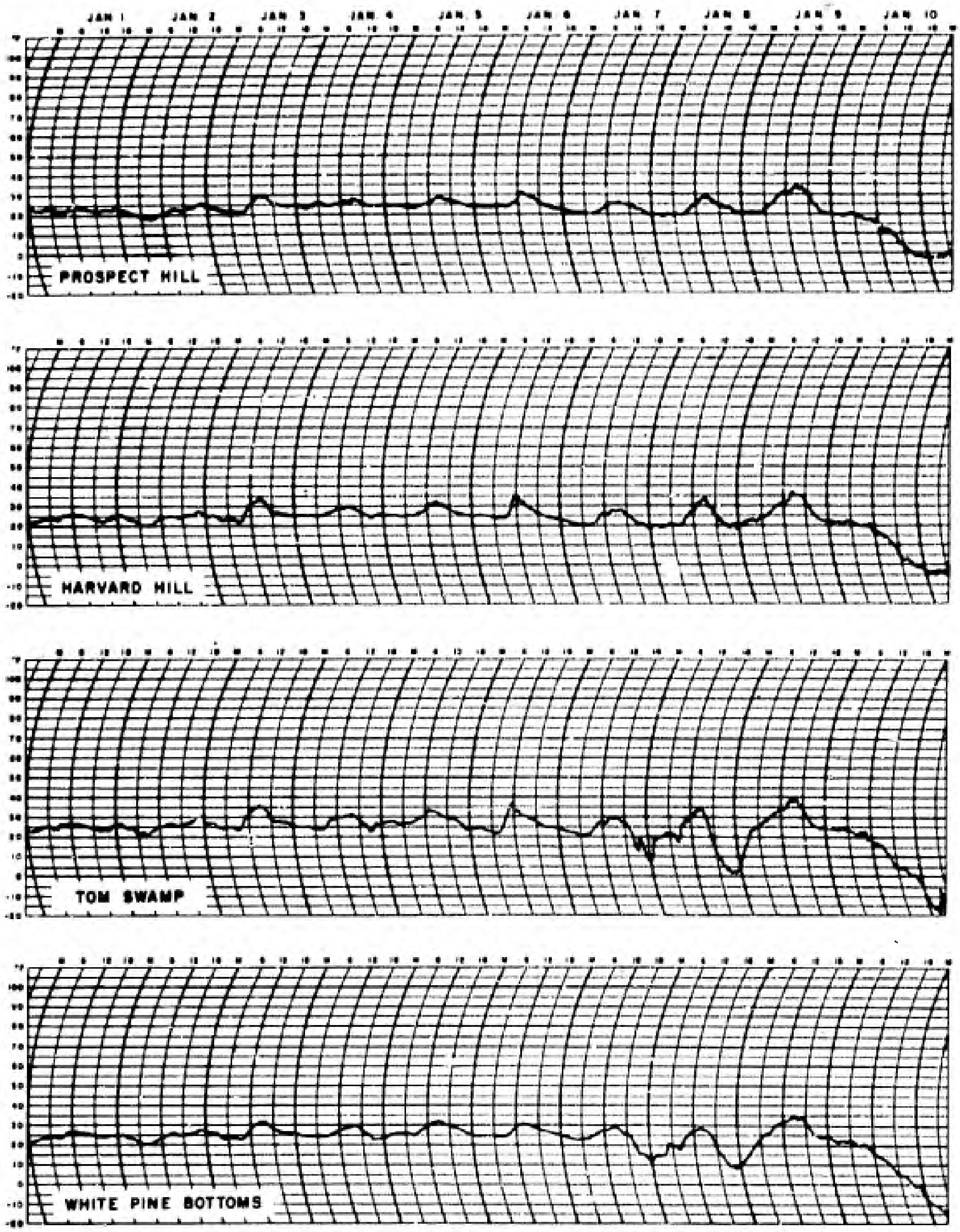


Figure 85

HARVARD FOREST, PETERSHAM, MASSACHUSETTS

TEMPERATURE RECORDS AT FOUR FIELD STATIONS COMPARED

JANUARY 21 TO 30, 1948

Timing of fine-line curves adjusted, where possible, to approximate that of compared station

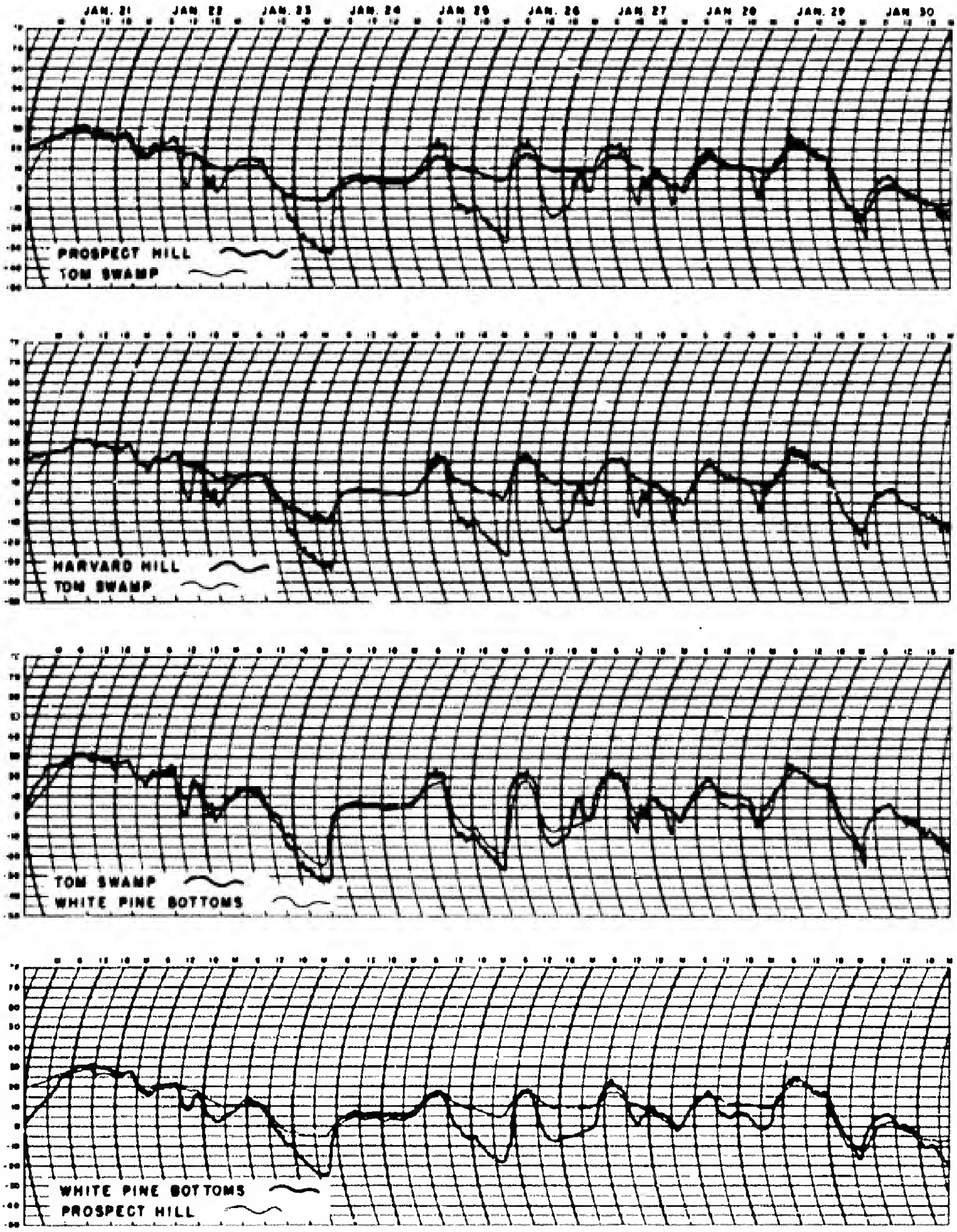


Figure 86

HARVARD FOREST, PETERSHAM, MASSACHUSETTS

TEMPERATURE RECORDS AT FIELD STATIONS

FEBRUARY 5 TO 14, 1948

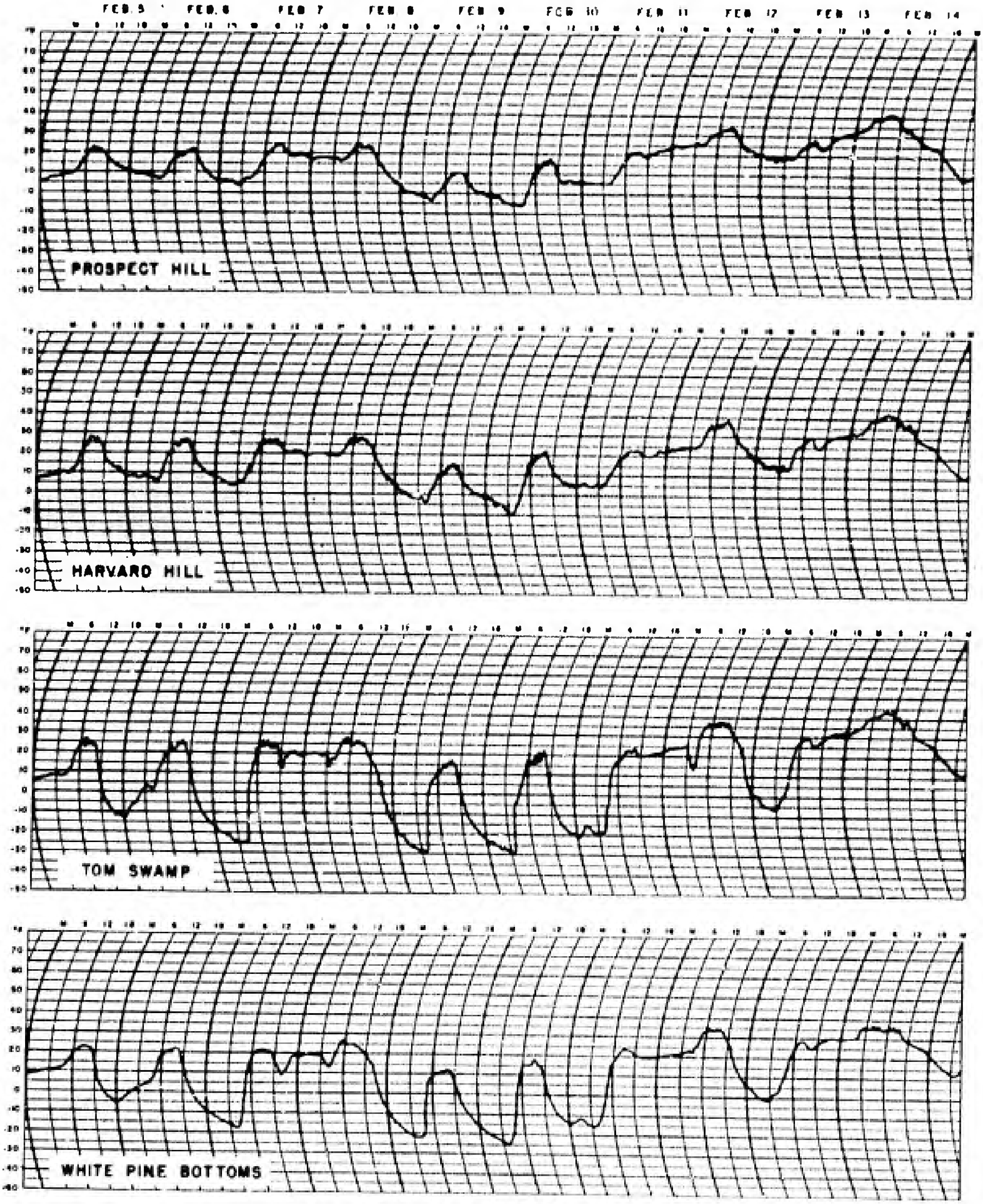


Figure 87

HARVARD FOREST, PETERSHAM, MASSACHUSETTS

TEMPERATURE RECORDS AT FIELD STATIONS

MARCH 4 TO 13, 1948

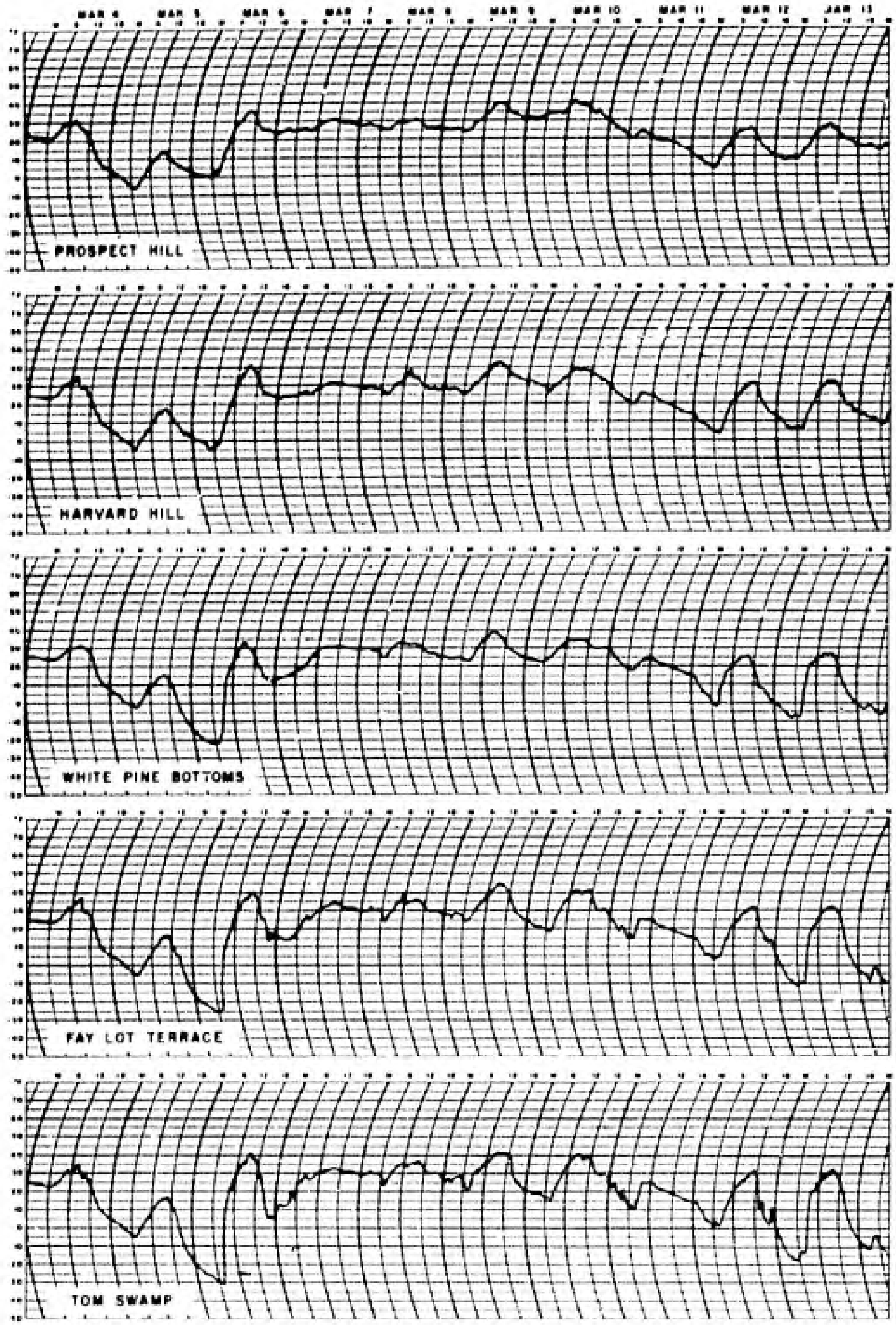


Figure 88

HARVARD FOREST, PETERSHAM, MASSACHUSETTS

TEMPERATURE RECORDS AT FIELD STATIONS

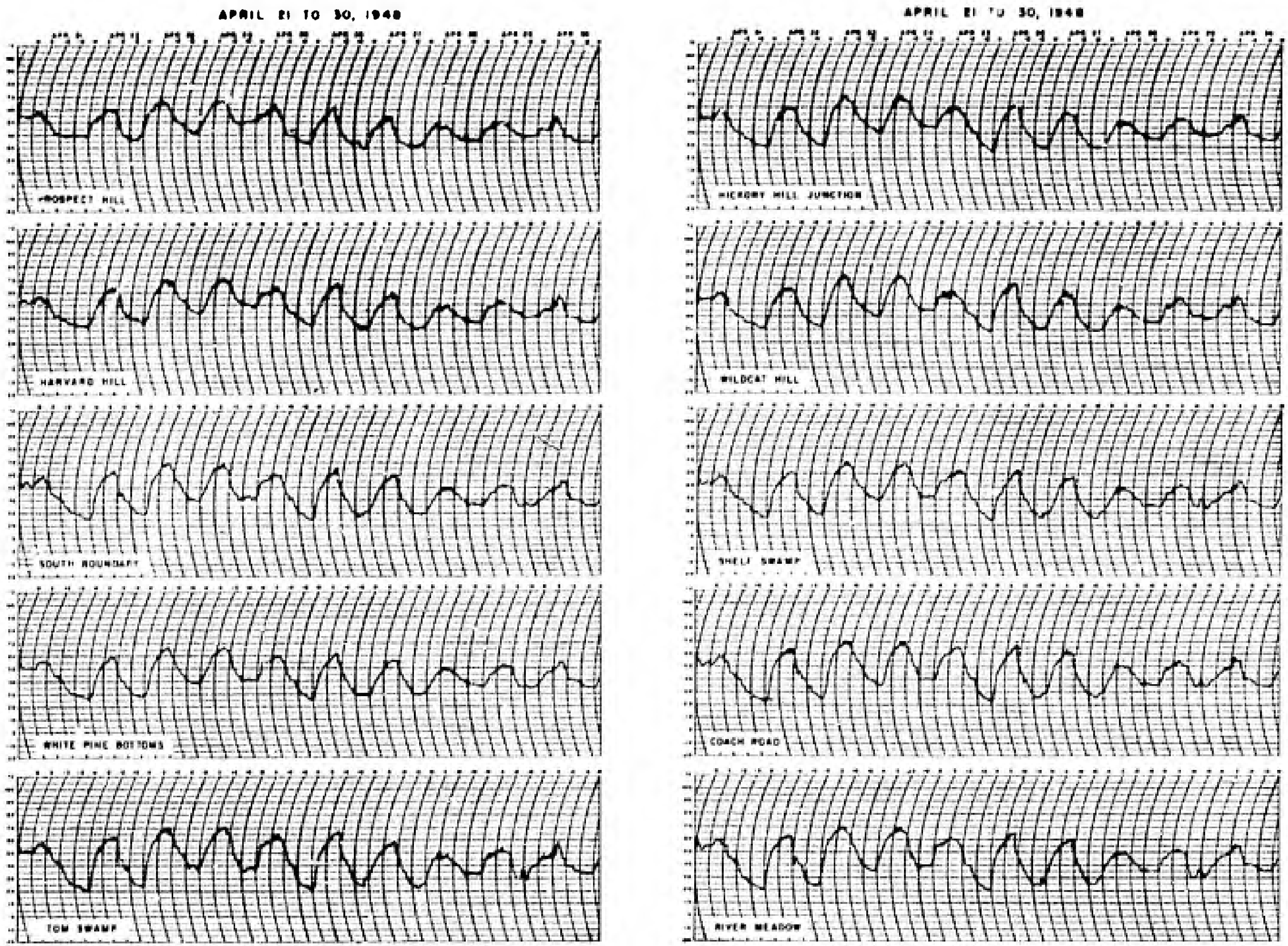


Figure 89

sets in the northwest. Figure 90 shows Northwest Midslope to have afternoon temperatures considerably higher than Prospect Hill. The explanation lies partly in differences in exposure and partly in vegetation, wind, and other relationships. Other factors being comparable, stations on south and west slopes have high maximum temperatures, on most days, compared to other stations. This is true even though they are shaded longer in the morning and so remain appreciably cooler, for several hours, than stations out in the open lowlands and on east-facing slopes. The general air temperature is higher in the afternoon and the ground is drier, and so less heat is used for evaporation of soil moisture; special local influences then combine with direct insolation and diffuse sky radiation to produce the highest temperature on these slopes (Geiger, 1950, p. 225). Early morning warming of east-facing slopes is shown in Figure 89 which shows Wildcat Hill has become 5 to 10 or more degrees warmer than Shelf Swamp by noon almost every day.

d. Exposure to Wind.

Many parts of Harvard Forest favorably exposed to sunlight are also exposed to the southwest wind, which blows much of the time in the warmer half year and fairly often in the colder. This wind is particularly frequent in drier years, when more of the low pressure areas follow a northern track. These winds not only warm the slopes exposed to them, but cause excessive evaporation as well. By contrast, the cool, moist, northeast winds strike fewer parts of Harvard Forest head on, and in many places strike most directly against the slopes which already are coolest because they face away from the sun. The contrasting effect of these winds, the southwest and northeast, is to intensify the contrast in temperature and moisture between southwest and northeast slopes. The cold, often dry, winds coming in from the northwest, and the generally mild, moist winds from the southeast, likewise have differing effects upon the slopes exposed to them. During the great hurricane of September 1938, however, the strongest wind, causing the major damage, was from the southeast. At that time the slopes facing southeast, the open flat areas, and wind-channelling troughs suffered the greatest damage. Northwest slopes, and troughs crosswise to the wind, suffered the least.

e. Effect of Vegetation.

Differing kinds of vegetation and differing heights of the same kind of vegetation have very different effects upon air temperature at standard shelter height. In general, the vegetation, which interposes a baffle between the sun and the ground, has a blanket effect, moderating conditions beneath it, but experiencing strong thermal activity within itself (Geiger, 1950, pp. 327-329). Obviously, the instruments in a shelter standing above a low shrubby or grassy vegetation (High Swamp and Tom Swamp - Figure 90), record essentially the general air temperatures, though such temperatures are influenced, to be sure, by the vegetation below. Shelters surrounded by vegetation high enough to cut off wind, but not high enough to form a canopy, are in the surface layer of limited air exchange (or local heat exchange), and experience extremes of heating by day and cooling by night. Northwest Midslope (Figure 90) is a prime example of this. Where the trees are high enough and close enough for their crowns to form a canopy over the shelter, the blanket effect results in a more moderate temperature pattern. Thus, within the red-pine plantation on Little Prospect Hill, conditions are even less extreme than in the open on Prospect Hill (Figure 90). Similarly, in the White Pine Bottoms, days are cooler and nights less cool than at Tom Swamp or other open stations (Figures 86, 88, 89, and 91).

It must be recognized that in many cases the temperatures at standard height are not the most critical for plant growth. Temperatures at the height of the leafy part of the plant are critical because they affect the transpiration rate, though the humidity relative to saturation at the temperature of the leaves is actually and directly more critical. Soil temperatures in the plant's root zone are probably even more significant to plant growth (Zon, 1941, p. 496). Within a forest, the readings at shelter height give some suggestion as to what general soil temperatures may be expected. In a dense pine stand the soil will be cool and moist except during extreme drouth. In an open hickory stand, where sunlight can reach the ground, the soil will be warmer and drier much of the time.

In general, hardwood forest has just as great a moderating effect upon air temperatures during its summer leafy season as has coniferous forest. In fact, in many mature coniferous stands where an understory of young hardwood trees is coming into succession, the summer canopy is notably more dense (Figures 66 and 68), and has greater effect than the winter canopy. Even in winter, however, the hardwood stands, though leafless, have a slight moderating effect (compare Fisher Stand and Trail Fork, Appendix B).

HARVARD FOREST, PETERSHAM, MASSACHUSETTS

TEMPERATURE RECORDS AT FIELD STATIONS

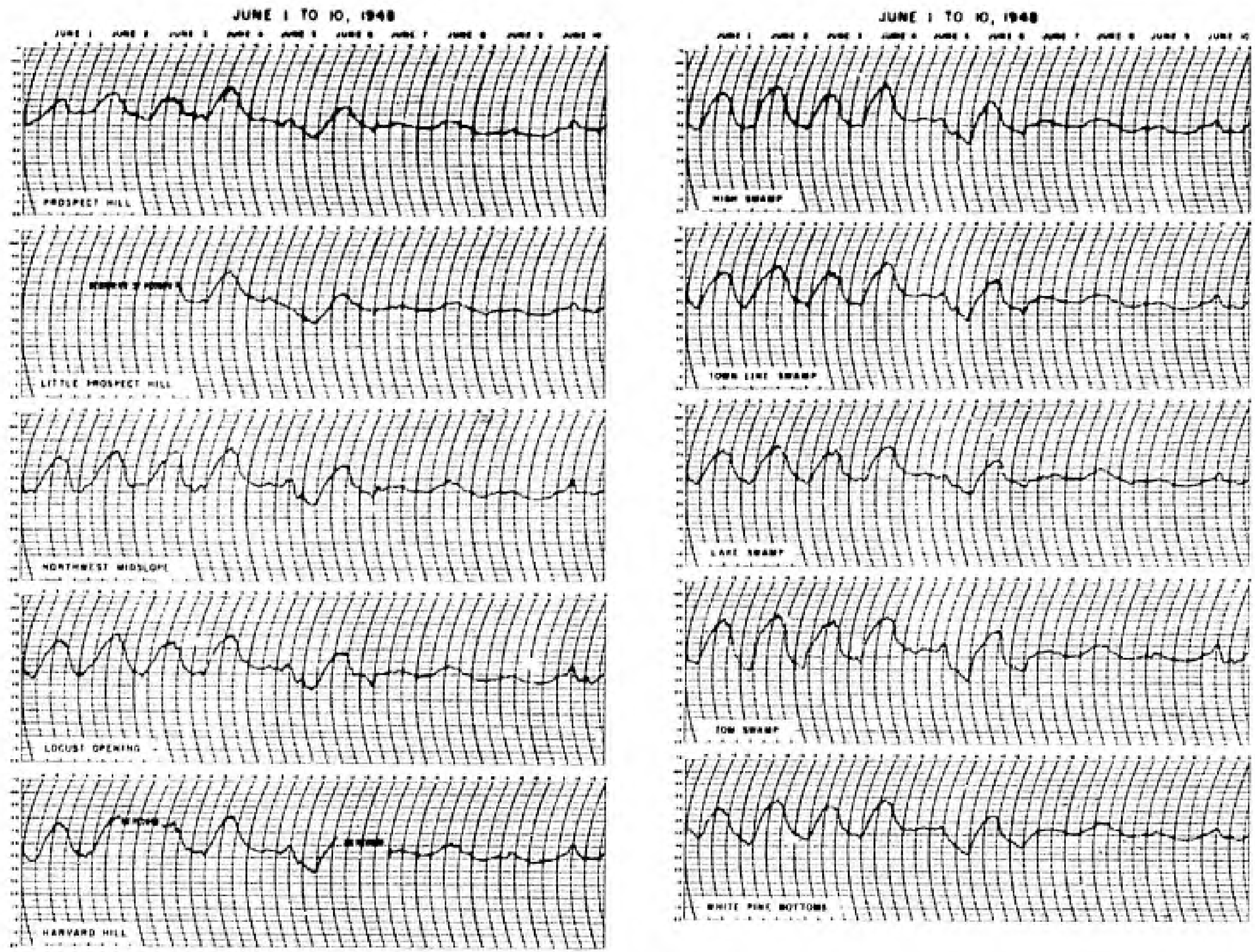


Figure 90

HARVARD FOREST, PETERSHAM, MASSACHUSETTS

TEMPERATURE RECORD AT TOM SWAMP COMPARED TO RECORDS AT TEN OTHER STATIONS

JULY 3 TO 12, 1948

Tom Swamp record is shown with fine line, with timing adjusted, where possible, to that of compared station. Records of named stations shown with heavy lines.

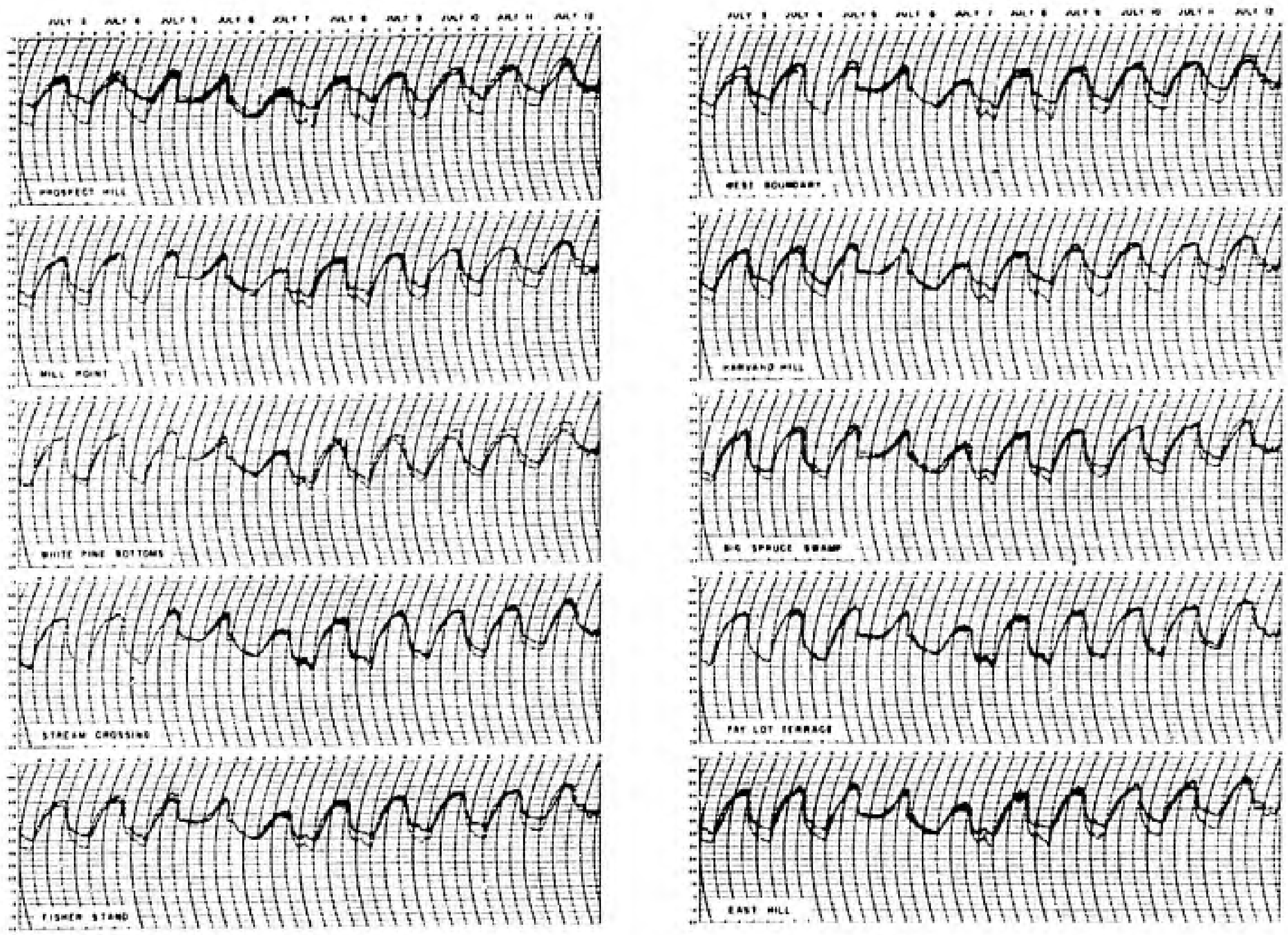


Figure 91

The forest's effect is relatively greater on day temperatures than on night temperatures. A heavy forest stand which during inversions will keep the night minimums as much as three to six degrees higher than those in the open, will keep day maximums as much as ten or twelve degrees lower than in the open. These locally observed differences are even greater than those reported by Kittredge (1948, p. 66). Such differences are sufficient actually to cause a continuous though moderate temperature inversion to exist by day as well as by night the year round in heavily wooded hollows. The Trailside Swale and White Pine Bottoms stations are in such areas. From this it will be evident that some kinds of forest, though in a sense having a moderating influence, tend to accentuate and perpetuate conditions favorable to certain of the species composing them. This is true particularly of coniferous stands in shaded, concave areas.

In moderately densely wooded areas at low elevations in Harvard Forest, the tree canopy reduces nocturnal cooling at standard shelter height markedly; as a consequence, the frost-free season is about half again as long in such wooded areas as in open places of similar topographic form at the same elevations. At intermediate and high elevations the effect of a tree canopy is similar but not so marked, except in concave areas. (Frost is discussed in greater detail in paragraph 6 below.)

f. Land - Water Relationships.

Water temperatures recorded in the course of this study are shown in Table II. Selected data for May, June, and July from this table are plotted by three different methods in Figure 92. For simplicity and ease of comparison, the data from only three of the stations are plotted on these diagrams.

Figure 92A shows the actual water temperatures recorded in successive weeks, regardless of the hour of reading. This diagram shows the general upward march of water temperatures in spring. It also shows the greater constancy of increase for Tom Swamp, where the water is largely blanketed by low shrub growth. The difference in actual temperatures between Tom Swamp and the two open pond stations also is greater in July than in preceding months.

Comparison with the mean daily maximum and minimum air-temperature curves superimposed on this diagram reveals that by July the mid-morning water temperatures of the open ponds, having risen rapidly in late spring, were almost as high as the mean daily maximum air temperature for July. At Tom Swamp, however, mid-morning water temperatures did not show this great seasonal increase. Late spring water temperatures in Tom Swamp averaged at least 15 F degrees cooler than the open pond temperatures. From an average of only 7 F degrees warmer than the mean daily minimum air temperature in May, the Tom Swamp water temperatures rose to 8 F degrees warmer than the mean daily air minimum in June, and to only 11 F degrees warmer than the mean daily air minimum in July.

Figure 92B shows the differences between air and water temperatures plotted for successive weeks, regardless of the hour of reading. It gives no conclusive evidence as to seasonal rates of increase of water temperatures, but does show the marked contrast between Tom Swamp and the two open pond stations. In all weeks but one, Tom Swamp water temperatures differ more markedly from the air temperatures than do the water temperatures at either Riceville Pond or Harvard Pond.

Figure 92C shows the differences between air temperatures and water temperatures plotted according to hour of reading, regardless of date. As this diagram gives only one reading for each station for any one day, it does not provide the necessary values to permit conclusions to be drawn as to diurnal trends in air - water temperature differences. Obviously, to get meaningful data regarding diurnal trends it is necessary to make a series of observations at intervals on the same day. Such studies, made elsewhere, have demonstrated that the daytime increase and nighttime decrease of water temperature characteristically lag behind those of air temperature (Conrad, 1935, p. 52 and 1936(b), p. 6; also Schmidt, 1930, p. 451).

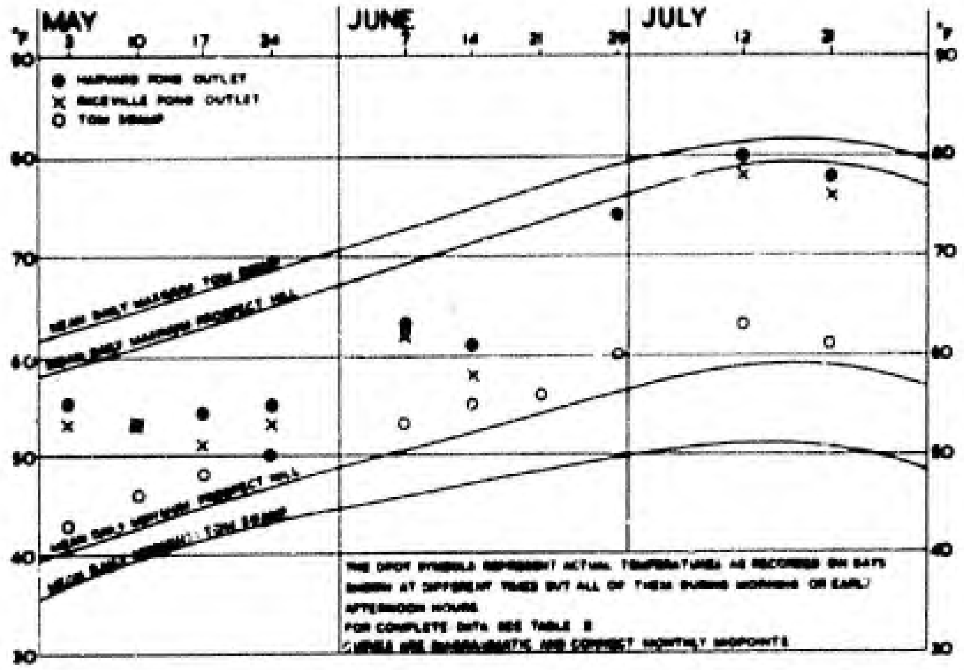
The preceding discussion, though in part inconclusive because based on partial data, indicates that the effect of vegetation on the water temperatures in swamps and marshes is unique. At Tom Swamp, for example, where the water has an overgrowth of shrubs, the water temperatures average as much as 15F degrees cooler, by day, than those for Harvard Pond or Riceville Pond (Table II and Figure 92). Even so, the water apparently gives off sufficient heat at night to diminish greatly the intensity of the temperature inversion in the lowest five feet of the atmosphere next to the water surface. This effect is noticeable only during those months when the water table covers the sphagnum moss layers under the shrub growth. Thus, the read-

TABLE II - HARVARD FOREST, MASSACHUSETTS WATER TEMPERATURES (in °F)

1948		RICEVILLE POND		TOM	HARVARD (BROCKS) POND			SWIFT	
		W. SHORE	OUTLET	SWAMP	E. SHORE	MILL PT	OUTLET	RIVER	
Apr. 12	Water Temp	-	-	40	-	48	-	Apr. 13	45
	Air Temp	-	-	55	-	60	-		50
	Time	-	-	0900	-	1400	-		1400
Apr. 19	Water Temp	-	-	41	50	-	-	Apr. 20	48
	Air Temp	-	-	44	55	-	-		51
	Time	-	-	0940	1445	-	-		0915
Apr. 26	Water Temp	58	-	47	55	60	63		-
	Air Temp	51	-	70	53	57	70		-
	Time	1050	-	1710	1140	1125	1700		-
May 3	Water Temp	54	53	43	56	55	55	May 3	57
	Air Temp	52	52	53	56	59	58		66
	Time	0900	0840	0800	1015	0950	1000		1300
May 10	Water Temp	55	53	46	55	-	53	May 11	58
	Air Temp	62	62	63	64	-	68		69
	Time	0815	0830	0850	1015	-	1030		1220
May 17	Water Temp	52	51	48	51	54	-	May 18	53
	Air Temp	60	60	59	58	62	-		60
	Time	1400	1340	1315	1300	1540	-		1430
May 24	Water Temp	56	53	50	54	-	55	May 25	54
	Air Temp	65	65	69	62	-	66		56
	Time	1035	1020	0945	0935	-	1055		1405
May 31	No Readings	=	=	=	=	=	=		=
June 7	Water Temp	61	62	53	56	63	63	June 8	54
	Air Temp	55	54	54	54	55	55		58
	Time	1020	1030	1100	1110	1130	1140		1145
June 14	Water Temp	64	58	55	63	69	61		-
	Air Temp	66	66	70	68	71	71		-
	Time	0930	0940	1000	1200	1215	1220		-
June 21	Water Temp	69	65	56	62	70	-		-
	Air Temp	67	67	70	72	72	-		-
	Time	0845	0900	0920	1105	1120	-		-
June 29	Water Temp	76	74	60	74	79	74	June 29	67
	Air Temp	83	83	76	80	80	80		82
	Time	0930	0940	0830	1025	1010	1015		1305
July 6	No Readings	=	=	=	=	=	=		=
July 12	Water Temp	-	78	63	78	83	80		-
	Air Temp	-	84	83	84	84	84		-
	Time	-	1015	0910	1105	1050	1030		-
July 21	Water Temp	-	76	61	74	-	78		-
	Air Temp	(Water	83	80	79	-	78		-
	Time	very low)	1040	1115	1130	-	1200		-

HARVARD FOREST - PETERSHAM, MASS.

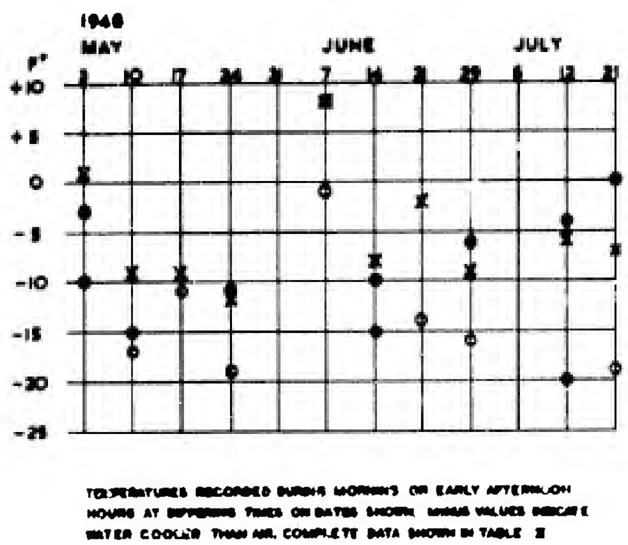
WATER TEMPERATURES
COMPARED TO MEAN DAILY MAXIMUM AND MINIMUM TEMPERATURES



A

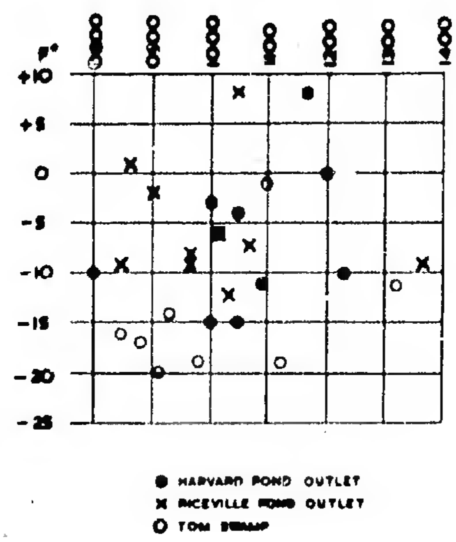
DIFFERENCES BETWEEN WATER AND AIR TEMPERATURES

PLOTTED ACCORDING TO DATE OF READING REGARDLESS OF HOUR



B

PLOTTED ACCORDING TO HOUR OF READING REGARDLESS OF DATE



C

Figure 92

ings on the Tom Swamp Bush thermometer were about the same as those in the Tom Swamp shelter from April to July, 1948 (Figure 74), when the water table was high. This was in contrast to conditions during late summer and autumn, 1947, when the water table was below the surface of the sphagnum moss layer. At that time, and during the winter months which followed (when the pond surface was frozen and snow-covered), minimum temperatures were markedly lower at bush level than at shelter height.

From this it appears that the presence of water increases the normal moderating effect of the vegetation upon air temperatures, at least where the vegetation is such that the water surface is largely shielded from direct sunlight and radiation. Shrub vegetation, like that near the shelter at Tom Swamp, being skeletal, has little actual mass to absorb heat, and has much surface through which to lose the little heat it does absorb. Yet *in toto* it forms a thick, if leaky, screen between the water and the open sky.

The water bodies within Harvard Forest are not large enough or deep enough to affect air temperatures over land at places very far from their shores, but the local effect at their margins is considerable during some seasons, particularly during the open-water season. Thus, during the summer, when the pond waters give off heat and warm the night air, such waterside stations as Mill Point and Riceville Pond have higher minimums than Burns Bridge or River Meadow (Appendix B). By day in summer, when the waters have a slight cooling effect, the air has lower maximums. In the winter, by contrast, when the ponds are frozen, they have little effect upon temperatures (although some heat continues to pass through the ice); all these stations are then closely comparable and "continental" in their behavior. Similar findings are reported for Arctic shore areas by Conrad (1936(a), pp. B213-214) who cites Baur (1929, p. 77) and Wagner (1919, p. 128) to the effect that at Green Harbor, Spitzbergen diurnal temperature ranges are five times greater in winter than in summer.

During spring and autumn the land-water relationships at Harvard Forest are complex and changeable, according to whether the ponds are open or frozen, but the general effect is to retard the onset of spring and autumn slightly. The ponds warm up slightly, however, each day in spring, and thereby diminish the danger of late spring frosts at night near their shores. In autumn they are effective, on their immediate shores, in lengthening the warm season for several weeks. The very local effect of the water bodies is indicated by the fact that lower readings of air temperatures were obtained at Fay Terrace Edge, only 50 feet from the shore of Riceville Pond than at the Riceville Pond station (Appendix B). The effect of Harvard Pond is probably felt a little more widely, as it is larger and deeper, and does not shrink to the extent that the others do.

The Quabbin Reservoir, to the southwest of Harvard Forest only a few miles, probably has a noticeable effect, because of its vast extent and great depth, on the climate of its immediate vicinity. No observations, other than a few early-morning rapid traverses, were made which would show whether this influence extended as far as Harvard Forest; however, minimum readings taken at Swift River Power Line Crossing, which is lower than any point in Harvard Forest, but nearer to the Quabbin, were generally several degrees higher than at such places as Burns Bridge or Tom Swamp, which are similar topographically, especially Burns Bridge. This suggests either that a breeze from the lake may delay the onset and also slow the rate of the late afternoon and early evening temperature fall, or that the upper element of a local thermal circulation (land-breeze type) may bring warm air at a higher level over this area at night, thereby reducing the net outgoing radiation. In either case, the effect of the reservoir is to retard the temperature fall in adjacent areas.

g. Effect of Snow-Cover.

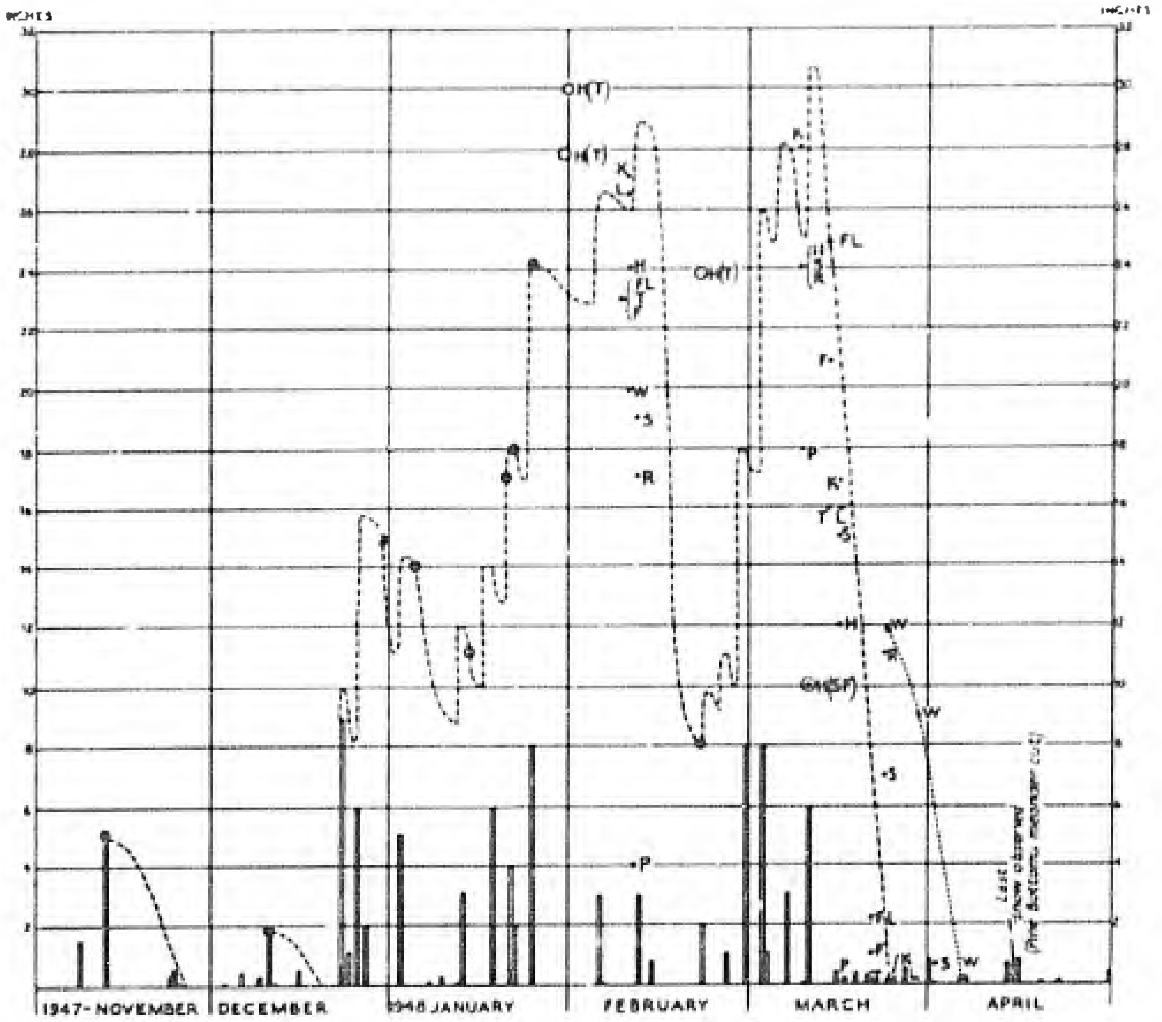
The general effect of a snow-cover is to lower air temperatures (Geiger, 1950, p. 164-165). During the winter of 1947-1948 at Harvard Forest the snow-cover was deep (Table III and Figures 93-99), and continuous cover lasted for more than 10 weeks. Air temperatures were lower than average and temperature contrasts at night were particularly large (Figure 74).

The deep snow-cover kept the ground relatively warm, however, and by the time of general snow melt, which was exceptionally rapid, in late March, the frost was out of the ground in most places. As a consequence, although melt-water runoff was great, soak-in was also great and no serious flooding occurred. Also, some insolation was able to penetrate the snow when the snow

HARVARD FOREST–PETERSHAM, MASSACHUSETTS

SNOWFALL AND SNOW-DEPTH

WINTER OF 1947-1948



KEY

DATA TAKEN FROM HARVARD FOREST HEADQUARTERS RECORDS (APPENDIX C)

Snow-depth measured at Headquarters weather station. Curved dashed line shows presumed depth at other times. Measurements made only after heavy falls or prolonged melting.

OH(T) Snow depth measured in timber stands near Headquarters.

OH(SF) Snow depth measured in south-facing open fields near Headquarters.

Snowfall, with amount as measured at Headquarters weather station.

Total Precipitation, whether as rain, or snow, or both.

DATA OBTAINED ON FIELD TEMPERATURE TRAVERSES (For Complete data see Table III)

Prospect Hill Tract

- S Spruce plantation (28 years old, pruned, canopied) Snow Station 6.
- P Prospect Hill, Summit (Open and wind-swept) Snow Station 11.
- H Prospect Hill, South Slope (Hawthorn patch) Snow Station 13.
- K Swamp Knoll, in Town Line Swamp (Open hardwoods) Snow Station 16.
- L Locust opening (Open field west of road) Snow Station 19
- R Red pine plantation (22 years old, pruned, dense canopy) Snow Station 31.

Tom Swamp Tract

- FL Fay Lot (Open, young growth, no canopy) Snow Station 49.
- T Tom Swamp (Shrub vegetation, no canopy) Snow Station 54.
- F Fisher Stand (40-year old hardwoods, thinned previous summer) Snow Station 67.

Slab City Tract

W White Pine Bottoms (70-year old stand. High canopy, 50% open) Snow Station 91. Dotted line shows presumed depth remaining during final melting period.

Figure 93

Figure 94 - Snow Cover. Spruce plantation at northeast base of Harvard Hill, after first snowfall. Looking southeast. November, 1947.

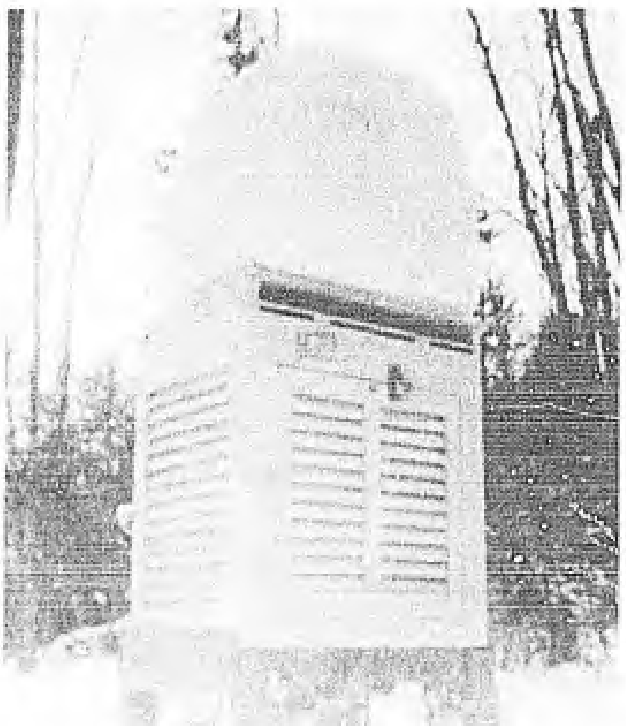


Figure 95 (left) - Snow Cover. Shelter in Transect Swale, with six weeks' accumulation of snow. Looking southwest. February, 1948.
Figure 96 (right)- Snow Cover. Fresh trail on road leading down from Choate Farm and Linden Terrace to River Meadow. Looking south. Late December, 1947.

TABLE III SNOW DEPTH MEASUREMENTS

(Percentages indicate estimate of area covered with snow.)

Snow Station Number (Fig. 97)		February 11	March 10	March 17
1	Orchard farm			
2	High Swamp Station	30 in.	28 in. (On March 3, snow was above cross-bars on shelter supports. Tramped down, and air exits tramped out to south.)	25 in. Up to cross-bars on shelter support, but bare ground under large hemlocks near road.
3	Flats near Kitchen Place	24 in.	27 in.	6 in., but bare around bushes.
4	Road south to Harvard Forest	25 in.	--	--
5	Field north of Harvard Forest Boundary	25 in.	24 in.	15 in.
6	Spruce plantation, east of road	19 in.	Under trees: 24 in. Open spots: 30 in.	Under trees: 15 in. Open spots: 24 in.
7	Road south between young plantations	25 in.	--	Patches
8	Young white spruce plantation	27 in. between trees	33 in. between trees.	28 in.
9	Open fields north of fire tower	25½ in.	27 in.	Patches
10	Approach slope to summit	Gradual decrease upslope, 27 to 6 in.	11 in. (north of tower)	Patches
11	Prospect Hill Station	4 in.	18 in.	Clear
12	Sloping field south of tower	24 in.	24 in.	25%, 4-10 in.
13	South slope, hawthorn	24 in.	24 in.	12 in.
14	South slope, trail junction	28 in.	24 in.	18 in.
15	Hemlock trail junction	21 in.	18 in.	15 in.
16	Swamp Knoll	27 in.	28 in.	17 in. on summit. Bare around tree trunks on south slope.
17	Town Line Swamp Station	25 in.	30 in.	23 in.
18	Locust Opening Station	24 in.	26 in.	15 in.
19	Open field west of station	26½ in.	--	16 in.
20	Brooks Hill	24 in.	29 in.	20 in.
21	Terrace trail to Lake Swamp	26 in.	25 in.	17 in.
22	Lake Swamp, east border	24 in.	24 in.	16 in. (estimated)
23	Lake Swamp Station	25 in.	25 in.	15 in. (estimated); bare around trunks of coppice growth in open.
24	Terrace northeast of station	24 in.	24 in.	16½ in.
25	Red pine plantation, east	20 in.	20 in.	--
26	Small upland swale	32 in.	Billowy, 18-36 in.; Avg. 26 in.	--
27	Red pine plantation, west	15 in.	--	--
28	Pin cherry, brush stand	26 in.	28 in.	21 in.
29	Red pines on west-facing slope	--	--	Clear
30	Upper millpond swale	East edge: 24½ in. West edge: 25½ in.	24 in.	East edge: 11 in. West edge: 14 in.
31	Red pines east of trail junction	17 in.	24 in.	--
32	Red pines west of trail junction	19 in.	--	--

- PROSPECT HILL TRACT - 1948

...ch measurements represent average depth. Dashes indicate no reading taken.)

March 24	March 31
Fields clear.	Fields clear.
Swamp 90% snow-covered, 10-12 in. Near shelter: 14 in. Under shelter: clear. Under white pines on west-facing slope east of shelter: clear.	Widely scattered small patches.
Fields clear. In road ruts and ditches: 6 in.	Clear
Snow in woods and shade. Field clear.	Clear
In open: clear. In shade of spruce plantation to south: 75%, 8 in.	Clear
Under trees: 6-8 in. In open: clear. Hardwood grove, southwest of road, 60%, 6-8 in.	Widely scattered small patches. In white pines, west of road: 15%, 4 in.
Patches	Clear
Small drifts between trees.	Small remnant drifts between trees.
Clear	Clear
Clear	Clear
Clear	Clear
Clear (Open south slope of Little Prospect Hill also clear.)	Clear
Not observed. Took alternate route; see below.	Clear
Not observed. Took alternate route; see below.	Clear
Not observed. Took alternate route; see below.	Small scattered patches.
Summit and west slope: clear. Hemlock grove to east; 95%, 10 in.	Clear
90%, 8 in.	Small patches in big woods on east-facing slopes, west of station.
Road from Town Line Swamp: muddy. In young hardwood stands: snow. In open spots: clear, except in patches.	Clear
Clear	Clear
Trail on east slope: 12 in.; trail on summit: 70%, 6 in.	Clear
West-facing slopes: clear; terrace top: 2%, 3 in.	Clear
60%, 4 in.	Clear
5%, 4 in.	Clear
75%, 4 in.	Clear
95%, 8 in.	--
90%, 10 in.	--
	--
In shade of red pines at south edge: 30 ft.-wide belt, 50%, 7 in. In open sunlight: clear.	-
Clear	--
Small patches, thin	--
100%, 11 in.	--
On flat terrace surface: 100%, 9 in. On west-facing slope, decreases from 6 in. at top to clear at base.	--

Figure 97 - Snow-Measurement Stations

Prospect Hill Tract.

SPECIAL TRAVERSE, March 24, 1948

From Prospect Hill westward across valley head to trail at east edge of Big Spruce Swamp, thence south on trail and southeast to Town Line Swamp:

33	Red pine plantation	Clear
34	Open clearing	80%, 6 in.
35	Close-grown spruce	Under trees, clear; in trail, 18 in. drifts.
36	Upper slope of valley	Open spots, where shaded, 80%, 8 in.; under big trees: clear.
37	Midslope terrace	6 in.
38	Lower slope, in hardwoods	Clear
39	Valley bottom	East bank, 80%, 9 in., but boulders protrude west bank, and V-notch in valley head, 75%, 12 in.
40	Gentle terrace slope west of stream, and steep slope up to Little Prospect summit	Clear
41	Hardwoods east of trail	80%, 9 in.
42	Young birch stand in old clearing on slope east of hardwoods	Clear on upper slope; thin snow on lower slope.
43	Thick stand of young sprout maple	90%, 12 in.
44	Open stand of mature maple on swamp floor, north of Town Line Swamp station	75%, 8 in.

TABLE III SNOW DEPTH MEASUREMENTS

(Percentages indicate estimate of area covered with snow.

Snow Station Number (Fig. 98)		February 9	March 15
45	Open trail on Fay Lot	24 in.	15 in.
46	Red pine plantation	18 in.	22 in. avg. (billowy)
47	Spruce trail	24 in.	--
48	Riceville Pond Station	17 in.	28 in.
49	Fay Lot Terrace Station	23 in.	25 in. avg. (16-36 range).
50	West Boundary Station	22 in.	19 in. avg. (less to west).
51	Intercliff swale	23 in.	27½ in.
52	West Terrace Station	23 in.	20 in.
53	Tom Swamp causeway	24 in.	15 in.
54	Tom Swamp Station	23 in. (Thin ice, water below)	16 in.
55	Road north to Harvard Hill	23 in.	--
56	Hemlock Base Station	23 in.	21 in.
57	Harvard Hill	25 in. (East slope)	--
58	Harvard Hill Station	23½ in.	23 in.
59	Road north to Chestnut Grove	23 in.	--
60	Chestnut Grove Station	18 in. avg. (15-26 in. range)	19 in. in timber 29 in. in clearing
61	Road east to Stream Crossing	25 in.	--
62	Stream Crossing Station	25 in.	29 in.
63	Road north to Trail Fork	23 in.	--
64	Trail Fork Station	26½ in.	24 in.
65	Road to East Hill	24 in.	24 in. on flats
66	East Hill Station	24 in.	21 in.
67	Fisher Stand Station	23 in.	21 in.
68	Gravel Hill Station	Drifts, 30 in. Shallows, 18 in.	Summit, 15 in. North slope, 6 in. South slope, 75% cover, variable depths.
69	Mill Point	Drifts, 30 in. Shallows, 18 in.	24 in.

Inch measurements represent average depth. Dashes indicate no reading taken.)

March 22	March 29
Patches, 6 in., road clear	Clear
Under trees, 3 in., road, 12 in.	Patchy, 2 in. Dead needles on top.
South-facing slopes: clear.	Clear
Scattered patches. Water up 9 in. on posts of shelter.	Clear. Water edge receded to 4 ft. north of shelter. Thin glass ice on pond.
40% snow cover, 5 in.	Clear
--	Clear
Road, 6 in. Swamp overflowing.	Road clear. Snow in woods to south.
--	Clear
--	Clear. Heat shimmer over road and swamp.
--	Clear. Thin glass ice on pond.
--	Clear
5% snow cover, 3-5 in. (Air warm)	Clear
East slope: 10% cover, 6 in. North slope: 95% cover, 12 in. West slope: open hdwds, 95%, 12-14 in.; dense hemlock, 20%, 2-3 in.; open hemlock 60%, 9 in. Southwest slope: open scrub clear.	East slope: clear. North slope, lower half: 4 in. (estimated).
Clear	Clear
14 in.	Small patches in shaded spots.
10-12 in. (air cool)	Clear, except patches.
	Clear
90%, 10 in. Stream out of banks.	Small patch to west. Bridge passable.
12 in. Stream up to bridge floor.	Clear. Stream down 18 in. from bridge floor.
North slopes: 60% snow cover, 5 in. South slopes: clear.	Clear
Scattered shallow patches.	Clear
Patches. No snow in timber to east.	Clear
Scattered patches. Numerous streams, flowing sheets of water.	Clear
Northeast slope and road trough to northeast: 75%, 6-8 in. Northwest slope: clear. South slope: clear	Clear, except for small patch in road trough to northeast.
30% snow cover, 4 in. More to north; less to south.	Clear. Harvard (Brooks) Pond 75% clear of ice.

Figure 98 - Snow-Measurement Stations
Tom Swamp Tract.

(Percentages indicate estimate of area covered with snow.

Snow Station Number (Fig. 99)		February 10	March 23
70	**Hickory Hill Station**	23 in.	10% snow cover, 6 in. Open areas on south slope: clear.
71	**Hickory Hill Junction Station**	23 in.	15%, 6 in., clear near station.
72	**Shelf Swamp Station**	23 in. but with bare ice on pond.	Clear in open. Snow in hemlock grove; air in grove 6°F cooler. Hardwood grove to south: 90%, 10 in.
73	**Road south to Wildcat Hill**	23 in. in woods	Cutover south slopes clear.
74	**Portal Swamp**	25 in.	Cliff-shaded road north: 100%, 18 in. At station: 85%, 12-24 in. Road southwest: 75%, 6 in.
75	**Wildcat Hill and Station**	Northwest slope: 18 in. In woods at summit: 15 in.	Northwest slope: Lower third, near road, 35%, 4 in. Thins upslope; upper third, clear. Summit woods: 15%, 8 in; water in hollows. In open, near station: 25%, 6 in. to west, but clear at edge of cliff. Northeast slope, above Portal Swamp: 50%, 10-20 in. Southwest slope: clear.
76	**Cave Road Swamp**	12-30 in. (avg. 22 in.) Billowy.	Clear. Water high. Southeast slopes of ridge on west: 40%, 6-12 in.
77	Road south to Linden Terrace	24 in. on upper levels. 22 in. on southeast slopes.	Upper levels: clear. Southeast slopes: clear. Northeast slopes: 50%, 4 in.
78	Linden Terrace Station	23 in.	20%, 4 in.
79	Road down to old barn	On flats: 24 in. On slopes: 23 in.	Avg. 50%, 4-6 in. High water in Hidden Swamp. Pine plantations: 90%, 6 in.+.
80	Coach Road Station	23 in.	Clear
81	Slope down to Hidden Swamp	24 in.	50%. Thin.
82	River Meadow	23 in.	Clear with wet spots. River high.
83	Connor Farm	General snow cover.	Timber: 50% snow cover. Fields: clear.
84	Trailside Swale Station	23 in.	100%, 14 in.
85	Hemlock Knoll Station	Summit: 18 in.	East base: 100%, 12 in. Thins upslope. Midslope: 70%, 7 in.; summit, clear. West slope: 5%, 3 in.
86	Pine and Hemlock Terrace	20 in.	95-100%, 10 in. or more. Deeper on road.
87	Transect Knoll	20 in.	Summit: 80%, 10 in. West slope: 10%, 2 in.
88	Road through hemlocks at transect	15 in.	Clear
89	Transect Swale	25 in.	25%, 7-15 in. (avg. 10 in.)
90	Base of steep slope to Pine Bottoms	18 in.	100%, 15 in.
91	White Pine Bottoms Station	20 in.	100%, 12 in.
92	South Boundary Station	23 in.	Clear in open
93	Burns Bridge Station	23 in.	Clear

. SLAB CITY TRACT - 1948

Inch measurements represent average depth.)

March 30	April 6	April 13
Clear		
Clear		
Clear in open, with high water. Snow patches under hemlocks.		
Clear		
Clear, except in deep shade.	Snow patch at entrance to Cave Road.	
Clear, except on north slope.		
Clear		
Clear		
Clear		
Clear		
Clear		
Clear		
Clear		
Clear		
65%, 6 in.+.		
East slope, upper half: clear. West slope: clear.		
Clear		
Clear		
Clear		
15%, 6 in.+.	Snow in patches shaded by hemlocks.	
Deep snow in shaded meander cut, to south.	Snow in shaded meander cut.	Small remnant of snow in shaded meander cut.
90%, 6-12 in.	Clear	
Clear		
Clear		

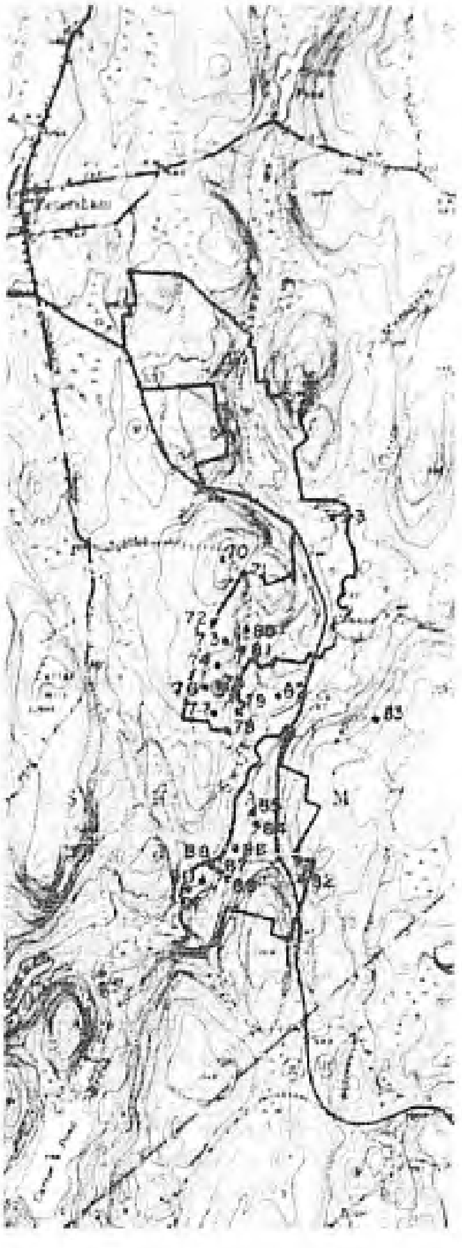


Figure 99 - Snow-Measurement Stations Slab City Tract.

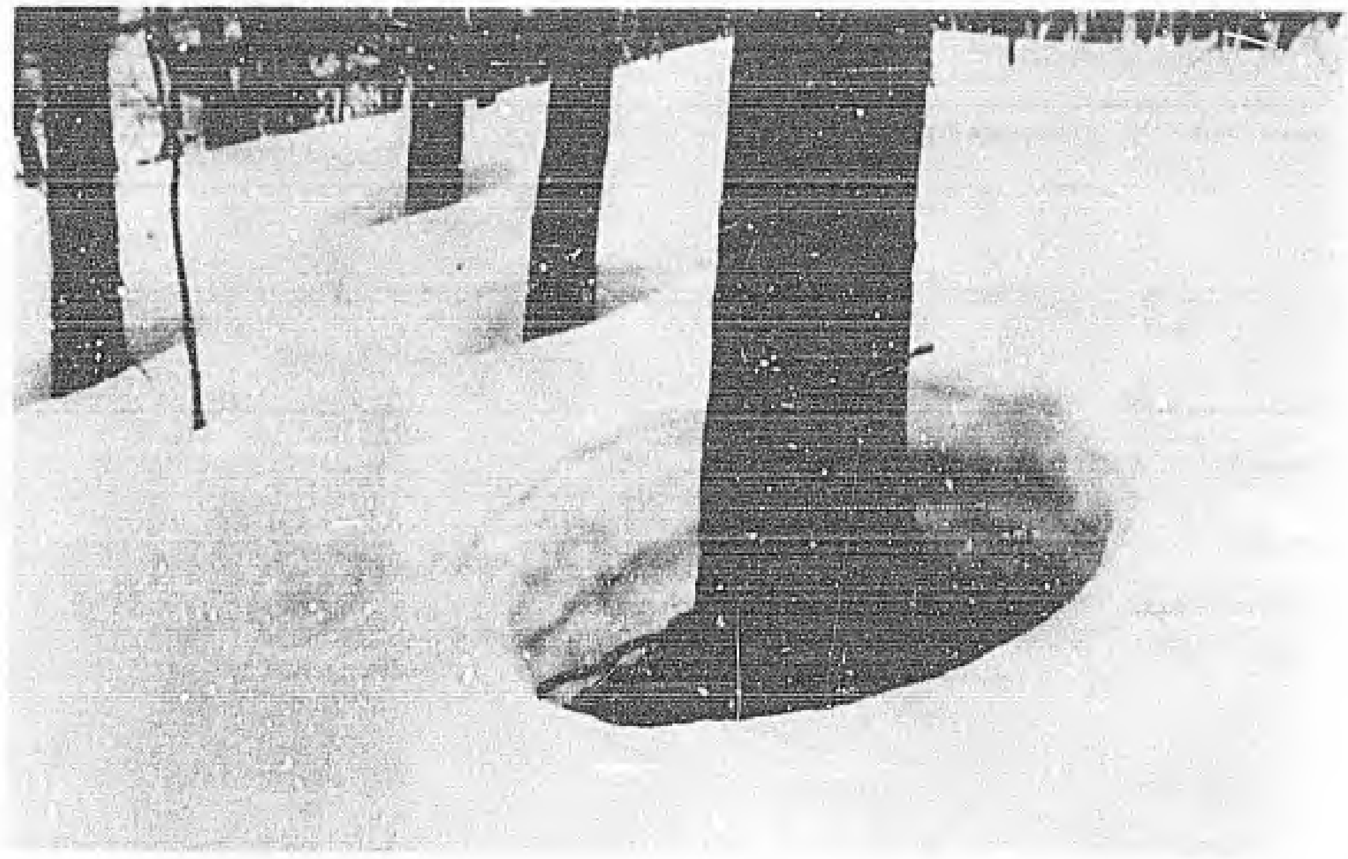


Figure 100 - Melt rings around trees on south slope of Town Line Swamp Knoll. Looking west toward swamp floor. March, 1948.

was no longer more than a few inches deep; and because the ground was warm almost everywhere, spring plant growth began virtually simultaneously throughout Harvard Forest, except in the most heavily wooded sections. Thus the deep snow-cover had a generally benign effect upon the forest, despite the lower air temperatures associated with it.

Had the winter been warmer or less snowy, with possibly some open periods, it may well have been that the local contrasts in depth and duration of snow-cover might have caused much greater local contrasts in temperature conditions for plant growth. During a more open winter, snow-cover would have disappeared occasionally on south and southwest-facing slopes, but would have remained for longer periods, or even continuously, in shaded locations. The ground on the south and southwest slopes would have been affected in somewhat the manner of horizontal ground in more southern regions of abundant winter rain and little snow (which have a C climate in the Koeppen classification). Although receiving more heat by day, the soil on these slopes might have cooled excessively at night, because no snow blanket was present to minimize radiational heat loss. This would have tended to result in some alternate thawing and freezing near the surface. The soil temperature would probably have averaged lower than on other sites where a snow cover remained. As a consequence, the period of dormancy would have been extended somewhat longer into spring, until general frost danger had become less. In this way the apparent great hazard introduced by lack of snow-cover might have been lessened by the lower soil temperatures. As has been seen, however, in most winters at Harvard Forest, all areas will have snow-cover most, if not all, of the time.

In general, early winter snow depths were considerably greater in open areas than in the woods (Table III). Accumulation in mature coniferous stands was very slow, but steady. Subsequently, snow accumulated to great depth in the space between the trees, although the average depth per acre was probably no greater than in the young hardwood stands. Lutz and Chandler (1942, p. 270) state that snow depths average deeper in hardwood stands than in coniferous stands, and that soil temperatures consequently become lower in the coniferous stands. In young coniferous stands, however, the snow could reach the ground rapidly and even in early winter had buried the lower branches of the trees.

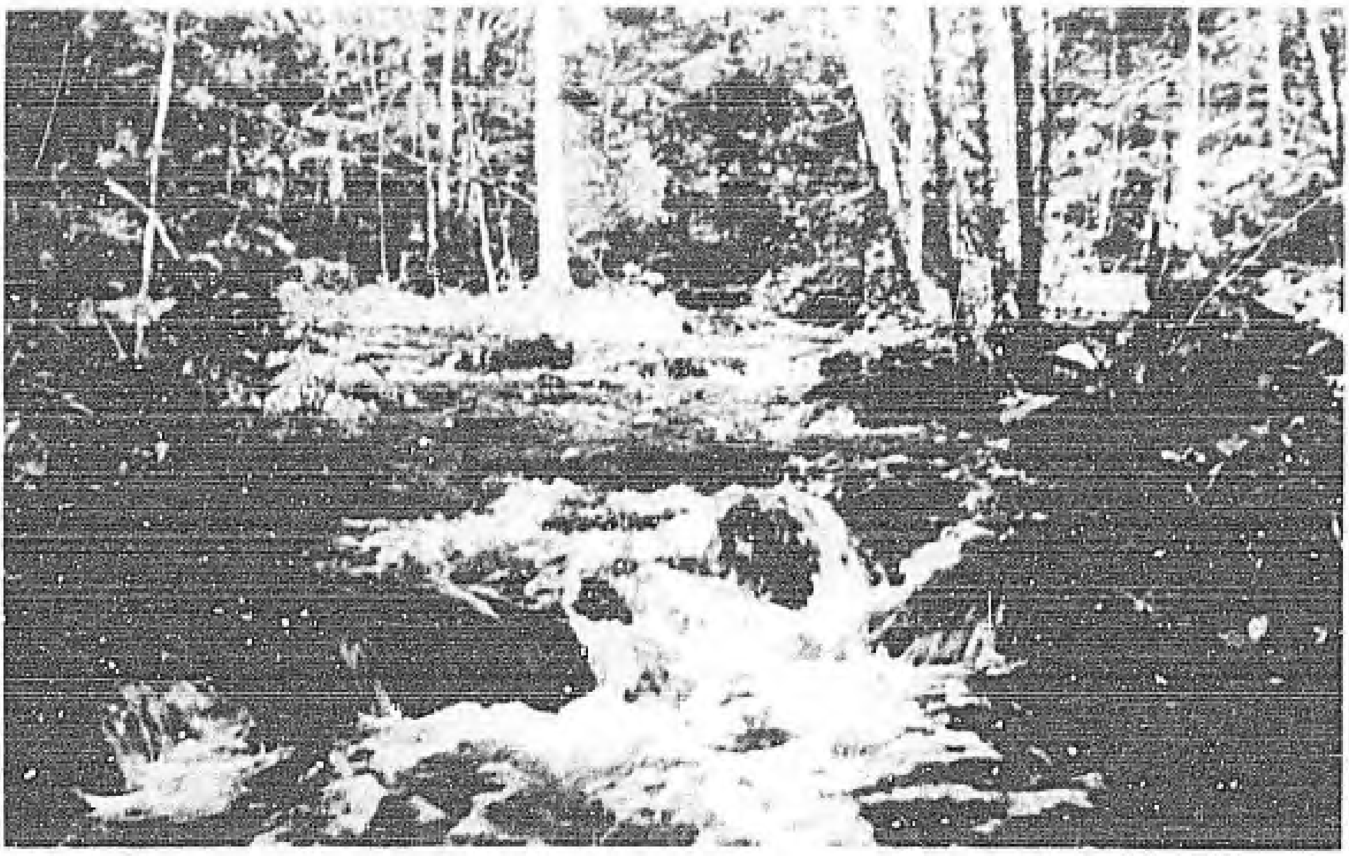


Figure 101 - Stream in full flood, draining Compartment V Swale, in Tom Swamp Tract. View is upstream from point near stream's entry into Harvard Pond. Looking east. Early April, 1948.

In the deep woods at Harvard Forest, daytime melting and sublimation of the snow did not occur to nearly the same extent on the ground that it did in the tree tops or on the ground in open, sunny places (Figure 100). Consequently, by late winter the total snow depth in many wooded areas (Figure 95) was comparable, except in the dense-canopied coniferous plantations, to that in most open areas, or was even greater. Diebold (1938, p. 1131 ff.) reports that near Ithaca, New York, late winter snow-cover was deeper in hardwood stands than in the open, also that the snow lasted longer there than in the open, and that it kept the ground in the woods unfrozen.

In spring the snow-cover disappeared first on exposed south and southwest slopes, and soon thereafter on east and southeast slopes and open flats. Hardwood stands, though leafless, retarded the snow melt slightly, and coniferous stands much more. Runoff was rapid (Figure 101) but very few areas were flooded, and those neither extensively nor for any very long periods.

The snow-cover lasted longest in the shady pockets in deep valleys and on north slopes. The heavily wooded lower Swift River Valley in the Slab City Tract, for example, retained a deep snow-cover for several weeks after snow had disappeared almost everywhere else. The last remnant patch seen in Harvard Forest was under a steep north-facing bank at the edge of the White Pine Bottoms. Kittredge (1948, p. 145), reports snow melt being retarded as much as six weeks by forest cover, with retardation increasing with increase in density of the canopy.

The temperature tables and Figure 74 indicate the marked rise in temperatures at the time of the spring melt. Seasonal temperature change and snow melt have a reciprocal relationship in which both are partly cause and partly effect. After the snow melt, however, temperature fluctuation was much greater than when a snow-cover was present. This was owing to the increase of maximum air temperatures, no longer held to near freezing by the great heat loss attending the conversion of snow to liquid or vapor on warm days. This greater range upward, however, was offset somewhat by the lesser range downward. Because of the absence of snow, the minimum temperatures, when they were above freezing, were no longer drawn down to freezing, as they would have been even on mild nights had a snow cover been present, nor were they drawn down to even lower temperatures by excessive radiational cooling of the snow surface as had been common on clear, still winter nights.

4

h. Summary.

From the foregoing discussion of factors causing temperature diversity within Harvard Forest it is evident that few, if any, recognizably contrasted places in a given region are likely to have the same temperature regime. At the same time, it is evident that places having essentially the same site factors will have similar temperature regimes, even though such places may be widely separated. Because various site factors have differing effects at different seasons, it is also evident that the temperature contrasts between any two stations will change from season to season unless all site factors are the same at both places. In some cases, however, because some of the site factors tend to counter-balance each other, places with very different combinations of factors might have essentially the same temperature regime. A careful analysis of the site factors at a given place should permit an approximately correct decision as to the probable temperature pattern of that place, particularly if adequate consideration is given to the seasonal change in the relative influence of each factor.

6. Temperature-Rank Scales. (Figures 102 to 106.)

In this section the temperature stations maintained at Harvard Forest are ranked according to minimum temperatures and according to maximum temperatures. These rank lists provide an approximate scale for purposes of comparison.

The charts accompanying this section set forth the approximate temperature rank for each Harvard Forest temperature station for every month during which such station was operated. The maximum-temperature scales were constructed by a slightly different method from that employed for constructing the minimum-temperature scales, but the systems used were essentially similar. Numerical examples showing the method employed are given on the title pages of Appendixes D, E, and F. The ultimate purpose in each case was to provide a scale extending from the warmest to the coolest conditions in Harvard Forest and to place every station in its approximate position on that scale.

a. Method of Determining Minimum-Temperature Ranks.

It will be seen that on the minimum-temperature rank charts (Figures 102 to 105) the stations are classified on a scale of 10. No intermediate places are assigned. If, for example, a station's monthly average of weekly minimum temperatures was anywhere in the upper 10 percent of the range between the monthly average of the highest weekly minimum temperatures and the average of the lowest weekly minimums (regardless of where read in the Forest), such a station was given a rank of 1. If its average placed it anywhere between 31 percent and 40 percent inclusive, it was given a rank of 4. A station with an average falling anywhere in the lowest 10 percent of the range (that is, from 91 percent to 100 percent), would have a rank of 10.

Obviously, the most desirable procedure would have been to take all readings on the same day each week, covering the same preceding seven days, and then determine a monthly mean of the weekly readings. In practice this was not possible. Not all the stations could be reached on one day. Readings taken on different days did not always give minimum temperatures occurring on the same night, or maximums which had occurred on the same day. Consequently, in arranging the stations in order of relative coldness, a somewhat subjective process was used. First, in the case of minimum temperatures, it was determined which weekly series of readings represented conditions occurring on the coldest night (or at least during the same coldest period). This was determined by analysis of available thermograph records. For some months, notably January and July, the readings taken each week, regardless of the day on which taken, formed a single comparable series for that week. In other months the readings taken on different days of some weeks were not comparable, but some ranking could still be done for some stations on the basis of each day's series of readings. In some weeks, two successive days' readings would form a single series, and the third day's readings would tie in with those taken on the first day of the following week. By use of such partial series, it was possible to arrive at a reasonably satisfactory approximate ranking of all stations in the network. The procedure might be likened to that used in matching overlapping partial sections of varved clays or tree-ring spectra.

As was described in Section 1, of this chapter, weekly readings give a useful approximation to the minimum-temperature rank of stations but do not always give the precise relative placement. It is apparent, therefore, that even a simple scale of 10, as used here, suggests a greater

APPROXIMATE RANK OF MINIMUM-TEMPERATURE STATIONS (INSTRUMENTS IN SHELTERS) ACCORDING TO MONTHLY AVERAGES OF WEEKLY MINIMUM TEMPERATURES

Scale is in tenths of the monthly total of weekly ranges between least cold and coldest stations. Warmest stations are in rank 1; coldest stations are in rank 10. For tables, see Appendix E.

Rank	1947 Aug	Sept	Oct	Nov	Dec	1948 Jan	Feb	Mar	Apr	May	June	July
1	HH OH EH	HH OH EH	HH EH	HH EH	PH WH EH WB HH LO	PH	PH	PH HH EH WH WB	PH HH	PH EH	FH LP	PH LP LSH
2	TF MP	TF MP			HHJ TF	HH LO WH WB EH	WH HH LO	LO	EH WB	HH WB LO WH HF TF	WH WB LSH	WB HH OH
3			TF OH	TF OH HF	FS HS	TF HHJ HS	HHJ WB EH	HHJ TF FS	TF	FS OH NHJ	EH HH NWM OH TF	EH TF HF MP WH NWM
4		HB		MP	HF OH LS	TLS HF FS	TF HS HF	CO	OH WH LO FS HHJ CO	CO MP LS	HF LS FS HHJ MP LO	HHJ LS LO FS
5	HB	HF	MP		SB MP HB TLS SS	CO LS	LS TLS CO FS	HS HF TLS	HF MP HS	HS TLS SS	CO HS TLS	HS TLS BSS CO NBF
6	HF			HB	HK CR TactS	OH SB SS HB CR HK	SS SB	BB SS OH LS TadeS SB HK	WPB HB TadeS	HB	SB TadeS	SB TadeS WPB HK
7			HB		WPB	WPB TactS MP	HB OH HK CR	WPB TactS CR	LS TLS HK RP TactS	HK TadeS RP SB WPB	WPB RP HK TactS	RP SS TactS HB
8			HF		SC	FLT	TactS WPB MP	MP SC	SB SS SC	TactS SC	SS CR	CR SC
9				SC	FLT	SC	FLT SC	FLT BB	CR BB RM	CR	RM SC HB BB	BB RM FLT
10	TS	TS	TS SC	TS	TS WT RM RP BB	WT RM RP TS BB	WT RM BB RP TS	TS WT RM RP	FLT TS WT	FLT WT TS BB RM	FLT TS WT	WT TS

Figure 102

APPROXIMATE RANKS OF SHELTERED STATIONS ACCORDING TO AVERAGES OF WEEKLY MINIMUM TEMPERATURES

Scale is in tenths of total of weekly range between least cold and coldest stations (1 = highest 10% of range; 10 = lowest 10% of range)

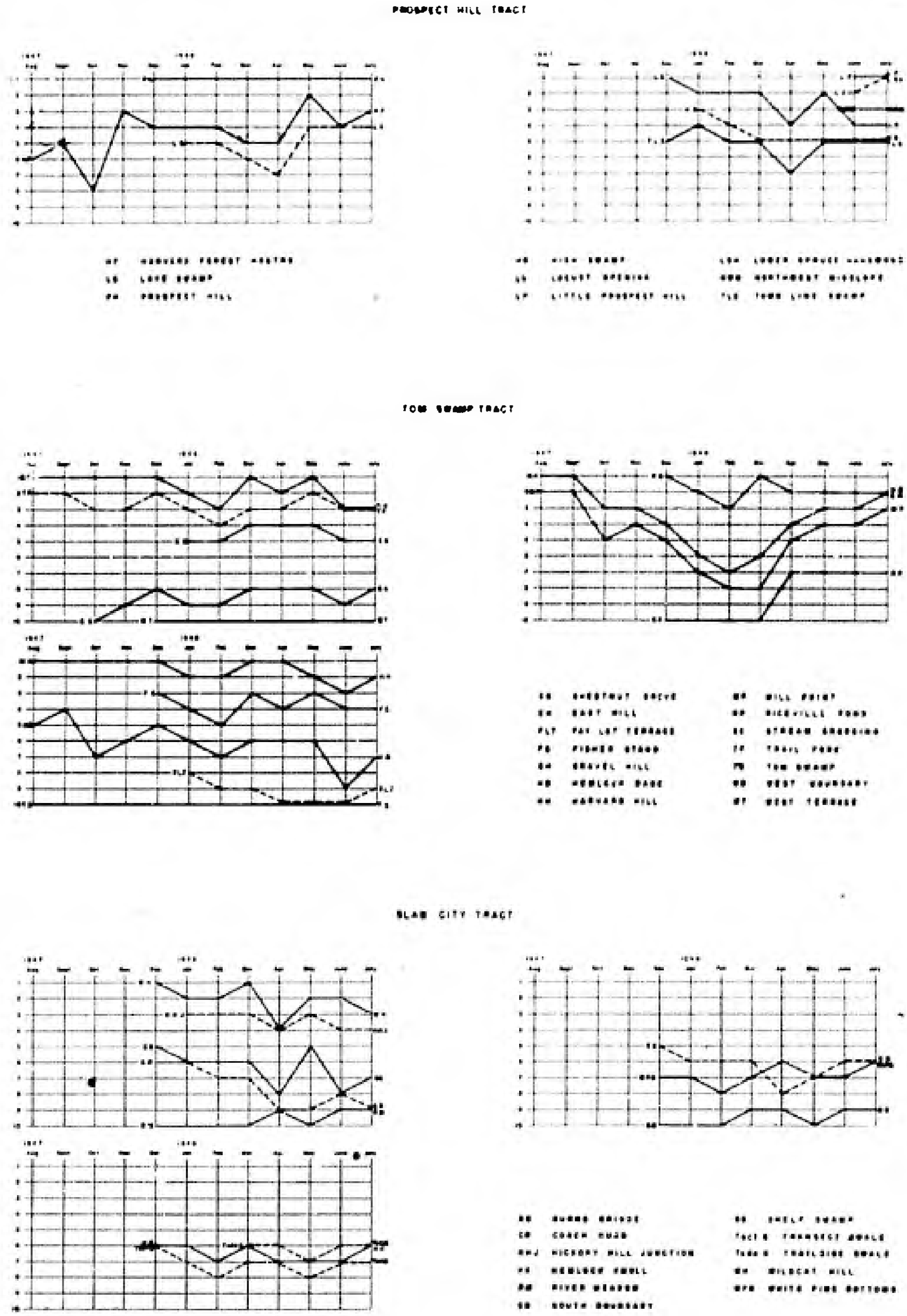


Figure 103

degree of comparability in the data than is actually present. A scale with only five categories, however, would obscure many of the fine distinctions which the weekly readings suggest and which daily readings from thermographs indicate.

The reason for setting up a relative scale of 10 rather than giving actual means in degrees Fahrenheit lies in the variability of conditions in the same month during succeeding years. A degree scale for, say, November of a given year would not be usable for a much warmer or colder November, with either smaller or larger temperature contrasts the following year, but the relative rank of stations on a scale of 10 from warmest to coldest could reasonably be expected to be comparable for each year (Figure 73), making due allowance for progressive changes in site factors.

b. Comparisons of Minimum-Temperature Ranks of Sheltered Stations (Figures 102 and 103.)

Keeping in mind the limitations inherent in the data, and the possibility that for some months some stations may have been ranked a step too high or too low, one notes that many of the sheltered stations, nevertheless, display a considerable consistency of placement with respect to one another, season by season, and in many cases month by month. Thus, Prospect Hill, Harvard Hill, and Brooks Hill are quite consistently the warm stations, while Tom Swamp, Burns Bridge, and River Meadow are consistently very cold. Other stations show reasonably consistent placement at intermediate ranks. Thus, the West Boundary station ranks near 2, Trail Fork usually at 2 or 3, Fisher Stand at 3 or 4, Chestnut Grove at 4 or 5, and Town Line Swamp (somewhat less consistently) at 5. The wooded stations in the Slab City Tract (Trailside Swale, Hemlock Knoll, Transect Swale, and White Pine Bottoms) average between 6 and 8. Fay Lot Terrace is slightly less cold in winter (8 to 9) than Tom Swamp (10), but just as cold in spring, (both 10). It also is warmer than its neighboring station on Riceville Pond shore in winter, but is several steps cooler from April to July.

Perhaps the most striking change in relative minimum-temperature rank is exhibited by Mill Point and Gravel Hill, where summer nights are kept warm by Harvard Pond, but where winter nights are almost as cold as at other valley-bottom stations. The hardwood forest on Mill Point, plus some possible slight heat still coming up through the pond ice, keeps it slightly warmer than Tom Swamp. Gravel Hill, which is 50 feet higher than Mill Point and is a convex surface, averages one to two ranks warmer throughout the year, even though it too lies deep in the cold-air lake formed during each inversion.

c. Comparisons of Minimum-Temperature Ranks of Nonsheltered Stations (Figures 104 and 105.)

The charts constructed for the nonsheltered minimum-thermometer stations indicate a consistency similar to that of the sheltered stations. These charts were cross-checked with those for the sheltered stations for all places where both a sheltered and a nonsheltered minimum thermometer were installed, and are all, therefore, on the same scale. As has been described previously in Chapter III, the two installations at each station were not exactly at the same spot, hence the readings from sheltered and nonsheltered instruments differ slightly, particularly for stations in hollows, such as at Shelf Swamp, or on flats, as at Locust Opening. On well-ventilated hilltops, however, the readings were usually identical or nearly so.

It is interesting to note that open, upland concave areas, such as High Swamp, Cave Road Swamp, and Shelf Swamp, are relatively higher in rank in winter than in summer. The explanation probably lies at least partly in the fact that vegetation at the exits from these areas, being in leaf during summer, provides more effective dams against air drainage.

d. Comparisons of Maximum-Temperature Ranks (Figure 106.)

As has been emphasized previously, weekly maximum temperatures are considerably less reliable than daily maximum temperatures for determining the relative rank of stations. An order of maximum-temperature rank for a given month of one year might be only partially comparable with the order for the same month in following years. For this reason no rank scales on a basis of 10 steps have been attempted here. The stations were arranged in order of decreasing warmth, however, by the same procedure outlined for minimum temperatures and are so shown in Figure 106. A monthly mean of the highest maximums recorded for each week was computed (or estimated, if not all weeks had comparable series), and a monthly mean was determined for each station. The stations are arranged on the chart according to their approxi-

APPROXIMATE RANK OF NONSHELTERED MINIMUM-THERMOMETER STATIONS ACCORDING TO AVERAGES OF WEEKLY TEMPERATURES

Scale is in tenths of monthly total of greatest weekly ranges between least cold and coldest stations. 1 = warmest stations; 10 = coldest stations. For tables, see Appendix ?

	1947 Aug.	Sept.	Oct.	Nov.	Dec.	1948 Jan	Feb.	Mar.	Apr.	May	June	July
1			PH BH	PH Soü BH	BH PH LO	PH BH LO	PH BH LO	PH BH H1H LO	PH H1H	PH LO	PH	PH
2				H1H LO	CRS CFH	H1H	H1H		BH	BH H1H	BH	
3		H1H FS	H1H LO		RFR H1H	RFR CRS		CRS	RFR CRS LO	CRS RFR	LO	BH LO
4		RFR	RFR	CRS RFR	FS SS	SS	SS RFR CRS	RFR SS		SK SS	CRS H1H	
5		CFH HD	CRS FS	SS FS CFH	HD	HD FS CFH	CFH FRS		CFH WAS SS	WAS	SK	CRS RFR SK
6		HD	HD	FRS	FRS				FS FRS	FRS TK	RFR WAS FRS	WAS
7			CFH HD	HD					SK TK		SS TK	FRS TK
8					PLC					MPF FS	FS	
9		BB	PLC	PLC		PLC		BB	BB MPF LT	LT	LT	FTK LT
10			BB	BB	BB	BB	BB			BB	BB	

Figure 104

APPROXIMATE RANKS OF UNSHELTERED STATIONS
ACCORDING TO AVERAGES OF WEEKLY MINIMUM TEMPERATURES

Scale is in tenths of total of weekly range between least cold and coldest stations.
(1 = highest 10% of range; 10 = lowest 10% of range)

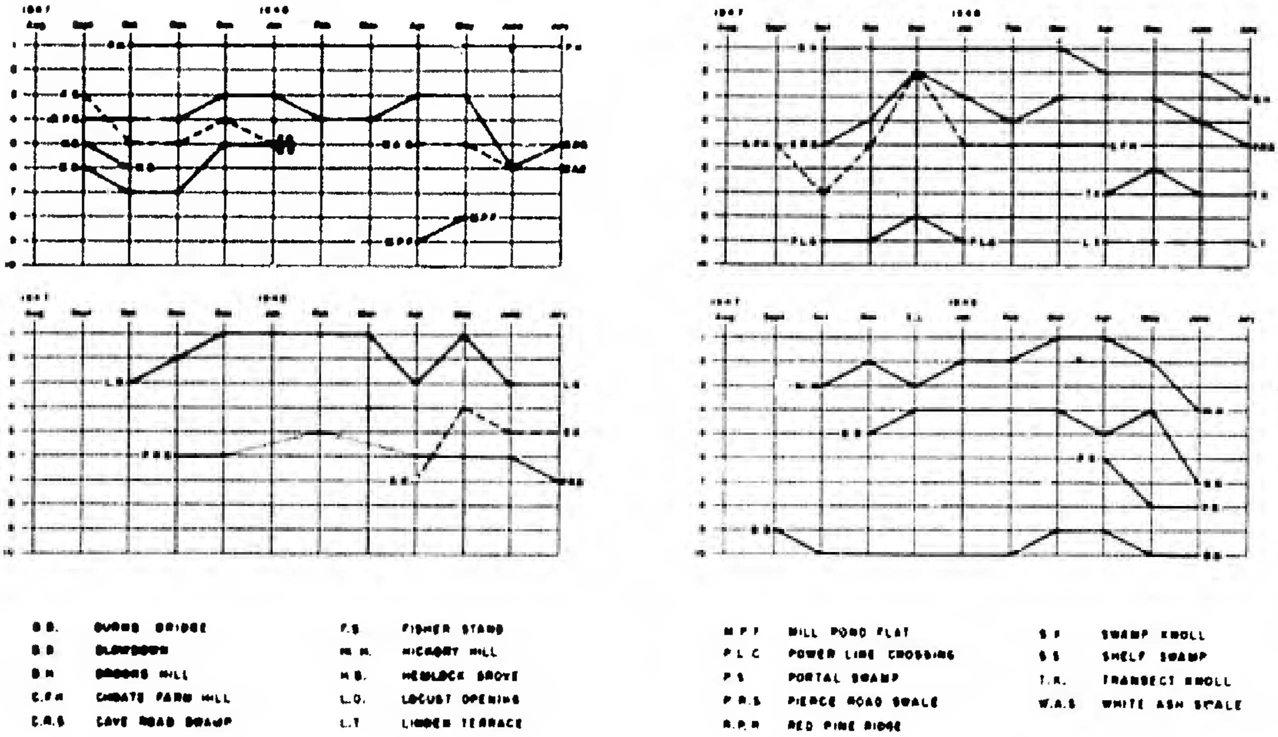


Figure 105

mate deviation from the mean of the highest weekly readings. This deviation is shown in Fahrenheit degrees.

Such a chart shows at a glance the greater diversity characteristic of summer months and the small diversity during winter months. To be sure, this chart does show the relative position of each station for each month also, just as the minimum-temperature rank charts do, but on a varying scale. In its entirety it gives a general picture of seasonal contrasts in the diversity of maximum temperature. Its limitations must be kept in mind, however, when the month-to-month temperature pattern of any single station is examined. The greater diversity in summer is largely a consequence of trees being in leaf. Places in the forest remain cooler than places in the open. In winter, when the trees are bare, and particularly when snow covers the ground, diversity of maximum temperatures is much smaller. This is in direct contrast to the diversity of minimum temperature, which is greater at all seasons than that of maximum temperature and is especially great during the winter months.

APPROXIMATE MAXIMUM TEMPERATURE RANK OF SHELTERED STATIONS ACCORDING TO AVERAGES OF WEEKLY READINGS ON MAXIMUM THERMOMETERS

Stations are arranged in approximate descending order of warmth. Degree scale indicates approximate difference between monthly mean for each station and monthly mean of highest recorded weekly maximums

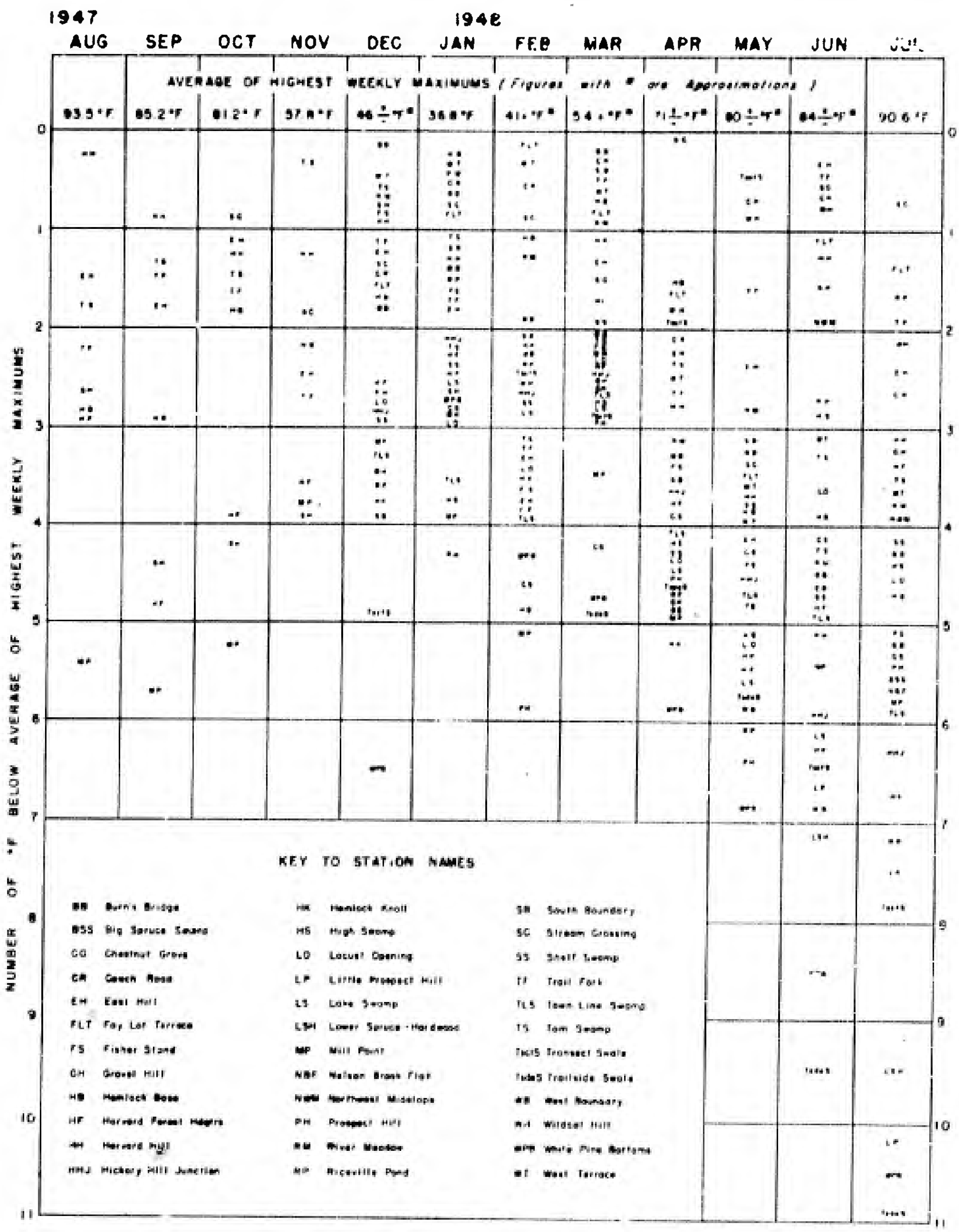


Figure 106

7. Frequency Distributions.

Discussion of temperature-rank scales, in the preceding section, was based primarily on readings taken once weekly. Discussion here, of frequency distributions, is based upon daily readings of maximum and minimum temperatures, and indicates the great amount of additional information derivable from such more numerous and more readily comparable data.

The distributions are shown graphically in Figures 107 and 108. Figure 107 shows the frequencies of daily maximum temperatures, plotted on a seasonal basis for all four seasons, for Harvard Forest Headquarters, Harvard Hill, and Tom Swamp. It shows, also, the spring-season frequencies at Prospect Hill and White Pine Bottoms. Figure 108 shows minimum temperatures plotted similarly. Data for the Headquarters station are from maximum and minimum thermometers read at about noon or shortly afterward. Data for all other stations are from the thermograph traces read for each 24-hour period ending at 1800 h. This hour was chosen because the temperature was usually intermediate and falling at that time. This assured a high degree of likelihood that the greatest true range between the temperature trough and crest for a given daylight period would be read for that day.

a. Frequencies of Daily Maximum Temperatures, by Seasons (Figure 107).

In general, all stations exhibit a considerable similarity in frequency distributions of daily maximum temperatures for each season. In summer the distribution is compact and quite uniformly grouped around a high mode. Autumn is a season with much less uniformity, a wider range and more than one mode. In general, three groupings are apparent for autumn, consequent upon markedly different weather each month. In winter the grouping is more compact again, with a slight skew toward the lower temperatures and a single high mode at about 32°F. The Headquarters chart shows two similar modes, one at higher and one at lower temperatures than those of the two other stations, but this may be a consequence of the different reading procedure at the Headquarters station, described above. The spring charts show as great a diversity as the autumn charts, but show a more definite concentration around a single mode or group of modes and a skew toward the higher temperatures. Not all the stations are alike, however. Harvard Hill and Tom Swamp, in the lowland, are the warmest; Harvard Forest Headquarters is almost as warm; but Prospect Hill is notably cooler. These differences are expressions of the normal and superadiabetic lapse rates frequently evident at the lowland stations. Maximums at White Pine Bottoms, however, are as low as those at Prospect Hill, indicating the influence of a dense forest canopy in neutralizing normal temperature decrease between a forested valley station and an open hill station.

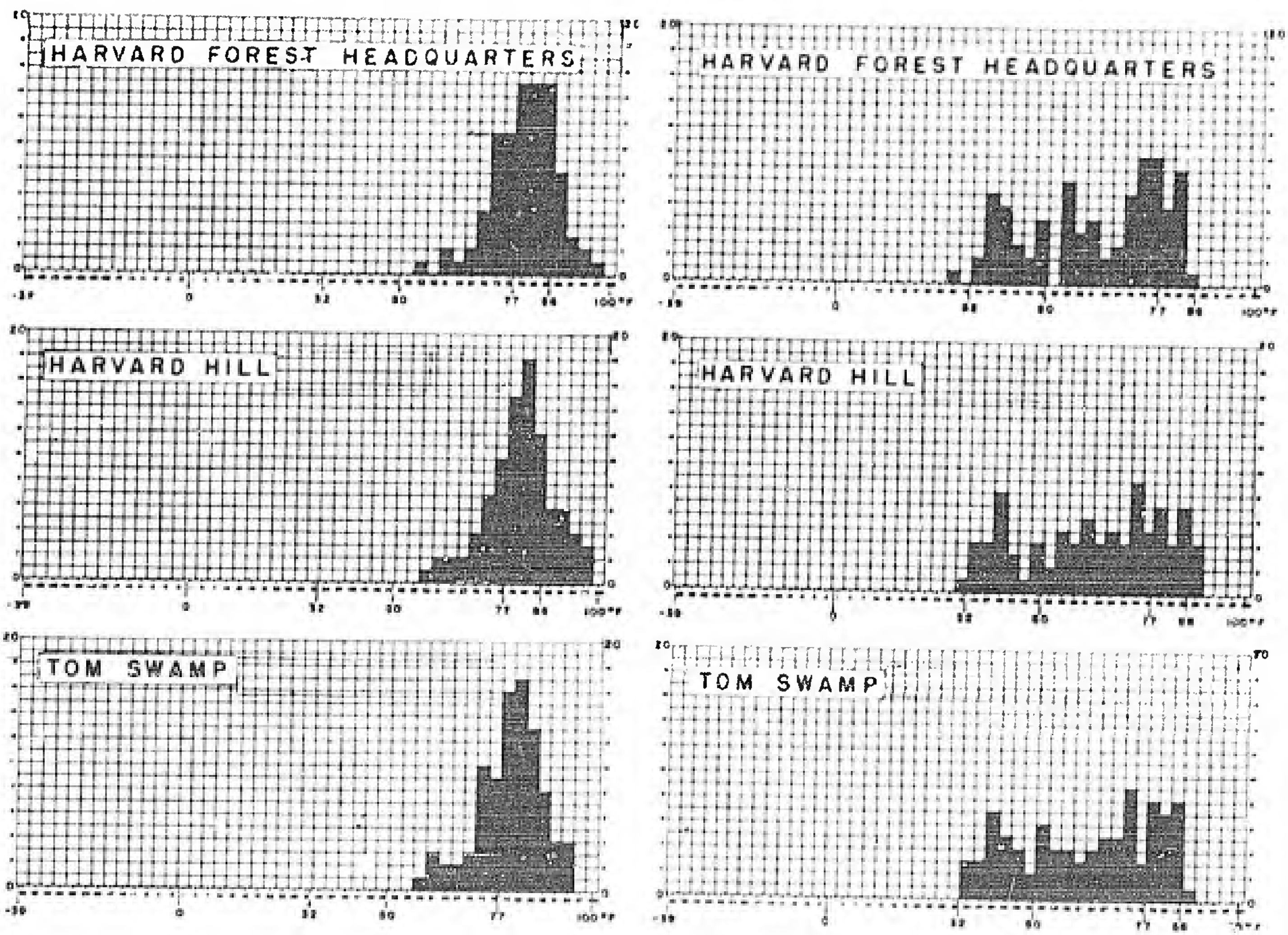
b. Frequencies of Daily Minimum Temperatures, by Seasons (Figure 108).

The frequency patterns of daily minimum temperatures differ markedly from the patterns of maximum temperatures, and for each season they exhibit a considerable individuality for each station. For summer, all stations have a compact grouping. Each station has one mode at or near 58°F, representing generally comparable conditions during periods of low-pressure weather. The Headquarters station also has a close grouping around 52°F, as does Harvard Hill. In contrast, Tom Swamp has its lower mode at 46°F; this is an expression of the frequent clear-night inversions common in summer as well as in the other seasons.

HARVARD FOREST — PETERSHAM, MASSACHUSETTS

FREQUENCIES OF MAXIMUM TEMPERATURES

SUMMER (June and July 1948; Aug. 1947) AUTUMN (Sept., Oct. and Nov. 1947)



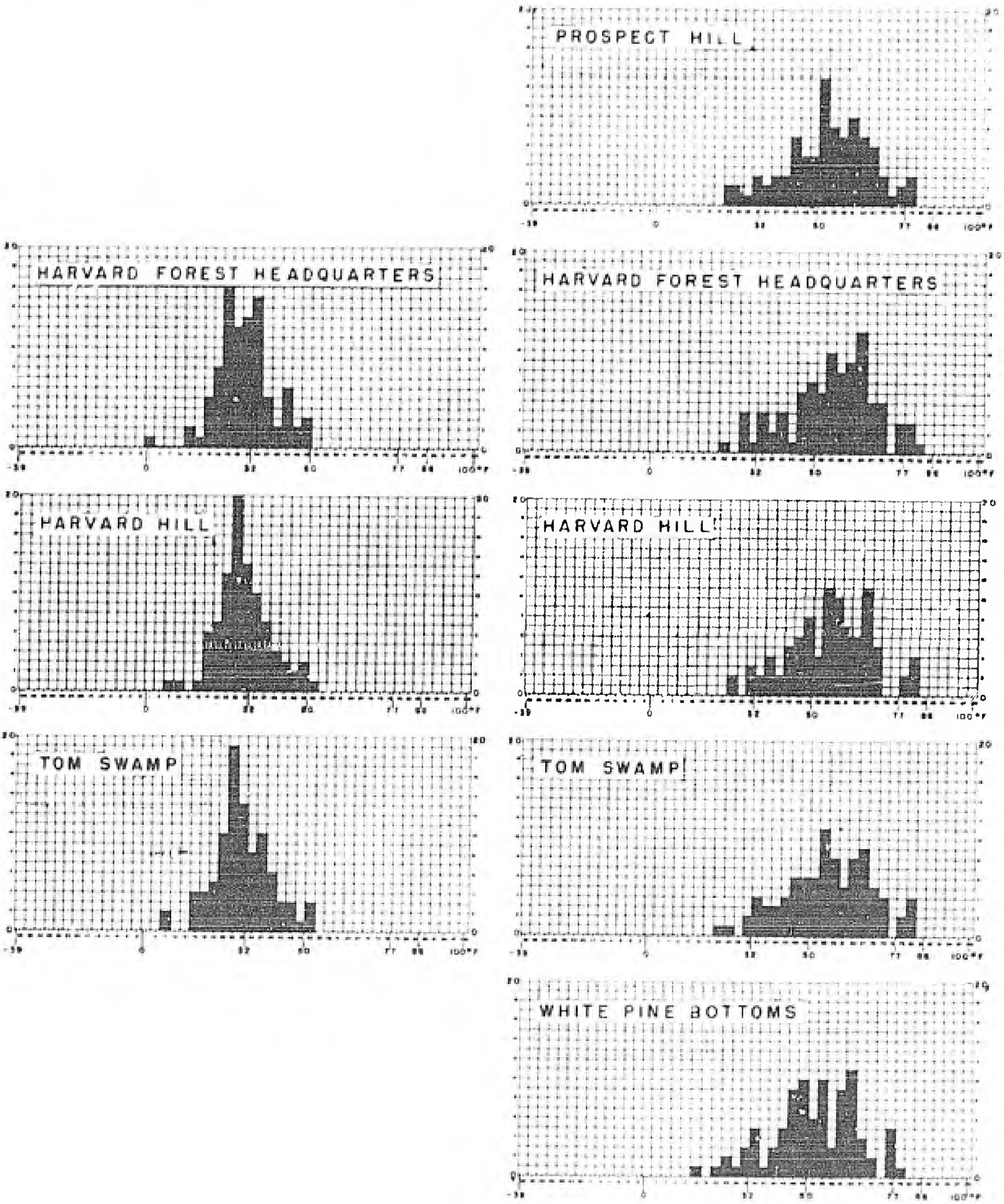
Each column on each diagram includes all readings in a 3° grouping, for which the central value is shown in °Fahrenheit at the base of that column.

Figure 107

HARVARD FOREST – PETERSHAM, MASSACHUSETTS

FREQUENCIES OF MAXIMUM TEMPERATURES

WINTER (Dec. 1947; Jan. and Feb. 1948) SPRING (Mar., Apr. and May 1948)



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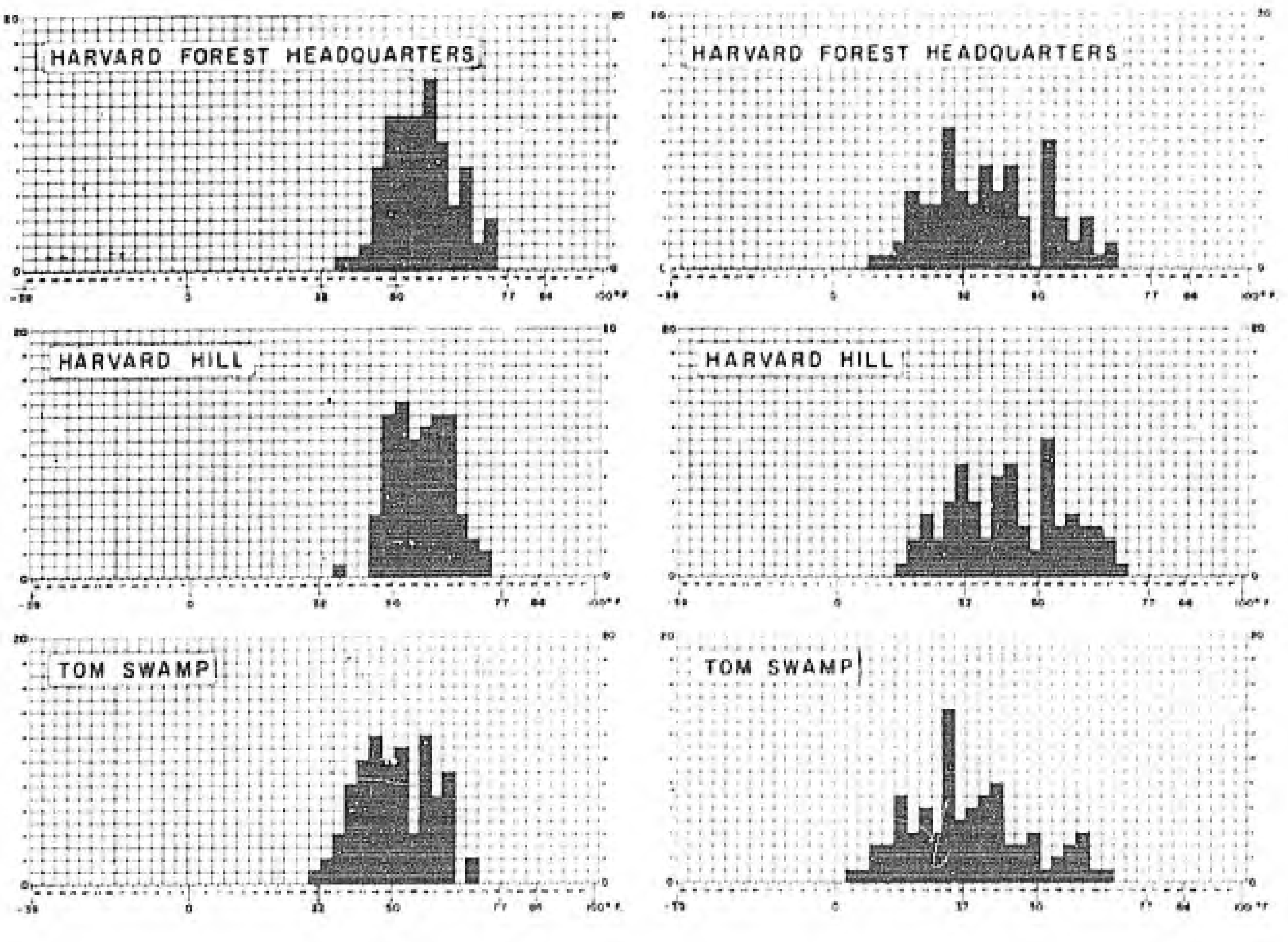
HARVARD FOREST — PETERSHAM, MASSACHUSETTS

FREQUENCIES OF MINIMUM TEMPERATURES

SUMMER (June and July 1948; Aug 1947) AUTUMN (Sept, Oct. and Nov. 1947)



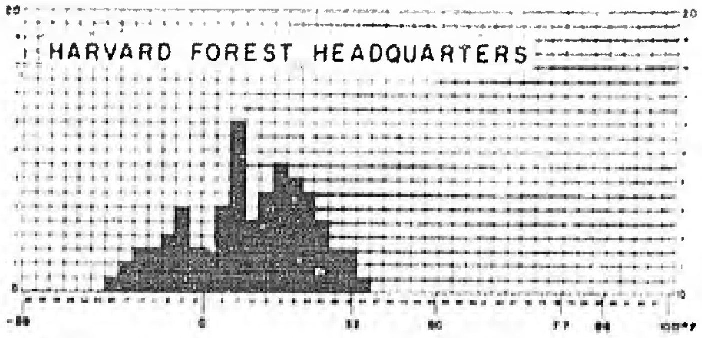
Each column on each diagram includes all readings in a 3° grouping, for which the central value is shown in °Fahrenheit at the base of that column.

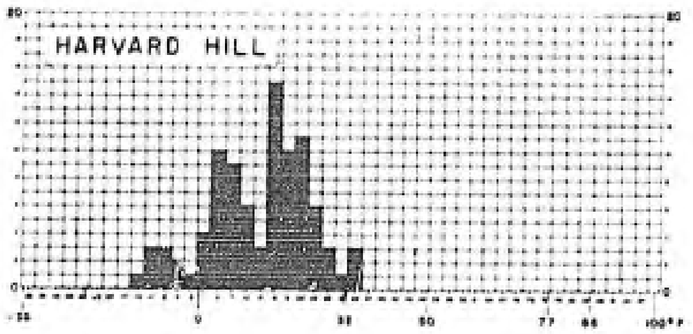
Figure 108

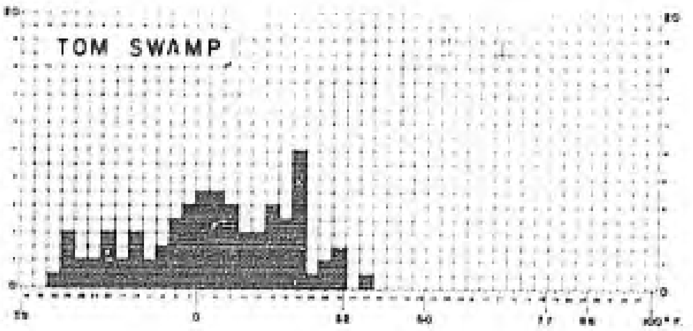
HARVARD FOREST — PETERSHAM, MASSACHUSETTS

FREQUENCIES OF MINIMUM TEMPERATURES

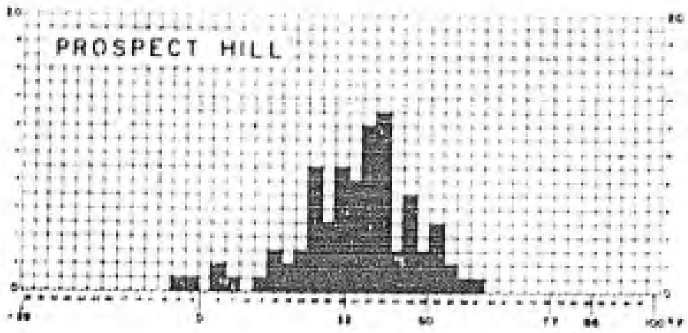
WINTER (Dec. 1947; Jan. and Feb. 1948)

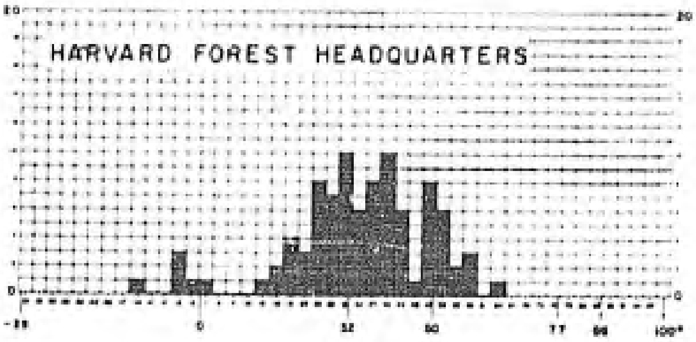


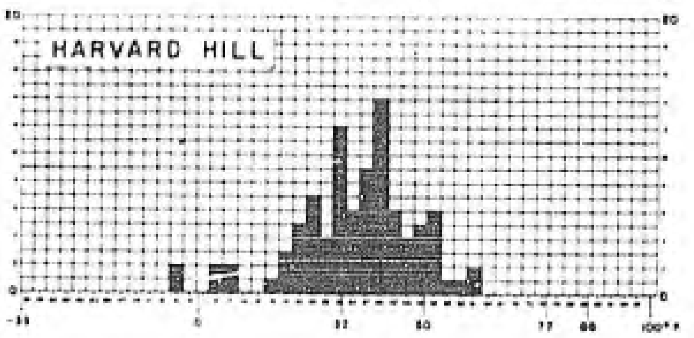


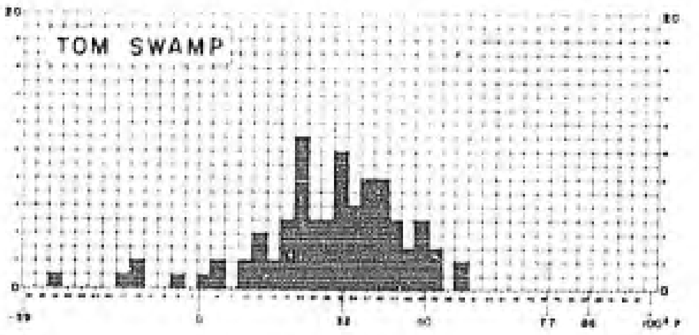


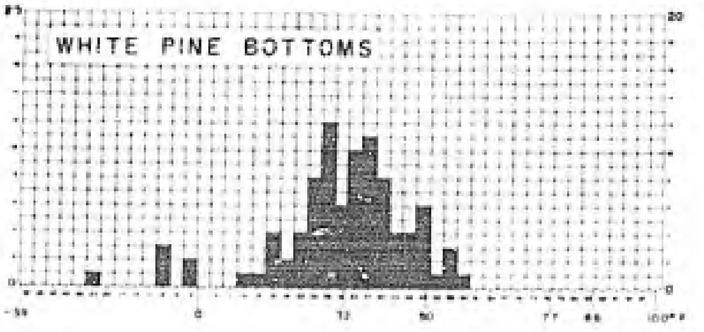
SPRING (Mar, Apr. and May 1948)











Autumn frequency patterns of minimum temperatures have three groupings, which again, as in the case of the maximum frequencies, indicate greatly differing conditions during each month. Headquarters is slightly cooler than Harvard Hill, but has a similar pattern. Tom Swamp is considerably cooler, again as a consequence of frequent inversions. It has almost twice as many autumn nights with frost as Harvard Hill (T. S. 48; H. H. 27), and less than half as many vegetative days (T. S. 22; H. H. 47).* The winter patterns exhibit an exceptionally large shift to cooler temperatures. Each station has at least three modes, the warmest of which is at 22°F or slightly below. For each station this warmest mode represents the relatively mild conditions during December. The coldest mode for each station chiefly represents the January conditions (H. F. Hq. -5; H. H. -8; T. S. -20). The grouping about the intermediate mode chiefly represents the February conditions (H. F. Hq.7; H. H. 4; T. S. 1). Seasonal frequency distributions based upon all values for a longer period of record would probably exhibit a more regular grouping, but the stations in concave areas might well have two or more distinct modes, one mode higher for higher temperatures occurring during cloudy weather and one or more modes for lower temperatures occurring during inversions on clear, still nights. The distributions charted here show a strong tendency toward a single central grouping for the hill stations and a wide scattering for the valley stations.

The spring patterns again reveal distinctive conditions for each month. A scattering of very low temperatures represents March, during which the general snow-cover persisted for more than three weeks. A large intermediate grouping includes numerous values from a relatively even April, as well as those of the warmer nights in March and the coolest nights in May. This grouping skews toward the warm temperatures for the hill stations, however, and toward the cool temperatures for the valley stations. The warmer nights of May show up as a grouping around a tertiary mode to the right. The spring charts show distinctly the variation in number of frost days. Prospect Hill has 37; Harvard Hill, 38; Harvard Forest Headquarters, 41; White Pine Bottoms, 44; and Tom Swamp, 52. The hill stations have a more compact grouping for the whole season than do the valley stations.

8. Special Temperature Factors Affecting Plant Growth.

It should be emphasized that temperature is only one of the important factors affecting plant growth. In the necessarily brief discussion which follows, little is said about other factors such as moisture and wind, which in many instances may be of relatively much greater significance. It must be kept in mind, however, that the effectiveness of any single factor is influenced by, and, conversely, itself influences, all the other factors. Temperature not only affects plant growth directly by its action on the plant, but indirectly by its influence on the other factors affecting the plant.

a. Length of Vegetative Season.

The length of the vegetative season is variously defined, by several differing criteria (Conrad and Pollak, 1950, p. 167). Quite commonly it is measured from the last killing frost in spring until the first killing frost in autumn. Such a measure, though unsatisfactory for some purposes, gives an approximate idea of total growing time available to many plants and of the time and duration of periods during which critical conditions may be expected. The response of an individual plant, however, is conditioned by different kinds of temperature factors at different stages (Zon, 1941, p. 496 ff; also Wolfe, Wareham and Scofield, 1949, pp. 125-130). Thus, germination depends chiefly upon soil temperature rather than upon air temperature. Danger to opening buds, by contrast, is chiefly related to air temperature. Once well beyond the budding stage, the plant may be hardy enough to experience no damage from hard frosts later in spring; thus its total seasonal growth is then dependent upon total hours or degree hours above a given temperature rather than upon total days between last spring frost and first autumn frost. For many plants, growth stops in late summer when the amount of soil moisture falls below a necessary minimum, often several weeks before any frosts occur. Keeping such considerations in mind, it is nevertheless desirable to begin this discussion with an analysis of the length of the frost-free season in differing parts of the Harvard Forest.

* A vegetative period is described by Conrad and Pollak (1950, p. 167) as being one during which the temperature does not fall below 43°F.

TABLE IV RECORD OF FIRST FROST, 32°F OR LOWER, IN AUTUMN 1947, AND LAST FROST IN SPRING, 1948

(Key to abbreviations for station names is shown on Figure 109)

	FIRST FROST AUTUMN, 1947		LAST FROST SPRING, 1948						
Week ending approximately:	September 22	29	April 28	May 5	12	19	24	31	June 8
Date of occurrence at most stations:	20	23	28	2		16			6
Stations with instruments in shelters: (Figures indicate temperature, in °F)	TS29 SC27	HP27 HH26 Pet30 EH28 TP27 GH27 MP26 HB22	PH29 LO28	HP28 HH30 Pet30 EH30 TP29 CH30 MP28 PS29 CG28 WB30 HHJ28 WH29 SS25 HS27 TLS27 LS26		WPB30 RP30 SB32 HK30 TedeS30 TacS29			TS30 BB31 SC32 HB31 PLT31 WT29 CR32 RM32
Stations with instruments not in shelters[a]	BB31		PH28 LO28	BH32 SK28 PRS25 RPR28[b] WAS26 HiH29 SS27 CRS28		PS28 TK30			BB31 LT31
Thermograph stations, in shelters	TS28	HH31	PH29	HH30 HHJ29 WH31		WPB30 SS32 TacS29			TS31

[a]The exposed thermometer at bush height at Tom Swamp recorded frost every month except July, 1948 (weeks ending: Aug. 4, 1947:28°; Sept. 11, 1947:27°; Sept. 22, 1947:20°; June 8, 1948:31°).

[b]A 32° reading, probably for May 3, was recorded on May 10. The reading given here for May 2 is considered better for purposes of comparison.

TABLE V EARLY AUTUMN AND LATE SPRING FROSTS RECORDED IN 1944 AND 1945 AT STATIONS MAINTAINED BY S. SPURR

Station locations are shown in Figure 109.

Station	Location (Compartment)	Description of Site	Approx. Elevation in Feet	1944 Spring Week Ending Mo.	Day	°F	1944 Autumn Week Ending Mo.	Day	°F	1944 Approximate period without frost, in days	1945 Spring Week Ending Mo.	Day	°F	1945 Autumn Week Ending Mo.	Day	°F	1945 Approximate period without frost, in days
S-1	PHI	Headquarters Station	1100	6	12	32	9	25	30	105	6	4	29	10	1	30	119
S-2	PHII	Expt. 41-1: lightly thinned stand of mixed softwoods	1130	5	22	27	9	25	32	126	Not in operation						-
S-3	PHII	Same: Reserve	1130	5	22	27	10	9	29	140	Not in operation						-
S-4	PHII	Same: Heavy thinning	1130	5	22	25	9	25	31	126	Not in operation						-
S-5	PHIV	Ridgetop: Open, 1943 cordwood cutting	1310	5	22	26	10	9	29	140	Not in operation						-
S-6	PHIV	Same: South midslope	1250	6	12	32	9	25	32	105	Not in operation						-
S-7	PHIV	Same: Slope bottom	1200	6	12	30	9	25	27	105	Not in operation						-
S-8	PHVI	Prospect Hill: Open summit	1400	5	22	30	10	9	32	140	Not in operation						-
S-9	SCII	Low swale in open flat near Highway 32	970	6	12	29	8	21	32	70	6	11	32	9	10	30	91
S-10	SCIV	Near Burns Bridge	750	6	12	29	9	25	25	105	6	11	29	9	24	29	105
S-11	SCII	Switchbacks: Top, open blowdown and cutover area	955	Not in operation						-	6	4	26	9	10	32	98
S-12	SCII	Switchbacks: Midslope	880	Not in operation							6	4	26	9	24	29	112
S-13	SCII	Switchbacks: Bottom	810	Not in operation							6	11	31	9	10	30	91

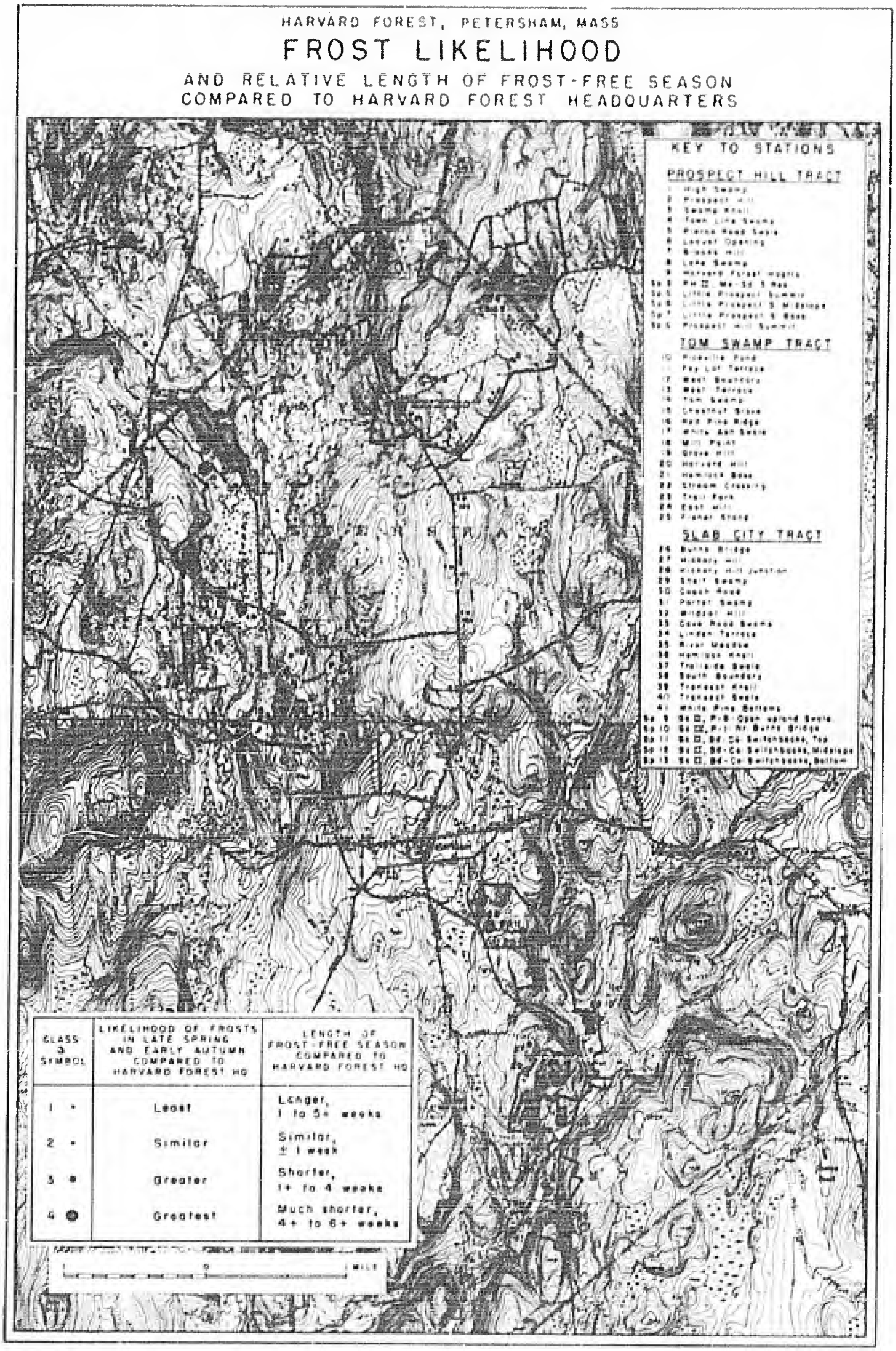
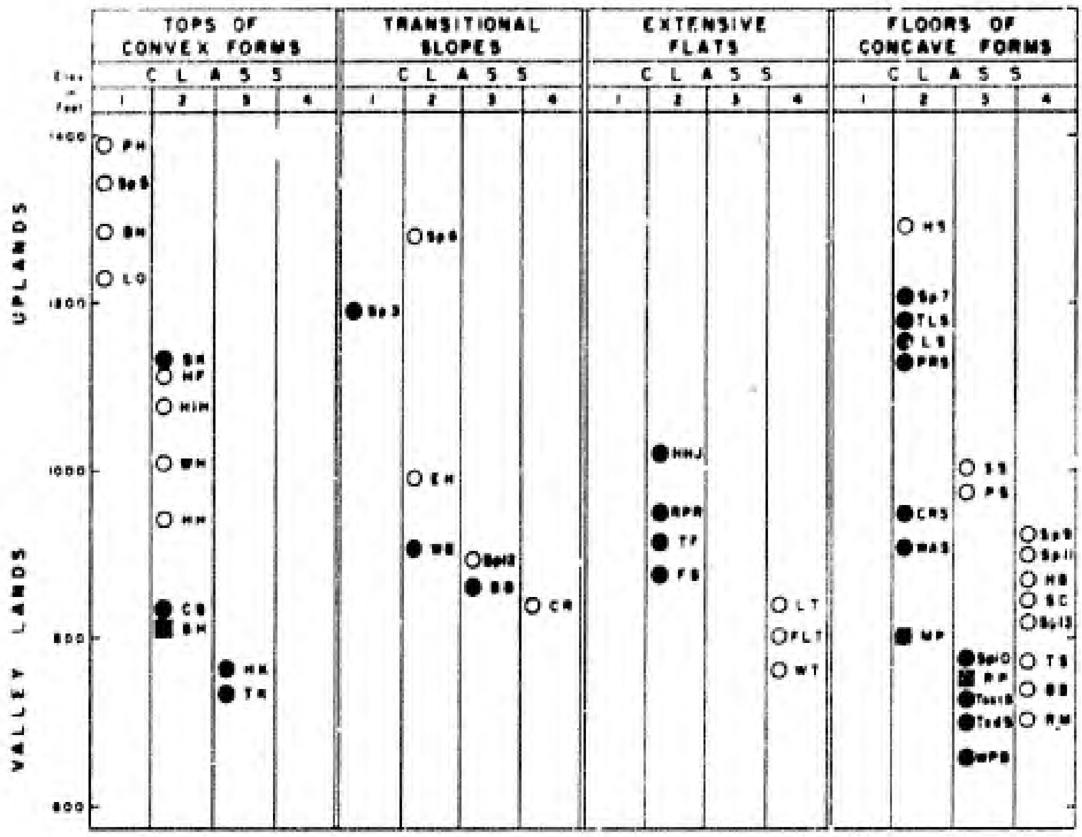

HARVARD FOREST, PETERSHAM, MASS
FROST LIKELIHOOD
AND RELATIVE LENGTH OF FROST-FREE SEASON
COMPARED TO HARVARD FOREST HEADQUARTERS
KEY TO STATIONS
PROSPECT HILL TRACT
TOM SWAMP TRACT
SLAB CITY TRACT
CLASS & SYMBOL
LIKELIHOOD OF FROSTS IN LATE SPRING AND EARLY AUTUMN COMPARED TO HARVARD FOREST HQ
LENGTH OF FROST-FREE SEASON COMPARED TO HARVARD FOREST HQ
1
Least
Longer, 1 to 5+ weeks
2
Similar
Similar, ± 1 week
3
Greater
Shorter, 1+ to 4 weeks
4
Greatest
Much shorter, 4+ to 6+ weeks
0
1 MILE

Figure 109

HARVARD FOREST — PETERSHAM, MASS.

SCALE FOR ESTIMATING LENGTH OF FROST-FREE SEASON AT VARIOUS SITES

ACCORDING TO DIFFERENCES IN SURFACE CONFIGURATION
VEGETATIVE COVER, ELEVATION, AND LAND-WATER RELATIONSHIPS



EXPLANATION

RELATIVE LENGTHS OF FROST-FREE SEASON:

CLASS 1 — Longer (1 to 5+ weeks) than at Harvard Forest Headquarters
CLASS 2 — Similar (plus or minus 1 week) to " " "
CLASS 3 — Shorter (1 to 4 weeks) than at " " "
CLASS 4 — Much shorter (4 to 6 weeks) than at " " "

● Wooded sites ○ Open sites ✕ Sites near water

Key to station abbreviations is given on figure 109
Supporting data are contained in tables IV and V and Appendices A, B, and C

Figure 110

Table IV shows the dates, to the nearest week, of the first autumn occurrence in 1947 and the last spring occurrence in 1948 of a temperature of 32°F or lower. Figure 109 shows different stations classified as to approximate length of frost-free season and relative frost danger. The map is based partly upon data gathered during this study, partly upon data gathered by S. H. Spurr during 1944 and 1945 (Table V), and partly upon the long record at the Harvard Forest Headquarters. The spring and autumn minimum-temperature ranks for each station were considered also, and proved useful for the extreme stations, but were not as useful for intermediate stations as had been expected.

In Figure 109 the stations are divided into four classes according to whether the frost-free season is (1) longer, (2) about as long, (3) shorter, or (4) much shorter than at Harvard Forest Headquarters. Harvard Forest Headquarters is used as a basis for comparison because of the long and continuing record being maintained there, and because the conditions there are representative of those at about half of the stations at which frost readings were taken. It will be noted that some large portions of the Harvard Forest, particularly in the Prospect Hill Tract, have a longer frost-free season than that at the Headquarters station, and that very large portions of the Forest, notably in the Tom Swamp and Slab City Tracts, have a shorter, or much shorter, frost-free season.

Figure 110 shows a scale which may prove useful in estimating the length of frost-free season to be expected in various portions of the Forest for which temperature data have not been obtained. The scale intervals are the same as those employed in Figure 109. From the map (Figure 109) and from the scale (Figure 110) used together, it is possible to reach general conclusions as to the length of the frost-free season in most parts of Harvard Forest. The estimating scale takes only the most important factors into account. Locally certain other factors may have a greater influence. It will be seen that the scale is incomplete. Values are given only for points for which data are at hand, and the stations providing such data are indicated. In a few cases the placement of a station in a particular site category is subjective and may be questioned. The blank spaces in the diagram can be filled in approximately by logical deduction.

The minimum-temperature data gathered in the course of this study show that at most times when conditions favor frost in this general region, all parts of Harvard Forest are within the inversion layer of the atmosphere. It should be noted, therefore, that the significant local differences in length of the frost-free season are not the expression of a normal lapse rate, as might be inferred from comparison with mountain regions, but just the opposite. Consequently, other factors being equal, the highest places have the longest frost-free season, and the lowest places the shortest. The other factors, however, differ considerably; and in most parts of Harvard Forest local differences in such factors as surface configuration and vegetative cover are as important, or even more important, than differences in elevation in determining the length of the frost-free season. Spurr's data (Table V) reveal the importance of forest cover in determining local differences in frost probability. (Compare his forested stations Nos. 2, 3, and 4 with a higher slope station in the open, No. 6. The open station, in 1944, had a frost-free season 3 to 5 weeks shorter).

An isoline map purporting to show the length of the frost-free season in all parts of Harvard Forest would give an unjustified suggestion of reliability (Conrad and Pollak, 1950, p. 260), and has not been attempted, despite its apparent feasibility.

In preparing a map and an estimating scale so general as those presented, it does not appear to matter that conclusions were drawn partly from data gathered at the end of one growing season and partly from data gathered at the beginning of the next season. Any attempt at constructing more precise maps and scales of frost expectancies or of average length of growing season would have to be based on more data. The first killing frost of 1947, for example, was exceptionally hard, and was followed in four days by another even harder frost. In 1944 and 1945 the first killing frosts affected only the low hollows; later frosts affected the hillsides to successively higher levels. A sequence of increasingly severe frosts in autumn and decreasingly severe frosts in spring is usual in many years, and is what the farmer expects in planning his harvesting and seeding operations. It may well be, however, that the one very late spring frost of a decade or the one very early frost in autumn might affect all the trees in a young forest stand so seriously as to determine in large measure the quality of the timber in such a stand a half-century or more later (Hough, 1945, p. 235-250). Many important tree species at Harvard Forest, however, grow as well in sections having the shortest frost-free season as in sections where the season is longest. This is true of the central or southern hardwood species as well as of the northern hardwoods and the conifers.

b. Frost Days.

Table VI shows the number of days each month on which the minimum temperature fell to 32°F or lower. During spring and fall — the critical seasons — the hill stations have far fewer frost days than valley stations in the open. Forested valleys are intermediate in the range between. Prospect Hill and Harvard Hill had no frost days in May. Tom Swamp had five frost days in May and one in June. During cool, dry summers Tom Swamp may possibly experience frost in July or August.

c. Ice Days.

Ice Days (Table VII), on which the maximum temperature does not rise above freezing, have a different distribution pattern from that of frost days, in that they are more frequent at hill stations and at forested valley stations than at valley stations in the open. No ice days occurred before November or after March (during the period of this study). Even in the very late fall or very early spring, however, the occurrence of an ice day might prove to be critical to plant growth on ridges and in the deep forest, particularly when rain, falling from warmer upper air, freezes onto the cold plants to form glaze, which kills the leaves or buds by suffocation

TABLE VI - FROST DAYS PER MONTH
(Minimum Temperature 32°F or lower)

	1947 A	S	O	N	D	1948 J	F	M	A	M	J	J	Yearly Total
Harvard Forest Hq.	0	6	3	23	30	31	29	25	15	1	0	0	163
Prospect Hill						31	29	25	13	0	0	0	
Harvard Hill	0	3	2	22	29	31	28	24	14	0	0	0	153
Tom Swamp	0	8	16	24	31	31	28	27	20	5	1	0	191
White Pine Bottoms						31	29	25	16	3	0	0	
Hickory Hill Junct.										1			
Wildcat Hill										1			
Shelf Swamp										3			
Coach Road										2			
South Boundary										3			
River Meadow									17	5			
Transect Swale										4			

TABLE VII - ICE DAYS PER MONTH
(Maximum Temperature 32°F or lower)

	1947 A	S	O	N	D	1948 J	F	M	A	M	J	J	Yearly Total
Harvard Forest Hq.	0	0	0	1	17	24	17	6	0	0	0	0	65
Prospect Hill						30	19	8	0	0	0	0	
Harvard Hill	0	0	0	1	16	26	19	5	0	0	0	0	67
Tom Swamp	0	0	0	0	15	25	19	4	0	0	0	0	63
White Pine Bottoms						28	19	8	0	0	0	0	

TABLE VIII - NUMBER OF HOURS PER MONTH 32°F AND BELOW

	1947 A	S	O	N	D	1948 J	F	M	A	M	J	J
Prospect Hill					(625)	741	592	(391)	110	0	0	0
Harvard Forest Hq.	0	7	10	260	(625)	735	571	396	100	9	0	0
Harvard Hill	0	15	5	281	610	725	(587)	371	110	0	0	0
Tom Swamp	0	64	81	335	620	717	575	404	149	29	2	0
White Pine Bottoms					(630)	739	601	430	145	20	0	0

( ) Based partly upon interpolation

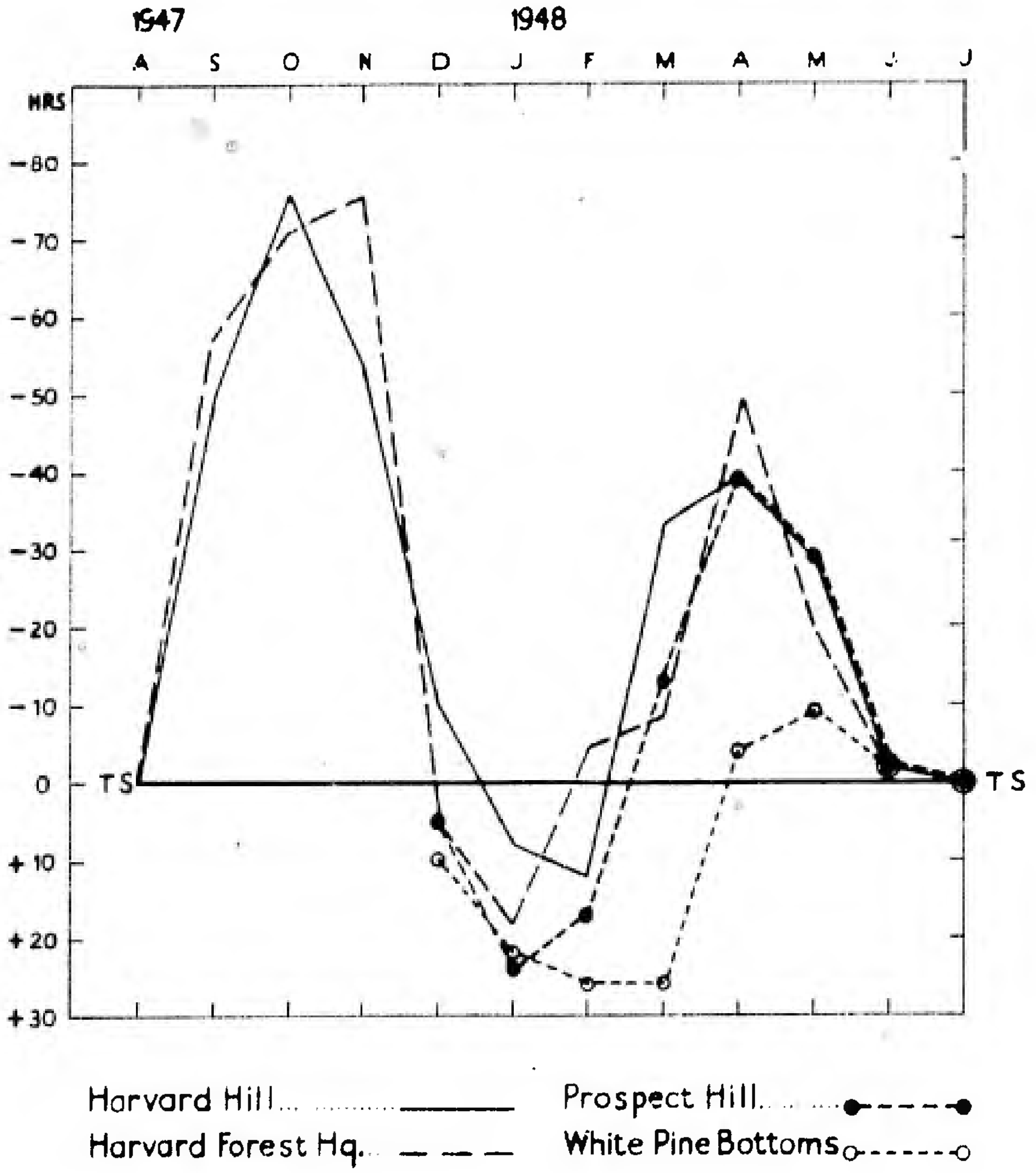
if not by freezing. As has been mentioned earlier, the lower maximum temperatures at the highest elevations are largely an expression of the usual decrease of temperature with height.

d. Hours per Month 32°F and below.

From the standpoint of the growing plant a most important consideration is the total number of hours per month (and for the whole growing season) that the air temperature remains below critical minimum limits and rises above certain critical maximum limits. In this study an analysis has been made, from thermograph records, of the number of hours per month the temperature remained below one such critical limit, 32°F.* The results are presented in Table VIII. From this table the differences between Tom Swamp and the other stations have been determined. These are shown graphically in Figure 111. It is interesting to note that during spring, summer, and autumn, the valley stations have more hours below freezing than the hill stations, but that in winter the situation is reversed, although the actual differences are not very large.

* Other possibly more critical considerations are the total degree-hours of frost during each freeze, the duration of the individual freeze, and the speed with which the freeze sets in.

DIFFERENCES BETWEEN TOM SWAMP AND OTHER STATIONS IN NUMBER OF HOURS PER MONTH 32°F. OR LOWER



Explanation: Base line represents Tom Swamp. Points above base line represent number of hours, 32°F. or lower, fewer than at Tom Swamp. Points below base line indicate number of hours 32°F. or lower, more than at Tom Swamp.

Figure 131

The winter reversal is explained by the fact that in winter the minimum temperatures are everywhere below freezing every night, and do not greatly alter the totals from station to station. On the nights when the greatest inversions develop, cooling is very rapid early in the night. Just after sunrise the next morning, the air warms up again at an even more rapid rate, except in shaded spots; and the inversion is soon eliminated. Thus, although the valleys experience much lower temperatures, their cooling period is about the same as that of the hills. By noon the valleys have become slightly warmer than the ridge tops, and then remain so for several hours. Moreover, on some days the maximums in the valleys rise slightly above 32°F, while on the ridges the temperatures remain slightly below 32°F. It is these higher maximum temperatures that cause the valley stations to have a few less hours below 32°F than the hill stations during the very coldest months. In comparison to the rest of the year this is a negative relationship.

In England, Balchin and Pye (1950, pp. 345-353) concluded that higher winter maximums in the valleys may account for the earlier budding of plants there than on hilltops. A few weeks later (when the relationships as to freezing temperatures are reversed, as shown in Figure 111) the plants on hilltops become more advanced than those in the valleys, apparently because they do not experience the low temperatures, during inversions, which slow the development of the valley plants. The ridges have "marine" conditions, with spring delayed but relatively free of severe cold; the valleys, by contrast, have "continental" conditions, with warm days coming sooner in spring but with many distinctly colder nights also.

From an analysis of the figures for frost days and ice days the following general rule can be inferred: "Differences between stations in hours per month below freezing are of the same sign as differences in the number of frost days, except in January and February, when they are of the same sign as differences in the number of ice days." The ratios, however, are not the same. More briefly and simply, one can say that valley stations in the open have more hours below freezing than valley stations in the forest, or than hill stations, except in winter. In winter the inter-station relationships for hours below freezing are quite the reverse of the winter relationships for mean monthly temperatures, and are in even more striking contrast to the winter relationships for mean minimum temperatures.

It is not unlikely that an analysis of number of hours per month above a vegetative growth threshold, such as 43°F, would similarly reveal more such hours for the valley stations in the open than for the hill stations or forest stations, for a month or two in spring, and again in autumn, despite the much cooler conditions at night in the valleys. In summer, however, the advantage would be with the hill stations. Then minimum temperatures on the hills remain above 43°F, while those in the valleys drop much lower.

Perhaps of equal, and at times of greater, importance to plant growth are the critical soil temperatures (Zon, 1941, p. 496 ff). Another important factor, probably not sufficiently stressed in the past, is the total number of hours per season the plant is exposed to sunlight. Hours of exposure to sunlight can be determined approximately by careful construction (from topographic maps) of skyline profiles from NE, by way of S, to NW, as viewed from each station (Conrad and Pollak, 1950, pp. 150-151).

e. Summer Days.

Table IX shows the number of days per month that maximums of 77°F or higher were recorded. This table indicates that open concave areas (High Swamp, Tom Swamp) and exposed slopes with stations shut in but not canopied by dense vegetation (Harvard Hill, Northwest Midslope), all have considerably more summer days, as compared with stations on open hills (Prospect Hill) or near water (Mill Point), or in dense, canopied forest (White Pine Bottoms). Fewest summer days are recorded in woods at high elevations, where shade and daytime lapse rate combine to hold temperatures down (Little Prospect Hilltop, Lower Spruce-Hardwood). These exceptional conditions obtain only under the canopy within the forest; in the crowns of these same stands temperatures are undoubtedly higher (Geiger, 1950, p. 328).

TABLE IX - SUMMER DAYS (Including Tropical Days)
Maximum 77°F or Higher

	1947					1948							Totals		
	A	S	O	N	D	J	F	M	A	M	J	J	ASO	MJJ	YR
Harvest Forest Hq.	22	13	6	0	0	0	0	0	0	7	12	29	41	48	89
Prospect Hill						0	0	0	0	4	6	23		33	
Harvard Hill	26	15	10	0	0	0	0	0	0	6	15	29	51	50	101
White Pine Bottoms						0	0	0	0	3	7	16		26	
Tom Swamp	26	16	9	0	0	0	0	0	0	6	13	28	51	47	98
Hickory Hill Jct.										6					
Wildcat Jct.										7					
Shelf Swamp										6					
Coach Road										6					
South Boundary										6					
River Meadow									0	6					
Transect Swale										6					
High Swamp											10				
Town Line Swamp											7				
Locust Opening											9				
Lake Swamp											9				
Little Prospect Hilltop											4				
Northwest Midslope											13				
Lower Spruce-Hardwood											6				
Big Spruce Swamp												27			
East Hill												29			
Fisher Stand												23			
Stream Crossing												29			
Fay Lot Terrace												29			
West Boundary												16			
Mill Point												23			

TABLE X - TROPICAL DAYS
Maximum 86°F or Higher

	1947					1948							Totals		
	A	S	O	N	D	J	F	M	A	M	J	J	ASO	JJ	YR
Harvard Forest Hq.	7	1	0	0	0	0	0	0	0	0	2	8	8	10	18
Prospect Hill						0	0	0	0	0	1	1		2	
Harvard Hill	13	5	0	0	0	0	0	0	0	0	2	5	18	7	25
Tom Swamp	13	3	1	0	0	0	0	0	0	0	2	3	17	5	22
White Pine Bottoms						0	0	0	0	0	0	0		0	
High Swamp											3				
Town Line Swamp											2				
Locust Opening											2				
Lake Swamp											2				
Little Prospect Hilltop											0				
Northwest Midslope											3				
Lower Spruce Hardwood											0				
Big Spruce Swamp												3			
East Hill												12			
Fisher Stand												1			
Stream Crossing												10			
Fay Lot Terrace												6			
West Boundary												1			
Mill Point												2			

f. Tropical Days.

Days with maximum temperatures of 86°F or higher are shown in Table X. On these excessively hot days, especially if the air is dry rather than moist, plant growth may be inhibited or stopped. Such days are few at Harvard Forest; they are most numerous on westward-facing slopes and in dead-air pockets in concave areas (Northwest Midslope, East Hill, Stream Crossing).

Perhaps of greater significance than number of tropical days would be the total number of degree hours above certain high critical temperatures for plant growth. Visher (1946a, pp. 348-349) has suggested the term "hot degree day" for each day with a mean temperature one degree or more above 70°F. A mean temperature of 85°F would represent 15 heat-degree units, and 20 such days would equal 300 heat-degree units. Such a measure, though desirable for determining air-conditioning requirements, may not be highly significant for determining inhibitions to plant growth, because the measurement is based on a daily mean. The actual fact of a temperature having exceeded an upper limit for plant growth, such as the 86°F figure for tropical days, may be more significant, and the actual duration of such "tropical" periods is probably still more so.

CHAPTER V - CONCLUSIONS

1. Harvard Forest a Representative Part of a Regional Mosaic of Many Temperature-Type Areas.

The findings reveal that Harvard Forest temperature differences are very great from place to place, and are caused by numerous, differing factors. It follows that rolling-to-rough upland regions, such as the one of which Harvard Forest is a part, must be studied as complex mosaics composed of small and diverse temperature subregions. Care must be exercised, however, to avoid the conclusion, often mistakenly reached for mountain regions also, that the least severe temperature conditions obtain in the valleys. In the high parts of alpine-type mountains, to be sure, the effect of great differences in altitude and decreasing mass is evidenced by low temperatures and strong winds; but at intermediate elevations are the so-called thermal belts, where the opposed effects of lapse rate and inversions are more frequently in balance, and where temperature differences consequently are less extreme. (Peattie, 1936, pp. 18-23).

At Harvard Forest, as has been shown, differences in topographic form, direction of exposure, and vegetative cover are all more important than elevation in determining temperature differences; nevertheless, the effect of elevation by day and of topographic form, together with elevation, by night is such that the ridges have a more moderate climate than the valleys. Because the air can move almost without hindrance above the upland surface, the ridgetops come under a more nearly uniform atmospheric influence than the valleys. The effect of the freely moving atmosphere upon the ridgetops is similar to that exerted by the ocean upon the climate of the land at its margins. In a sense, the ridgetops have a mild type of climate (Figures 79 to 82). The valleys, by contrast, have greater extremes and have more severe climates. Such a comparison, however, is relative. Despite notable differences from place to place, all parts of Harvard Forest came within the broad limits of the Dfb type of climate by the Koeppen classification, during the period of this study. Nevertheless, the local complexities of relief are sufficient to give the region great climatic diversity.

2. Types Repetitive and Findings Applicable Elsewhere.

Within Harvard Forest many stations with like site factors had similar temperature patterns, even though the stations were widely separated. It would appear feasible, therefore, to make a comparative analysis for a region similar to Harvard Forest in topographic diversity by maintaining a relatively small network of stations, each situated in a carefully chosen location, with some locations representative of the most contrasted conditions within the region, and some representative of the most typical kinds of areas. It would be necessary to give careful consideration to local landform, land - water, and vegetation relationships, and it might be desirable so to locate all stations that certain of these relationships would be the same at all stations. In the present study some station locations were chosen for such comparability. Other locations were chosen to provide observations for as wide a variety of conditions as possible.

From analysis of readings obtained it should be possible, by application of "extreming" factors, such as concavity, and of "moderating" factors, such as convexity or vegetative cover, to make general estimates of temperature patterns at other places in the region, including estimates as to temperature extremes, frost susceptibility, growing-season length, soil heating and cooling, snow accumulation and melting, and annual temperature regime. As Geiger says (1950, p. 260) "Microclimatology in turn now makes it possible to draw conclusions as to meteorological conditions at one place by a study of known conditions at a neighboring place." In addition to the discussion in Chapter IV of such applications as were made for places within Harvard Forest, it might be mentioned that at Silver Lake, N. H., about 150 miles to the northeast, in a topographic situation similar in most respects to that of the Tom Swamp Station, the winter's minimum temperature was the same, -31°F.* As has been indicated for Harvard Forest, the inter-factoral relationships change from month to month, and care must be used to include all factors.

*Reported by C. F. Brooks

3. Standard-Height Readings Useful as Indicators of Local Differences.

It has been stated frequently that measurements of natural conditions affecting a growing plant should be made at plant height (Geiger, 1950, pp. xvii-xviii; and Wolfe, Wareham, and Scofield, 1949, pp. 10-11, 94-104), and that these measurements should include whole series of measurements at all heights, from deep in the root zone of the soil to the highest part of the plant. Moreover, it has been shown that the temperature relationships differ greatly for plants growing singly in the open, as compared to plants growing in groups. Some investigators consider measurements near the ground to be preferable to standard-height shelter measurements for analyzing conditions influencing plant growth, particularly during critical periods. Obviously, all such measurements not only are desirable but are essential in any detailed microclimatological study. The differing records of the three instruments at Tom Swamp—a thermometer at bush height; a thermograph on the shelter floor; and another thermometer on the bracket, higher up in the shelter—give ample evidence of the desirability of taking readings at various heights. At the same time, the findings in the present study indicate that readings taken at standard shelter height have value in bringing out much of the diversity of local temperature patterns, and also emphasize the importance of considering local site factors in choosing locations for climatic stations intended to be representative of a considerable area.

From standard-height readings it is possible to make some inferences by use of tables as to whether the temperature would be higher or lower near the ground (Geiger, 1950, pp. 71-75, citing Ramdas and Katti, 1934, pp. 923-937; also Geiger, 1950, p. 85, citing Steinhauser, 1935, pp. 439-443, whose conclusions are based partly on data presented by Johnson, 1929, and Best, 1935). Obviously, actual readings would be preferable, particulary for maximum temperature. Inferences as to vertical gradients of minimum temperat[illegible] at night are more likely to be useful, because night air generally is more stable. Baum (1[illegible]) cites evidence to show that the daytime and nighttime conditions, although contrasted, do not offset each other. He states that the correction factor to be applied to means of standard-height readings, to obtain the means at lower levels, has a definite seasonal variation.

The chief value of standard-height readings is to make possible the comparison of like places. Hilltop stations are readily comparable with one another. Because such stations are likely to feel the effect of even the slightest regional wind, temperature gradients from shelter height to very near the ground are small or absent. Similarly, stations in hollows are comparable with one another, although in such places it must be expected that temperature gradients will be steep from the ground to shelter height. The actual amount of contrast at ground-level between a convex surface (hill) station and a concave-surface (hollow) station would be difficult if not impossible to determine from standard-height temperature comparisons.

Standard-height temperature readings taken in an open area give a useful general indication of regional temperatures affecting plant growth in that area. By contrast, the readings taken at standard-height within a forest reflect the modifying influence of the forest itself upon the climate. In such a situation it could be inferred that during the leaf season superadiabatic gradients would be slight or absent during the day and that the temperature-inversion gradient from the ground to shelter height would also be slight because of the blanketing effect of the tree canopy (Geiger, 1950, pp. 313-314, and 326-331). This leads to the conclusion that, as the vegetative cover changes, the surface climate changes also. An open station such as Burns Bridge would have considerably cooler soil by day in summer if it had a sprout growth cover such as grows on Northwest Midslope, even though shelter-height readings would be somewhat higher. Night temperatures of the soil would be higher. Twenty years later, with a dense stand of young trees occupying the area and providing not only a blanket in the canopy but a dead air zone beneath, temperature gradients from shelter-height to ground would be even gentler in summer, though not so greatly influenced in winter. In a mature coniferous stand, with a succession understory of hardwoods, the moderating influence of the canopy upon soil temperatures would be even greater.

It would be incorrect to assume that readings at standard-height taken at such contrasted stations as Burns Bridge, Northwest Midslope, and White Pine Bottoms would be in the same relationship as readings taken a foot from the ground at each station. Allowance must be made for differences in topography and vegetative cover before approximations can be inferred. Nevertheless, one can conclude that foot-high plants at Northwest Midslope would experience abundant warmth by day, moderate cold at night, and a moderately long growing season; at Burns Bridge similar plants would experience abundant warmth by day, severe cold at night, and a relatively short growing season; and at White Pine Bottoms the plant would receive moderate warmth but little sunshine by day, moderately severe cold at night, and a growing season which would be longer than at Burns Bridge and might be longer or shorter than at Northwest Midslope, depending upon whether cooling occurred by advection of cold air over warm, or by steady heat loss from a uniform air mass already lying calm over the whole area.

Although such conclusions, reached by processes of logical deduction from standard-height readings, can be useful in a general way, the possibility of overlooking one or another important factor is obviously great. Precise determinations require actual readings.

4. Local Differences in Distribution of Tree Species Partly a Response to Differing and Changing Local Temperature Regimes.

The present forest-species associations in Harvard Forest, although diverse, include numerous stands which are more or less directly descended from and similar to those which occupied the same respective sites in the pre-colonial period. These stands differ considerably according to site quality, which, here as elsewhere, differs greatly according to geological history, climatic differences, accidents of vegetational succession, and other factors (Toumey and Korstian, 1937, pp. 63-74, and 151-173; Lutz and Chandler, 1942, pp. 267-272). It is generally accepted, however, that during some climatic periods certain species-associations increased their areas of dominance at the expense of other associations, only to lose ground as climatic conditions changed and became more favorable for other associations (Deevey, 1939, p. 708; Zeuner, 1946, pp. 7 and 70).

As the climate changed, however, successive generations of individual species made gradual adjustment to such changed conditions and continued to flourish, or at least to remain as significant forest elements, under conditions which might have eliminated the earliest generations of those same species (Toumey and Korstian, 1937, pp. 48-49). Thus many species today have a considerable range of tolerance, and could grow to maturity on many different kinds of sites at Harvard Forest provided all competition from other species were eliminated by intensive thinning practices. Actually, however, such thinning is not possible economically, and probably undesirable silviculturally. In the natural forest now establishing itself after the cutting of the old-field pine, individual members of certain species sometimes are found in most unexpected places, but most members of many species are distributed according to definitely recognizable site characteristics or combinations of characteristics which favor certain species at the expense of others.

In the paragraphs to follow, the important timber species and a few others of particular interest are discussed individually, with some indication being given of the natural factors which specifically favor them.

In nature these species seldom grow in pure stands; rather, they grow in type-associations, which are repetitive and generally recognizable. Despite considerable variation in proportionate representation of individual species, and some gradational combinations which include numerous species of more than one type-association, the basic combinations are few in number; six common associations form a system by which almost all natural stands in Harvard Forest can be classified. A few of these associations have so many common elements that they might be considered variants of one association. As has been outlined in Chapter II, the six associations may be grouped into three major forest groups: a northern forest, a transition forest, and a central or southern forest. In the discussion below, the individual species will be discussed in order according to the forest group in which they are most common. In later discussion, the natural associations of these species will be emphasized, particularly as they reflect the influence of temperature differences and of other differing factors; the implications of an association-concept of silviculture, as distinguished from a species-concept, also will be considered.

a. Species of the Northern Forest.

(1) Black Spruce and Red Spruce. The two largest natural stands of spruce at Harvard Forest are in the Big Spruce Swamp of the Prospect Hill Tract and in Tom Swamp. These areas have very low night temperatures and a relatively short growing season. The night minimums in the Tom Swamp stand are much lower, however, than those in the Prospect Hill spruce stand. Black spruce is distinctly a northern species, with a southward extension in the Appalachian Highland. It has a vast range, chiefly in a region of cool climate and moist, ill-drained sites. It may be that it is concentrated in these sites not so much because it requires such conditions, but because it cannot compete with other species on warmer, drier or richer soils.

Spruce can stand more cold than other species, yet is not adversely affected by excessive heat. This is partially explainable in terms of its branching habit; the widespread lower branches shade the ground so thoroughly that the soil and the water in the soil both remain cool. The needle-type leaves minimize moisture evaporation from the tree into the hot atmosphere.

Evidence from fossil pollen studies and buried forest beds indicates that in certain periods when the climate was cooler and moister, possibly because of closer proximity of continental ice sheets, spruce was much more widespread than at present (Raup, 1937, p. 104; Deevey, 1939, p. 714; Transeau, 1941, p. 208; Cain, 1944, p. 127; Potzger, 1946, p. 234). Its present distribution in southern New England suggests a last-stand occupation of those sites that have a climate generally suitable to it, together with a cold, wet soil which offers poor conditions for species that are less tolerant of excessive water (Wilde, 1946, pp. 50-51).

(2) Hemlock. Moderately damp, but not wet, areas suited to black spruce or red spruce are suitable also for hemlock. In addition, hemlock grows in many places where spruce cannot compete. Although it is found nearly everywhere in the Harvard Forest, it flourishes best in areas with considerable cool weather or cool ground. Many of the chief stands are on north slopes or in deep valleys which are shaded from the sun for a good part of each day. Here, by its relatively greater shade tolerance than most other trees, it finally gains a dominant or at least co-dominant place in the mature forest association. Once thus established it keeps the day climate near the ground cooler, and keeps the soil moist also, thereby making conditions more favorable for its own continuance. Many other sites are favorable for hemlock, but hardwoods at first gain dominance on them. Some hemlock may manage to come through to large size in such stands, but usually this happens where one or another site factor is somewhat less favorable for hardwoods.

(3) Birch Species. Several species of birch are widespread in Harvard Forest. Some of these, like gray birch, are relatively shortlived and tend to die out as the stands in which they are growing become mature. Two species, paper birch and yellow birch, are important as a source of timber. Black birch also is a component of many stands. Paper birch establishes itself readily in many places, and if not shaded too much will form good stands in newly established forests. In older forests which have been undisturbed for more than a century, the paper birch is less common, except on exposed slopes which receive more sunlight. The paper birch is widespread, however, both through the northern forest and the transition forest. The yellow birch is more definitely a cool climate species. It is most common in swales, or in cool, moist sites, where it is associated with hemlock, beech, and sugar maple.

(4) Sugar Maple. The sugar or hard maple is only locally abundant in Harvard Forest, but in many parts of New England, southern Canada, and the Middle West it is an important element in northern-forest stands.

(5) Beech. In its many subspecies or varieties, beech ranges southward to the Gulf of Mexico, but it is considered a northern-forest tree. At Harvard Forest it grows chiefly in marginal locations at the edges of low concave areas, generally near the bases of long slopes, in places having considerable topographic shade. In general these sites are moist but well-drained, and have relatively low night temperatures. Because the beech forms a heavy canopy, it can protect the ground beneath its branches from the high maximum temperatures characteristic of the pocket lowlands. The hot air of the crown rises into the open atmosphere. Beneath the crown a slight daytime inversion exists, and the soil, receiving little direct sunlight during the leaf season remains quite cool (Kittredge, 1948, p. 60). At night, conditions change. Cold air settles, and although the tree crowns slow the settling a little, the air and ground become very cool. Although the air-temperature relationships are very important, it is probable that cool, moist well-drained soil is particularly a requirement for the beech (Wilde, 1946, p. 60; Heimberger, 1934, pp. 36-37).

(6) Other Northern-Forest Species. The northern forest, as defined for New England, includes several other species in considerable numbers. Most of these are equally numerous or even more so in the transition-forest association, however, where the northern-forest species are less frequent. These species, therefore, are described as transitional, even though they are also common in many northern-forest stands.

b. Species of the New England Transition Forest.

In those parts of Harvard Forest where night temperatures remain noticeably higher, and where the northern-forest species are few in number or totally absent, the numerous so-called transition species are dominant. As has been said, these also thrive in competition with the northern species in all but the coldest, most shaded, and wettest locations. Harvard Forest lies in or near the center of the area of optimum environmental conditions for many of these species. It is not surprising, therefore, that some of these species appear to thrive almost everywhere in the forest. Rather, it is significant that some parts of the Forest have climates or soils or ground-water conditions definitely unfavorable to the transition species, which are so much at home in this region.

(1) White Pine. Although frequently classed as a northern species, the white pine does best, in the Harvard Forest area, on medium soils and in association with the transition hardwoods and central hardwoods, though it also is associated with hemlock, a dominantly northern species, on some sites.

The remarkable increase and subsequent decline in importance of white pine during the last century has been described. Under normal conditions white pine is generally unsuccessful in competition with hardwoods on better soils in this area (Lutz and Cline, 1947, p. 167). On many sites of medium quality it has a somewhat less-than-even chance to compete, but flourishes locally under careful silvicultural management. On lighter sandy loam soils, especially on warm, sunlit sites, it flourishes in company with hemlock, and at the expense of hardwoods. On deeply shaded sites, however, hemlock achieves dominance.

Most sites in Harvard Forest have a combination of natural conditions suitable for white pine, as is amply demonstrated by the great variety of sites on which old-field stands of white pine once flourished. Considered from a long-term point of view the species has a wide range of tolerance and adaptability (Potsger, 1946, pp. 217). It loses out, at least temporarily, and often for long periods, on many of the more fertile sites where faster-growing species, even though more exacting, can overtop it and become dominant. On some of these better sites, as on many more of the poorer sites, white pine may eventually come to dominance in places, owing to the fact that it normally lives much longer than most other species common in this region and because it grows taller than any of them. In the course of a normal lifetime of white pine, extending over a century and a half, such natural accidents as windfall, or fire, or drought might release it locally from competition with more aggressive neighbor species. Left to itself, white pine at Harvard Forest would probably be suppressed for long periods on all but the poorest sites. Under silvicultural management, however, it can be brought through profitably on many medium and low quality sites (Lutz and Cline, 1947, pp. 171-175).

(2) Red Maple. The red maple grows well in all parts of the Forest where soil moisture is abundant. It grows particularly well in wet swales, especially those which become less wet or even dry in late summer and autumn, in contrast to the spruce and peat areas where the water table remains high all year. Even in such continously wet places, red maple is represented, but cannot easily meet the competition of spruce and hemlock. It has been stated frequently, and Spurr (1950, pp. 87-90) has demonstrated by statistical analysis of all the stands in Harvard Forest, that red maple and red oak occur in inverse proportion to each other in given stands according to the wetness of the soil. Red maple becomes increasingly dominant and red oak decreasingly so on the wetter soils. Most of the swale red maple growing in untreated stands consists of sprouts growing from stumps. This "coppice" growth does not yield good lumber, as the trunks invariably develop heart rot, but it is so vigorous that it suppresses other species almost completely. The eventual result is that red maple composes three-fourths or more of the stand; which as a whole has little value except for fuel.

(3) Red Oak. Perhaps no other timber tree species is showing such vigorous growth at Harvard Forest, at least in the first-succession stands following the old-field white pine stands, as red oak, except in deeply shaded areas and in poorly drained areas. Although red oak has a wide northern range, it is sensitive to frost. In low open basin areas and in places such as those

which suffered considerable hurricane damage in 1938, or otherwise had the protecting canopy opened, considerable frost damage occurs, particularly to young red oak and white ash (Lutz and Cline, 1947, p. 103). Because of its rapid growth rate, however, red oak soon becomes dominant in many places, particularly on better-drained, fertile soils. This is true even in young coniferous stands on medium quality soils, where the conifers, because of their conical shape cannot form a high canopy to shade out the red oak. The red oak soon pushes through and slowly eliminates or seriously retards the conifers except where they form very dense stands (op. cit., p. 111). On Brooks Hill, for instance, a very healthy white pine stand is being overtopped by red oak in many places.

(4) White Ash. The white ash is an excellent timber species and grows well throughout a wide range in North America. It grows in many parts of Harvard Forest but is most common near the base of long slopes or on higher slopes where the water table is high. It is most common on sites where the soil is always moist and where the water table is so high in spring that the water, in places, actually runs across the ground surface. This is the case at the heads and sides of swales which in their lower parts may be too wet for ash and are there dominated by red maple. Most of the better sites for ash are on the slightly higher edges of basins, where night temperatures are low but not extremely so, and particularly in places which receive much sunlight in the course of each day. White ash, like red oak, is sensitive to frost when young, and requires a protective overstory to get a strong start.

(5) Black Birch. This species is abundant in the transition hardwood and central-hardwood forests. It is most common on sites that are well to moderately drained, though it is occasional on poorly drained sites.

(6) Other Transition-Forest Species. Several other species are common in the transition forests of New England, although they generally compose only minor portions of stands. In some places, however, they are more numerous. Among such species are elm (chiefly near water-courses), black cherry, large-tooth aspen, and, on more favored sites, the central-hardwood species, discussed below.

c. Species of the Central Hardwood Forest.

This forest is often called the oak-hickory forest because various species of oak and hickory form such important elements of it. Several other species are numerous in this forest, however, including most of those already described as members of the transition forest. The species here described as central hardwoods are those which, although intermixed in many places with the members of the transition forest, are generally most common on the warmer sites.

(1) White Oak. The white oak has a wider range than the white ash, and might well be considered a transition species. Apparently it thrives best on lighter soils on warm sites, in contrast to white ash which does best on moist sites.

On sunny slopes, with open growth, and less competition from species requiring richer soils, white oak does particularly well. Hickory is commonly intermixed with white oak in such places.

(2) Black Oak. The black oak is a common associate of white oak on warm, dry, south-facing slopes, where the soils are very well to excessively drained. It is a characteristic species in the central hardwood forest.

(3) Shagbark Hickory. Two hickory species are represented at Harvard Forest: pignut and shagbark. Only shagbark hickory, which forms the most numerous stands, is discussed here. Shagbark hickory is widely distributed in North America, but here, near the northern limits of its range, it is most common on the warm, sunny slopes, chiefly those facing south and southwest. Some of the best hickory grows at low points on such slopes, where nights are as severely cold as anywhere in the forest. The days, however, are unusually warm, and the soil - because the slopes receive the sun's rays at a high angle of incidence—is exceptionally warm. The budding habit and bud form of hickory render it relatively immune to late spring frosts. On the warm spring days the buds lengthen rapidly, telescope fashion, within a frost-proof coat, unaffected by the severe night temperatures which do such damage to red oak and white ash. Later, they burst forth, when frost danger is past or at a minimum, and the tree soon leafs out to form a heavy canopy. It is characteristic for hickory stands to be quite open,

with a grassy floor. In part this is because of the growth form and habit of the tree itself. Hickory rapidly develops a long taproot which can draw sufficient moisture from the sub-soil to sustain vigorous growth, while shallow-rooted species find insufficient water in the upper soil and are easily displaced by grasses. Also, hickory is distasteful to browsing animals, and so, in pastured woodland it frequently maintains itself while other species are destroyed (Cheyney, 1942, pp. 293-294).

In the Slab City Tract of Harvard Forest the hickory is on the dry, south-facing, sunny slopes north of the Swift River. Across the river from it, on cool, moist, shaded, north-facing slopes, the dominant species include hemlock, yellow birch, and beech. Hickory is absent. In the Tom Swamp Tract, hickory grows on the west-facing slopes, to their bases, while beech is more common at the base of east- and north-facing slopes.

A few scattered specimens of hickory grow in less favored places. This suggests the gradual development of hardier strains as the climate, once drier and warmer, became cooler and wetter. During the warm-dry period often referred to as the postglacial optimum, oak, hickory, and chestnut probably were much more numerous in this region than at present (Braun, 1938, pp. 515-522; Sears, 1948, pp. 177-185).

(4) Basswood. The American linden, or basswood, is not common at Harvard Forest, although many sites are favorable for it. It grows commonly in proximity to hickory, as well as in stands of mixed transition and northern hardwoods. In many places basswood is growing as a sprout in recently cut areas, and in a few areas some basswood may be brought through to form part of a timber crop.

(5) Black Gum. The black gum trees growing at Harvard Forest are few in number, and are scattered throughout one single area. Black gum is distinctly a southern species which does best where the growing season is long and warm (Wilde, 1946, p. 60 ff.) and is here near the extreme northern limit of its range. In the Big Spruce Swamp, at an elevation of 1100 feet, it finds hot days and abundant moisture. The nights in this part of the Prospect Hill Tract are cold, but are not so excessively cold as in the low parts of the Tom Swamp Tract, where black gum does not grow. The Big Spruce Swamp is unusual in that it lies in a shallow saddle from which streams drain both to the west and east. It is possible that the peat accumulation in this swamp is not exceptionally thick, and that the roots of species such as the gum penetrate to underlying glaciofluvial deposits. One might suppose that black gum had been more abundant here on the moist soil during a warmer period when hickory was flourishing on drier sites, and that the peat accumulation, begun during an earlier period or periods of periglacial climate, had slowed or halted at that time, to be resumed later as the climate entered a cooler cycle. Black gum apparently is a minor but certain-to-be-present species throughout much of the central hardwood forest (Cheyney, 1942, p. 332). Its remarkable range of tolerance and hardiness is evident here where it grows intermixed with species of the northern forest. Its presence in the Big Spruce Swamp possibly gives additional evidence that the present climatic period is a warming one, in which central hardwood species such as hickory might again flourish on the uplands, as they did in the late pre-colonial period during a similarly warm period.

5. Distribution of Major Forest Types or Associations in Relation to Natural Factors.

The discussion in the preceding section has indicated chiefly the notable differences in shade tolerance, temperature-hardiness, and growth habits of selected individual species. It has emphasized the fact that many natural factors influence the growing tree, and that temperature is only one of those factors, though a very important one. The influence of different species upon each other is also a factor of great importance. This influence in some situations is competitive, as when red oak spreads out a wide canopy to rob slower-growing species of sunlight and heat. In other situations the relationship is co-operative, as when fast-growing but short lived forest "weed" species such as gray birch and pin cherry (frequently the first occupants of an opened area) provide frost protection for more sensitive species such as white ash. Later the situation becomes competitive, and the sensitive species, though having grown slowly at first, eventually replace the shortlived species (Cheyney, 1942, pp. 56-67). Because the various tree species differ in their life span, they compose varying proportions of stands at different times. Some are fast-growing, and for them for a time all else must stand aside. Others grow slowly, and at first or for long periods they remain subordinate to other species, then increase in importance when the fast-growing species die.

Some species, though few in number, are ever-present, and lend a distinctive character to the pattern as a whole. The very same species, however, when present in differing proportions, give a very different pattern.

In New England, as elsewhere, plant geographers and foresters find it difficult to reach agreement as to the number of distinct forest patterns to be recognized. Various classifications proposed differ considerably in detail, though each gives a generally useful understanding of the diverse kinds of forests in the region.

Each such classification gives recognition to one or more of the important natural factors which condition forest-species associations. It is worth noting at this point, however, that differing names are given to the main forest regions or formations and to their component types or associations, by various authorities, and that the bases for distinction differ in detail even where there is general agreement along broad lines. Moreover, they may appear to be quite different because of the dissimilar names applied to them. For example, the Canadian foresters and climatologists recognize a Great Lakes–St. Lawrence Forest as a southern transition zone between the true boreal or northern forest, consisting chiefly of conifers, and the great hardwood forests of eastern United States (Halliday, 1938, pp. 1055 ff.; Villeneuve, 1946, pp. 72-76; Hare, 1950, pp. 616-618). Foresters in eastern United States consider this same "transition" zone to include two elements: (1) a northern element which is considered to be a distinct forest formation or region and comprises the northern hardwoods, with hemlock; and (2) a southern element or transition forest, including some or all of the above, plus numerous so-called transition-hardwood species which have optimum growth in this zone. This transition zone also includes the more hardy species of the central hardwood forest which lies to the south. The distinction between these northern and transition forests in New England is based largely on the hardwoods. White pine is sometimes grouped with the northern forest, is sometimes given independent status, and is sometimes grouped with the transition forest. Like several other species, it never quite fits into the logical pattern of any classification. Obviously, with each species having different growth habits, limits of tolerance, and range, any grouping into types and formations must involve compromises and exceptions. This merely illustrates once again the difficulties and shortcomings inherent in almost all systems of regionalization (Hartshorne, 1939, pp. 472-481, 498-500).

Perhaps no classifications are more generally useful than those that simply describe the major contrasting patterns and associations that are sufficiently widespread and repetitive to be recognizable and describable, and which in many places appear to have some degree of local relationship or adjustment to combined topographic and climatic factors. The system employed in the discussion which follows is essentially of this type, and is substantially the same as that in common use at Harvard Forest (Spaeth, 1920, pp. 8-10; Fisher, 1933, pp. 213, 223; McKinnon, Hyde and Cline, 1935, pp. 1-18; Raup and Carlson, 1941, pp. 56-60; Lutz and Cline, 1947, pp. 15-21). The terminology is the same as that already employed in describing individual species in Section 4, above.

a. Northern-Forest Types or Associations.

(1) Northern Swamp-Forest Type. This is the typical spruce-tamarack swamp common on the numerous, and in places extensive, areas of poorly drained lands of the North. Its purest composition is in the lowlands, where the night temperatures are lowest. Tom Swamp is the best example of this type at Harvard Forest. The spruce forest there represents an outlier of the true boreal forest of Canada, and is the most truly "northern" forest type represented at Harvard Forest. Although black spruce and tamarack are the most common species, as is true farther north, other species are locally important. Hemlock is abundant in some less wet places; and red maple is common as a minor element. Trees are few or absent in many parts of the swamp, and a bushy formation consisting largely of northern-shrub species, such as Labrador tea and leather leaf, with an understory of sphagnum, is characteristic.

Upland spruce-swamp forests, by contrast, have less severe night temperature conditions and generally have a greater variety of species, including red spruce, hemlock, and such northern and transition hardwoods as are water-tolerant. This type has a large proportion of hardwood dominants if drainage is rather better and a large proportion of spruce if drainage is poorer, or if the acidic peat soils are deep. The Big Spruce Swamp includes both kinds of groupings, together with black gum, whose presence may indicate more complex successional history or a present trend toward a milder climate, or both. In the Big Spruce Swamp, some of the more northern and the most southern of the species represented at Harvard Forest grow side by side.

(2) Northern Mixed Hardwood - Evergreen Forest Type. In this type the major hardwood species are yellow birch, beech, sugar or hard maple, and paper birch. The chief evergreen, or softwood species are hemlock and, less commonly, white pine. Numerous transition-hardwood species are minor elements in varying proportions, and in some places the admixture of these is very great. The usual sites for this forest are cool and moist yet well drained, and the type becomes increasingly dominant northward in New England. On low slopes near swale edges but sunlit at least part of each day, yellow birch and hard maple may dominate. In very cool, shady places, but not limited to such sites, hemlock is more common and locally forms almost pure stands, the so-called ravine-forest type. A large part of the Slab City Tract south of Swift River is of this type. Locally, on sunnier sites, paper birch is more common and may form almost pure stands where temporary conditions, previously discussed, are favorable. Within parts of the northern-hardwood forest which have been undisturbed by man for long periods, white pine is also a prominent species, particularly where soils are lighter, or where unusual occurrences in nature have favored it at the expense of more vigorous species. Such white pine areas are rare at Harvard Forest, except in low-lying places with low night temperatres. The original pine-hemlock forest on the Fay Lot may have been of this type, with northern hardwood associates (Marshall, 1927, p. 9), but at present the hardwoods growing there with pine are those common to the transition and central forest (Lutz and Cline, 1947, p. 151).

b. Transition-Forest Types.

The term transition forest is used here in the New England sense. This transition forest, in its various forms, occupies a major part of the Harvard Forest. Several definite associations distinctly recognizable within the transition forest in central New England each occupy so much area locally as to merit individual discussion. Certain temporary types, such as the even-aged old-field white pine type, and the gray birch - pin cherry volunteer growth on cutover, burned over, or blowdown areas, are not discussed. The emphasis is placed, rather on describing associations which the forester will seek to develop as semi-permanent types.

(1) General Hardwood-Dominant Type. The usual transition hardwood forest includes a great variety of species, each in varying proportions according to differing site quality and to chance accidents in successional history. The most common species are red oak, red maple, black birch, and white ash, with additional minor species locally numerous. These include white oak, basswood, elm, and all the northern-forest species. As has been noted, red oak is an aggressive dominant on moderately dry sites, and red maple takes control on moist sites. This situation would not necessarily continue unchanged even in nature, and can be modified somewhat by careful silviculture to favor the best timber species. Large areas of Harvard Forest might ultimately be developed into hardwood-dominant stands, in which, however, species dominance will be varied from place to place in accordance with local differences in such site factors as elevation, slope, direction of exposure, soil type, ground water, land - water relationships, and current stage of vegetational succession. As has been seen, greatly contrasted sites lie in close proximity.

(2) Swale-Hardwood Type. In moist swales, and on moist terraces, where days are warm and nights comparatively cool for the region, and where the water supply is abundant much of the year, but not stagnant, white ash is a particularly abundant species, so much so as to form a distinct variant. The swales are very similar to many northern-forest sites; and some of the northern hardwoods, notably yellow birch, are common along the lower margins and on the swale floors where night temperatures are lower or where shade is deeper. The Fisher Stand is a good example of a swale-margin type.

Where these swale forests have been cut repeatedly without receiving silvicultural management they consist chiefly of red maple stump sprouts (coppice). This is particularly true in the lowest parts of swales, in many of which water stands for long periods. Many such wet areas are natural in origin. Others are a result of man having dammed streams for water power. The sluice gates have long since rotted away, but the earth dams remain and hold back some water at flood seasons; or at least the silt beds of the old ponds remain and provide a moist and fertile site. In the swale south of Stream Crossing station, for example, red maple is strongly dominant. The lower parts of Town Line Swamp also have considerable swamp red maple. In many such swamps, however, the original forest must have been a mixture which included many better species. In contrast to the swale edges with better water and air drainage, however, the swamp floors are much colder (at night), and northern species can be encouraged.

Soil drainage in many instances can be improved, or is actually sufficiently good to permit silvicultural eradication of inferior maple stump sprouts and to hasten re-establishment of a mixed forest, including white ash, elm, and yellow birch, together with red maple of seed origin (op. cit. p. 175-176).

(3) Evergreen-Dominant Type. Just as the dramatic occupation of abandoned old fields by white pine obscured the fact that most such fields had originally supported hardwood forests, so the present re-occupation of the cutover areas by hardwoods leads too easily to the conclusion that such lands are exclusively hardwood lands. Such a conclusion gains apparent additional support from the fact that the understory in most mature old-field pine stands consists chiefly of hardwoods. Temperature conditions obviously are suitable for either hardwoods or white pine, as the succession within the last hundred years has shown. Silvicultural experimentation at Harvard Forest during the thirty years preceding the disastrous hurricane of 1938 brought forth abundant evidence that on many sites at Harvard Forest, particularly on the heavier soils, hardwoods can and do prosper at this time to the almost complete exclusion of white pine. On some sites with light soils, such as Fay Lot Terrace, however, white pine and hemlock, with only a minor representation of hardwoods, appear to be the natural long-term forest type, under present conditions. The relationship appears to be chiefly to soil and only secondarily to temperature; and the conclusion is hard to escape that other parts of Harvard Forest now supporting hardwood growth almost exclusively might possibly include numerous local sites equally suited to white pine. Lutz and Cline (1947, pp. 107-142, and 171-173) emphasize that white pine can be matured successfully in a group-wise distribution among hardwoods on many sites with medium soils. On such sites the hardwoods do not find sufficient nourishment for the relatively rapid growth they experience on heavier, more fertile soils where white pine cannot compete.

Sandy outwash terraces, which are so common in New England and which have extensive areas of light soil, compose only a small part of Harvard Forest, notably along the edges of the Riceville Pond — Tom Swamp — Harvard Pond valley and some parts of the Swift River valley. It should be noted that elsewhere in New England the outwash soils are so very poor in places that pitch pine, rather than white pine or hemlock, is most common. On the outwash terraces at Harvard Forest, by contrast, the young growth after cutting is of hardwood in many places. As the years pass, however, white pine increases markedly on the lighter, sandy loam soils.

c. Central-Forest Type.

Only one central-forest type is represented at Harvard Forest - the oak-hickory (and formerly chestnut), most common on south, southwest, and west slopes of warm aspect. The temperatures and other factors favoring oak and hickory have been discussed in Section 4, together with mention of the earlier dominance of oak-hickory forests during the so-called postglacial optimum. Where these species attain dominance they eventually form an open forest. Borchert (1950, pp. 16 and 36) who carefully correlates his findings with those of numerous other investigators, points out that during the postglacial warm-dry period the central grasslands expanded quite far eastward, with outliers common at least as far as New York state. His climatic-controls maps provide an explanation for grassland origin even farther to the east than he claims. It may be that at such a time the warm, dry, southwest exposures and other dry sites in southern New England had a natural prairie cover, while the less dry, but nevertheless warm, sites had oak-hickory-chestnut forest. On the south slopes of Hickory Hill at Harvard Forest, as on similar sites, some of the present grassy forest floor may represent relict prairie, which became established during relative drought at the time of the postglacial temperature optimum, as Borchert and others have suggested. The giant Ledyard oak in southern Connecticut may have been a hardy pioneer invader of such a natural prairie.

On many slope sites at Harvard Forest a great number of species are in vigorous competition. This is to be expected when one considers that these long slopes leading from ridgetops with a semimarine climate to valley floors with a very extreme climate extend through almost the entire range of local macroclimates and include innumerable variations of microclimates as well. Facing the sun and intercepting the sun's rays at a very high angle of incidence, particularly during the growing season, these warm slopes nevertheless have sufficient local variation in steepness and soil type and moisture conditions to offer a great variety of sites, well suited to many kinds of silvicultural experiment. One may surmise that on some south slopes where hickory is not now represented, such as the south slopes of Prospect Hill and Little Prospect Hill, it might be possible to establish oak-hickory stands, associated with numerous transition hardwoods in many places, and with northern hardwoods near the bases of the slopes. White pine might be intergrouped on areas of lighter soil.

6. Factors Influencing Continuity or Change in Forest Composition.

Preceding discussion has emphasized that many of the most vigorous young stands at Harvard Forest are those bearing a close resemblance to the pre-colonial forest types which grew on the same sites, except where coppice types, such as red maple in wet swales, are dominant. Although temperature differences account for important differences in forest type from place to place, many species have a remarkable local range of temperature tolerance, and their distribution is influenced more directly by differences in ground-water conditions and soil type than by temperature differences (Coile, 1938, p. 1062 ff; Wilde, 1946, p. 66 ff). As has been seen, the distinctly different forest-types are few in number; but slight local differences in site quality or history may result in a type having a higher proportion of one species in some places and a higher proportion of another species at other places. It is reasonable to expect that over a period of time every site can be made to produce as great a variety of lumber trees as grew on the site in pre-colonial times and that by careful silviculture the quality of the trees can be made considerably higher than in untended stands.

In deciding what stand composition to favor, the forester must consider the relatively long life span of certain species, such as white pine, hemlock, and beech; and he must also anticipate that on each site the various species may come to maturity and dominance in waves. Also, the forester must anticipate that in every century at least one abnormal natural occurrence, such as strong wind, widespread fire, or prolonged drought, will be sufficiently severe to have a profound effect upon the forest succession. Were there no unusual occurrences in nature the replacement within stands would be relatively constant on a tree-by-tree basis. It is not unreasonable to assume that the unusual occurrences, together with cyclic trends, cause a certain amount of oscillation. Therefore, one may conclude that even though white pine, for example, apparently was rare in the Harvard Forest area in the late pre-colonial and colonial periods, it may have been more abundant just a few centuries earlier. So also with other species at other times.

Quite another factor which will be of increasing importance is the artificial or hastened improvement of species by plant geneticists. These efforts involve crossing of strains from widely separated regions. It might also be desirable to cross local strains growing in greatly contrasted sites which have extreme differences in temperature pattern, in soil fertility and structure, and in water supply and drainage.

The forests of New England grow somewhat more slowly than those farther south, but when carefully handled produce lumber of excellent quality and high sale value. The temperature and other natural factors are favorable to the growth of many valuable species, but nevertheless, impose certain limitations and local differentiations. In this region, where wages are high, it is questionable in many cases whether intensive plantation forestry will pay its way. On many sites the natural growth displays such vigor, and is evidently benefiting by such remarkably good adaptation to local environmental factors, that a less intensive type of forestry practice, aimed at establishing and improving the natural, usually mixed, stands of the native species appears to be more desirable than plantation forestry (Lutz and Cline, 1947, p. 21 and 27).

7. Effect of Local Temperature Differences upon Glacial Wastage and Postglacial Afforestation.

The greater severity of minimum temperatures occurring in valleys, and the lower mean temperatures occurring there, suggest that glacial and periglacial climates may have set in earlier and lasted longer in such locations than on the rolling uplands. During the periods of ice wastage this would have favored the continued existence of ice in the valleys long after the uplands were clear. Vegetation might have become established on the slopes and ridges while vast quantities of ice remained, often buried under, and flanked by, huge quantities of glaciofluvial deposits in the valleys. Under such circumstances coniferous forests probably would have preceded hardwoods, except on sun-drenched slopes (C. E. P. Brooks, 1949, p. 296). When the climate moderated, because of general, widespread influences, and locally because of ice wastage, the coniferous forests may slowly have been supplanted by hardwoods, except on exposed summits where strong wind caused excessive evaporation, or in areas where soil was of light texture, or in valleys and hollows where some sites were deeply shaded and where drainage was poor. In general, the hardwoods probably became dominant on those sites where few, if any, factors were unfavorable, while conifers held their ground wherever one or more factors were decidedly unfavorable for hardwoods.

C. E. P. Brooks (ibid) estimates that during the postglacial optimum the mean temperatures were perhaps 5° higher than at present. It has been shown that in Harvard Forest the mean temperatures of warmest and coldest stations differ by at least this amount. Local differences from place to place today may be as great as the differences between the coolest and warmest periods which occurred between early postglacial time and the present. The differing forest types now present at Harvard Forest probably include most types which were dominant in this region at one time or another in the long succession of minor climatic changes which have occurred since the last glaciation. Today, although hickory thrives on the warmest, well-drained sites, the spruce forests make their last stand in the cold, wet basins and valleys.

On many sites, as has been stated, temperature conditions favor many species, and it is chiefly the soil and ground-water conditions that encourage some species at the expense of others. Indirectly, however, these soil and drainage conditions are a result of local temperature differences which prevailed during long-past periods, particularly during periods of glacial and postglacial erosion and deposition. It is worth emphasis that the nature of these glacial and postglacial processes was controlled not alone by climatic cycles affecting a large portion of the earth simultaneously, but by the local, small-scale, climatic differences evident everywhere as a consequence of topographic diversity. These local climatic differences must have been particularly significant during periods of ice wastage. Although local climatic relationships between ice-free ridges and ice-filled valleys were no doubt complex, the chief climatic factor causing different rates of ice wastage on uplands and in valleys was quite probably differences in temperature. As has been seen, the differing patterns of upland soils and lowland soils are a reflection in large measure of differing manners of origin during glacial and postglacial periods; then, as previously and since, the differing physiographic processes taking place on uplands and in lowlands were in large part consequent upon differences in temperature.

In summary, it may be said that (1) present-day local temperature differences are of some direct significance in influencing forest-type distribution, (2) in the early postglacial period the local temperature differences probably had a direct influence upon the manner of original establishment of the various forest types, and (3) during earlier periods the local temperature differences affected physiographic agents and processes greatly; through these agents and processes the temperature differences were a principal determinant of soil patterns and ground-water relationships which persist today, and which influence the present forest-type distribution even more than do the present-day temperature differences. Thus it is seen, not only that present-day local temperature differences have a significant direct influence upon the present-day forest pattern, but that local temperature differences which obtained in ages past had an even greater, if indirect, influence upon that pattern.

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The basic field notes and all original thermograph traces from this study are filed at Harvard Forest and are available there for further reference and analysis by anyone wishing to use them. Copies of these basic records also are filed and available for reference in the Environmental Protection Research Division, Quartermaster Research and Engineering Command.

H. H. R.

Uijongbu, Korea
November, 1957

APPENDIX A. COMPARATIVE DATA FROM FIVE HARVARD FOREST STATIONS AND ELEVEN OTHER NEW ENGLAND STATIONS

MEAN DAILY TEMPERATURE

		1947 A	S	O	N	D	1948 J	F	M	A	M	J	J
WEATHER BUREAU STATIONS													
First Conn. Lake, N. H.	L	65.4	54.2	48.6	27.8	10.8	6.3	5.5	19.9	36.4	46.2	55.8	62.6
St. Johnsbury, Vt.	J	71.0	60.5	54.0	33.0	16.8	13.8	14.6	29.0	44.4	52.6	62.0	69.0
Concord, N. H.	C	70.3	59.6	55.2	34.6	21.4	14.1	16.4	31.0	43.8	52.8	61.6	70.0
Pittsfield, Mass.	P	68.7	59.4	53.8	34.0	21.8	15.0	18.3	31.1	43.6	53.0	61.9	67.8
Springfield, Mass.	S	74.4	65.4	60.6	40.6	28.9	22.2	25.2	38.8	50.0	59.4	67.2	74.8
Hartford, Conn.	H	73.2	63.7	57.8	39.0	27.8	20.0	23.2	36.3	47.8	57.4	65.9	73.4
Amherst, Mass.	A	73.2	62.9	57.4	38.0	25.6	18.0	21.4	34.9	47.2	57.3	64.4	72.4
Keene, N. H.	K	72.0	61.9	55.4	35.6	22.9	16.4	19.8	33.7	46.8	56.0	63.6	70.0
Worcester, Mass.	W	70.8	61.2	57.0	37.0	26.0	18.6	22.4	35.6	45.9	54.7	62.2	71.0
Boston, Mass.	B	73.2	64.8	61.6	41.2	30.4	23.4	26.6	38.0	48.0	55.0	63.6	74.5
Mount Carmel, Conn.	M	70.1	61.0	54.0	37.0	26.3	18.2	22.0	34.6	45.1	54.1	62.6	71.0
Mean of 11 W. B. Stations		71.1	61.3	56.0	36.2	23.5	16.9	19.6	33.0	45.4	54.4	62.8	70.6
HARVARD FOREST STATIONS													
Prospect Hill	PH	———No Record———					16	21	34	44	53	62	69
Harvard Forest Hdqtrs.	HF	68.9	60.0	57.7	35.1	22.9	16.3	20.0	33.0	46.0	55.0	63.2	71.3
Harvard Hill	HH	73	63	59	36	24	18	22	34	46	54	63	70
Tom Swamp	TS	68	59	52	33	21	13	18	31	43	54	61	66
White Pine Bottoms	WPB	———No Record———					14	17	29	44	53	60	66

DEPARTURE OF MEAN DAILY TEMPERATURE FROM NORMAL

		1947 A	S	O	N	D	1948 J	F	M	A	M	J	J
WEATHER BUREAU STATIONS													
First Conn. Lake, N. H.	L	+4.3	+0.4	+5.9	-2.4	-5.8	-5.0	-6.1	-2.1	+1.3	-2.3	-2.2	+0.9
St. Johnsbury, Vt.	J	+5.0	+1.7	+6.6	-1.2	-4.3	-2.4	-2.7	+0.4	+2.3	-4.6	-2.0	+0.8
Concord, N. H.	C	+4.8	+1.6	+7.4	-0.8	-2.6	-4.9	-3.9	+1.9	+2.2	-0.1	-0.1	+2.6
Pittsfield, Mass.	P	+3.4	+2.0	+7.0	-2.0	-3.1	-6.7	-3.1	+1.2	+2.7	-1.5	-1.2	+0.3
Springfield, Mass.	S	+3.0	+1.6	+6.7	-1.6	-1.9	-5.3	-2.3	+1.8	+1.5	+0.3	-0.9	+1.7
Hartford, Conn.	H	+4.3	+2.0	+6.6	+0.3	-2.0	-5.5	-4.0	+1.3	+1.1	-0.1	-1.2	+1.8
Amherst, Mass.	A	+4.9	+2.5	+7.1	-0.7	-1.8	-5.8	-1.9	+1.4	+2.3	+0.3	-1.0	+2.6
Keene, N. H.	K	+5.7	+2.5	+6.8	-1.1	-1.9	-4.7	-1.3	+1.7	+3.1	+0.7	+0.2	+1.2
Worcester, Mass.	W	+1.9	-0.8	+5.6	-2.7	-2.7	-6.8	-2.7	+0.8	+0.4	-2.7	-4.0	-0.1
Boston, Mass.	B	+3.3	+1.6	+8.0	-0.8	-2.1	-4.5	-2.2	+2.4	+1.6	-2.1	-2.9	+2.8
Mount Carmel, Conn.	M	NR	NR	NR	-2.9	NR	-7.4	-4.9	+1.5	+1.1	-1.0	NR	+0.9

HARVARD FOREST STATIONS
(No data available)

APPENDIX A. COMPARATIVE DATA FROM FIVE HARVARD FOREST STATIONS AND ELEVEN OTHER NEW ENGLAND STATIONS (CONT'D)

MEAN DAILY TEMPERATURE: DEVIATION FROM MEAN OF 11 WEATHER BUREAU STATIONS

		1947 A	S	O	N	D	1948 J	F	M	A	M	J	J
WEATHER BUREAU STATIONS													
First Conn. Lake, N. H.	L	-5.7	-7.1	-7.4	-8.4	-12.7	-10.6	-14.1	-13.1	-9.0	-8.2	-7.0	-8.0
St. Johnsbury, Vt.	J	-0.1	-0.8	-2.0	-3.2	-6.7	-3.1	-5.0	-4.0	-1.0	-1.8	-0.8	-1.6
Concord, N. H.	C	-0.8	-1.7	-0.8	-1.6	-2.1	-2.8	-3.2	-2.0	-1.6	-1.6	-1.2	-0.6
Pittsfield, Mass.	P	-2.4	-1.9	-2.2	-2.2	-1.7	-1.9	-1.3	-1.9	-1.8	-1.4	-0.9	-2.8
Springfield, Mass.	S	+3.3	+4.1	+4.6	+4.4	+5.4	+5.3	+5.6	+5.8	+4.6	+5.0	+4.4	+4.2
Hartford, Conn.	H	+2.1	+2.4	+1.8	+3.6	+4.3	+3.1	+3.6	+3.3	+2.4	+3.0	+3.1	+2.8
Amherst, Mass.	A	+2.1	+1.6	+1.4	+1.8	+2.1	+1.1	+1.8	+1.9	+1.8	+2.9	+1.6	+1.8
Keene, N. H.	K	+0.9	+0.6	-0.6	-0.6	-0.6	-0.5	+0.2	+0.7	+1.4	+1.6	+1.0	-0.6
Worcester, Mass.	W	-0.3	-0.1	+1.0	+0.8	+2.5	+1.7	+2.8	+2.6	+0.5	+0.3	-0.6	+0.4
Boston, Mass.	B	+2.1	+3.5	+5.6	+5.0	+6.9	+6.5	+7.0	+5.0	+2.6	+0.6	+0.8	+3.9
Mount Carmel, Conn.	M	-1.0	-0.3	-2.0	+0.8	+2.8	+1.3	+2.4	+1.6	-0.3	-0.3	0	+0.4
Mean of 11 W. B. Stations		71.1	61.3	56.0	36.2	23.5	16.9	19.6	33.0	45.4	54.4	62.8	70.6
HARVARD FOREST STATIONS													
Prospect Hill	PH	——No Record——					-0.9	+1.4	+1.0	-1.4	-1.4	-0.8	-1.6
Harvard Forest Hdqtrs.	HF	-2.2	-1.3	+1.7	-1.1	-0.6	-0.6	+0.4	0	+0.6	+0.6	+0.4	+0.7
Harvard Hill	HH	+1.9	+1.7	+3.0	-0.2	+0.5	+1.1	+2.4	+1.0	+0.6	-0.4	+0.2	-0.6
Tom Swamp	TS	-3.1	-2.3	-4.0	-3.2	-2.5	-3.9	-1.6	-2.0	-2.4	-0.4	-1.8	-4.6
White Pine Bottoms	WPB	——No Record——					-2.9	-2.6	-4.0	-1.4	-1.4	-2.8	-4.6

ABSOLUTE MAXIMUM TEMPERATURE

		1947 A	S	O	N	D	1948 J	F	M	A	M	J	J
WEATHER-BUREAU STATIONS													
First Conn. Lake, N. H.	L	89	83	80	66	41	30	45	59	64	78	86	85
St. Johnsbury, V.	J	96	89	86	66	45	37	50	65	71	83	93	92
Concord, N. H.	C	98	89	89	65	50	38	52	68	76	82	92	93
Pittsfield, Mass.	P	92	85	82	60	54	35	49	65	72	82	87	90
Springfield, Mass.	S	97	89	87	64	56	43	53	73	71	83	94	93
Hartford, Conn.	H	95	88	85	62	56	45	53	75	71	85	92	93
Amherst, Mass.	A	95	89	86	60	52	39	50	69	73	81	93	94
Keene, N. H.	K	96	89	85	63	48	38	50	70	74	83	93	93
Worcester, Mass.	W	96	89	86	63	57	42	51	70	72	84	93	92
Boston, Mass.	B	99	88	89	59	60	45	54	72	74	83	92	96
Mount Carmel, Conn.	M	94	87	84	62	56	45	51	73	71	84	92	94
HARVARD FOREST STATIONS													
Prospect Hill	PH	——No Record——					34	47	66	69	78	89	87
Harvard Forest Hdqtrs.	HF	96	86	83	60	50	38	50	66	71	81	88	89
Harvard Hill	HH	98	89	85	62	50	37	51	66	71	83	90	92
Tom Swamp	TS	94	88	86	63	52	39	52	68	73	81	92	91
White Pine Bottoms	WPB	——No Record——					35	48	61	69	80	83	84

APPENDIX A. COMPARATIVE DATA FROM FIVE HARVARD FOREST STATIONS AND ELEVEN OTHER NEW ENGLAND STATIONS (CONT'D)

MEAN DAILY MAXIMUM TEMPERATURE

		1947 A	S	O	N	D	1948 J	F	M	A	M	J	J
WEATHER BUREAU STATIONS													
First Conn. Lake, N. H.	L	78.2	66.2	62.4	36.3	20.6	17.8	23.2	36.4	47.9	56.3	67.9	74.9
St. Johnsbury, Vt.	J	84.6	74.5	70.0	42.3	26.4	25.0	29.1	43.5	57.1	63.3	74.7	82.8
Concord, N. H.	C	83.3	73.7	72.1	44.4	32.1	25.8	31.5	44.8	56.8	62.3	73.7	83.7
Pittsfield, Mass.	P	79.4	71.2	67.6	41.8	30.0	23.7	30.0	42.5	54.8	62.3	73.3	79.6
Springfield, Mass.	S	85.4	76.4	73.9	49.0	37.3	31.4	35.5	49.6	61.1	69.8	78.9	86.8
Hartford, Conn.	H	83.7	75.0	71.5	48.3	36.7	29.5	33.6	47.1	58.9	67.0	76.3	84.6
Amherst, Mass.	A	84.5	74.9	71.7	46.1	34.3	27.1	32.2	46.2	58.5	67.0	74.7	84.5
Keene, N. H.	K	84.2	74.7	71.2	44.2	32.1	26.6	32.2	46.5	59.2	66.1	76.0	83.5
Worcester, Mass.	W	82.2	72.6	70.7	45.6	35.5	28.5	32.9	47.1	57.3	64.9	71.6	82.1
Boston, Mass.	B	81.8	73.4	71.5	47.7	37.9	30.3	34.8	47.1	56.5	62.1	71.8	83.9
Mount Carmel, Conn.	M	82.1	73.6	69.2	47.4	36.3	29.0	34.3	46.7	57.5	66.1	75.8	86.3
Mean of 11 W. B. Stations		82.7	73.3	70.2	44.8	32.7	26.8	31.8	45.1	56.9	64.3	74.1	83.0
HARVARD FOREST STATIONS													
Prospect Hill	PH	——No Record——					24	29	43	54	62	71	79
Harvard Forest Hdqtrs.	HF	81.3	72.2	69.8	43.6	32.5	26.1	31.8	44.3	57.3	64.3	74.3	83.0
Harvard Hill	HH	85	74	71	44	32	26	32	45	56	64	75	82
Tom Swamp	TS	83	74	70	44	34	27	32	45	57	66	75	81
White Pine Bottoms	WPB	——No Record——					25	28	40	55	63	70	76

MEAN MAXIMUM: DEVIATION FROM MEAN OF 11 WEATHER BUREAU STATIONS

		1947 A	S	O	N	D	1948 J	F	M	A	M	J	J
WEATHER BUREAU STATIONS													
First Conn Lake, N. H.	L	-4.5	-7.1	-7.8	-8.5	-12.1	-9.0	-8.6	-8.8	-9.0	-8.0	-6.2	-8.1
St. Johnsbury, Vt.	J	+1.9	+1.2	-0.2	-2.5	- 6.3	-1.8	-2.7	-1.7	+0.2	-1.0	+0.6	-0.2
Concord, N. H.	C	+0.6	+0.4	+1.9	-0.4	- 0.6	-1.0	-0.3	-0.4	-0.1	-2.0	-0.4	+0.7
Pittsfield, Mass.	P	-3.3	-2.1	-2.6	-3.0	- 2.7	-3.1	-1.8	-2.7	-2.1	-2.0	-0.8	-3.4
Springfield, Mass.	S	+2.7	+3.1	+3.7	+4.2	+ 4.6	+4.6	+3.7	+4.4	+4.2	+5.5	+4.8	+3.8
Hartford, Conn.	H	+1.0	+1.7	+1.3	+3.5	+ 4.0	+2.7	+1.8	+1.9	+2.0	+2.7	+2.2	+1.6
Amherst, Mass.	A	+1.8	+1.6	+1.5	+1.3	+ 1.6	+0.3	+0.4	+1.0	+1.6	+2.7	+0.6	+1.5
Keene, N. H.	K	+1.5	+1.4	+1.0	-0.6	- 0.6	-0.2	+0.4	+1.3	+2.3	+1.8	+1.9	+0.3
Worcester, Mass.	W	-0.5	-0.7	+0.5	+0.8	+ 2.8	+1.7	+1.1	+1.9	+0.4	+0.6	-2.5	-0.9
Boston, Mass.	B	-0.9	+0.1	+1.3	+2.9	+ 5.2	+3.5	+3.0	+1.9	-0.4	-2.2	-2.3	+0.9
Mount Carmel, Conn.	M	-0.6	+0.3	-1.0	+2.6	+ 3.6	+2.2	+2.5	+1.5	+0.6	+1.8	+1.7	+3.3
Mean of 11 W. B. Stations		82.7	73.3	70.2	44.8	32.7	26.8	31.8	45.2	56.9	64.3	74.1	83.0
HARVARD FOREST STATIONS													
Prospect Hill	PH	——No Record——					-2.8	-2.8	-2.2	-2.9	-2.3	-3.1	-4.0
Harvard Forest Hdqtrs.	HF	-1.4	-1.1	-0.4	-1.2	-0.2	-0.7	0	-0.9	+0.4	0	+0.2	0
Harvard Hill	HH	+2.3	+0.7	+0.8	-0.8	-0.7	-0.8	-0.2	-0.2	-0.9	-0.3	+0.9	-1.0
Tom Swamp	TS	+0.3	+0.7	-0.2	-0.8	+1.3	+0.2	-0.2	-0.2	+0.1	+1.7	+0.9	-2.0
White Pine Bottoms	WPB	——No Record——					-1.8	-3.8	-5.2	-1.9	-1.3	-4.1	-7.0

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APPENDIX A. COMPARATIVE DATA FROM FIVE HARVARD FOREST STATIONS AND ELEVEN OTHER NEW ENGLAND STATIONS (CONT'D)

MEAN DAILY MINIMUM TEMPERATURE

		1947 A	S	O	N	D	1948 J	F	M	A	M	J	J
WEATHER BUREAU STATIONS													
First Conn. Lake, N. H.	L	52.5	42.2	34.9	19.3	1.1	-5.2	-12.2	3.4	24.8	36.0	43.6	50.3
St. Johnsbury, Vt.	J	57.5	46.5	38.1	23.7	7.3	2.5	0.2	14.6	31.8	41.8	49.4	55.1
Concord, N. H.	C	57.3	45.5	38.2	24.7	10.8	2.4	1.2	17.3	30.8	43.2	49.4	56.2
Pittsfield, Mass.	P	58.0	47.7	40.1	26.3	13.5	6.4	6.6	19.7	32.4	43.7	50.5	56.1
Springfield, Mass.	S	63.5	54.5	47.3	32.1	20.5	13.1	14.9	28.1	38.9	49.1	55.6	62.7
Hartford, Conn.	H	62.7	52.4	44.2	31.2	19.0	10.5	12.8	25.5	36.8	47.8	55.6	62.2
Amherst, Mass.	A	61.8	50.9	43.2	27.8	16.8	8.8	10.6	23.6	35.8	47.6	54.1	60.2
Keene, N. H.	K	59.7	49.1	39.6	27.1	13.7	6.3	7.4	20.9	34.3	45.8	51.6	57.6
Worcester, Mass.	W	59.4	49.9	43.2	28.3	16.6	8.8	12.0	24.2	34.5	44.5	52.9	59.9
Boston, Mass.	B	64.5	56.1	51.6	34.7	23.0	16.4	18.3	28.9	39.4	47.8	55.5	65.1
Mount Carmel, Conn.	M	58.1	48.4	38.7	26.6	16.3	7.4	9.8	22.5	32.7	42.1	49.7	55.6
Mean of 11 W. B. Stations		59.6	49.4	41.7	27.6	14.4	7.0	7.4	20.8	33.8	44.5	51.6	58.3
HARVARD FOREST STATIONS													
Prospect Hill	PH	———No Record———					9	13	24	35	44	52	59
Harvard Forest Hdqtrs.	HF	56.4	47.8	45.6	26.6	13.3	6.4	8.2	21.6	34.7	45.6	52.1	59.6
Harvard Hill	HH	61	52	47	29	16	9	13	24	35	45	51	58
Tom Swamp	TS	54	44	33	22	08	-1	3	16	29	41	47	51
White Pine Bottoms	WPB	———No Record———					3	6	18	32	43	49	55

MEAN MINIMUM: DEVIATION FROM MEAN OF 11 WEATHER BUREAU STATIONS

		1947 A	S	O	N	D	1948 J	F	M	A	M	J	J
WEATHER BUREAU STATIONS													
First Conn. Lake, N. H.	L	-7.5	-7.2	-6.8	-8.3	-13.3	-12.2	-19.6	-17.4	-9.0	-8.5	-8.0	-8.0
St. Johnsbury, Vt.	J	-2.5	-2.9	-3.6	-3.9	-7.1	-4.5	- 7.2	-6.2	-2.0	-2.7	-2.2	-3.2
Concord, N. H.	C	-2.7	-3.9	-3.5	-2.9	-3.6	-4.6	- 6.2	-3.5	-3.0	-1.3	-2.2	-2.1
Pittsfield, Mass.	P	-2.0	-1.7	-1.6	-1.3	-0.9	-0.6	- 0.8	-1.1	-1.4	-0.8	-1.1	-2.2
Springfield, Mass.	S	+3.5	+5.1	+5.6	+4.5	+6.1	+6.1	+ 7.5	+7.3	+5.1	+4.6	+4.0	+4.4
Hartford, Conn.	H	+2.7	+3.0	+2.5	+3.6	+4.6	+3.5	+ 5.4	+4.7	+3.0	+3.3	+4.0	+3.9
Amherst, Mass.	A	+1.8	+1.5	+1.5	+2.2	+2.4	+1.8	+ 3.2	+2.8	+2.0	+3.1	+2.5	+1.9
Keene, N. H.	K	-0.3	-0.3	-2.1	-0.5	-0.7	-0.7	0	+0.1	+0.5	+1.3	0	-0.7
Worcester, Mass.	W	-0.6	+0.5	+1.5	+0.7	+2.2	+1.8	+ 4.6	+3.4	+0.7	0	+1.3	+1.6
Boston, Mass.	B	+4.5	+6.7	+9.9	+7.1	+8.6	+9.4	+10.9	+8.1	+5.6	+3.3	+3.9	+6.8
Mount Carmel, Conn.	M	-1.9	-1.0	-3.0	-1.0	+1.9	+0.4	+ 2.4	+1.7	-1.1	-2.4	-1.9	-2.7
Mean of 11 W. B. Stations		59.6	49.4	41.7	27.6	14.4	7.0	7.4	20.8	33.8	44.5	51.6	58.3
HARVARD FOREST STATIONS													
Prospect Hill	PH	———No Record———					+2.0	+ 5.6	+3.2	+1.2	-0.5	+0.4	+0.7
Harvard Forest Hdqtrs.	HF	-3.2	-1.6	+3.9	-1.0	-1.1	-0.6	+ 0.8	+0.8	+0.9	+1.1	+0.5	+1.3
Harvard Hill	HH	+1.0	+2.6	+5.3	+1.4	+1.6	+2.0	+ 5.6	+3.2	+1.2	+0.5	-0.6	-0.3
Tom Swamp	TS	-5.0	-5.4	-8.7	-5.6	13.6	-8.0	- 3.4	-4.8	-4.8	-3.5	-4.6	-7.3
White Pine Bottoms	WPB	———No Record———					-4.0	- 1.4	-2.8	-1.8	-1.5	-2.6	-3.3

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APPENDIX A. COMPARATIVE DATA FROM FIVE HARVARD FOREST STATIONS AND ELEVEN OTHER NEW ENGLAND STATIONS (CONT'D)

ABSOLUTE MINIMUM TEMPERATURE

		1947 A	S	O	N	D	1948 J	F	M	A	M	J	J
WEATHER BUREAU STATIONS													
First Conn. Lake, N. H.	L	38	20	16	5	-17	-30	-41	-32	9	25		
St. Johnsbury, Vt.	J	41	22	16	9	-13	-31	-34	-22	15	26	[illegible]	[illegible]
Concord, N. H.	C	42	21	16	10	-12	-23	-26	-13	16	29	41	46
Pittsfield, Mass.	P	43	24	23	11	- 1	-16	-19	- 6	20	29	40	46
Springfield, Mass.	S	52	32	28	17	7	-18	-18	- 4	28	36	47	52
Hartford, Conn.	H	50	30	26	15	- 1	-16	- 9	- 4	25	32	47	53
Amherst, Mass.	A	48	29	23	15	0	-16	-10	-14	23	31	41	52
Keene, N. H.	K	43	24	20	12	- 7	-19	-23	-15	20	29	38	48
Worcester, Mass.	W	48	27	23	12	2	-14	-14	- 5	19	29	42	50
Boston, Mass.	B	54	37	38	25	12	- 3	2	1	30	42	47	53
Mount Carmel, Conn.	M	46	26	20	12	3	-16	-11	-11	19	26	40	44
HARVARD FOREST STATIONS													
Prospect Hill	PH	——No Record——					-14	- 6	- 6	20	34	41	48
Harvard Forest Hdqtrs.	HF	40	27	27	10	1	-19	-18	-15	19	28	37	48
Harvard Hill	HH	46	28	30	16	3	-14	-10	- 5	23	33	38	50
Tom Swamp	TS	33	18	11	3	-17	-33	-30	-31	12	20	31	37
White Pine Bottoms	WPB	——No Record——					-24	-25	-22	18	24	34	44

APPENDIX B - WEEKLY READINGS ON MAXIMUM AND MINIMUM THERMOMETERS AUGUST 1947 THROUGH JULY 1948

PROSPECT HILL TRACT

STATIONS WITH THERMOMETERS IN SHELTERS

APPROXIMATE WEEKLY PERIODS ENDING

STATION	ELEV. IN FT.	1947:		AUGUST				SEPTEMBER					OCTOBER				NOVEMBER					DECEMBER		
			4	11	18	25	1	8	15	22	29	5	13	20	27	3	10	18	24	30	8	15	22	31
Prospect Hill	1383	Max.																			49	42	50	27
		Min.																		16		6	6	5
High Swamp	1280	Max.																						27
		Min.																						2
Town Line Swamp	1125	Max.																			47	42	49	28
		Min.																		9	5	-1	2	-2
Locust Opening	1200	Max.																			50	40	50	28
		Min.																		11	10	6	4	
Lake Swamp	1125	Max.																						
		Min.																						-1
Harvard Forest Hq.	1100	Max.	86	85	95	96	90	82	86	81	63	70	76	83	80	77	59	45	49	41	50	39	50	30
		Min.	40	41	49	49	44	51	46	34	27	27	22	30	23	25	29	19	17	10	5	3	4	1
Little Prospect Hill	1300	Max.																						
		Min.																						
Northwest Midslope	1210	Max.																						
		Min.																						
Lower Spruce Hardwood	1150	Max.																						
		Min.																						
Big Spruce Swamp	1180	Max.																						
		Min.																						
Nelson Brook Flat	930	Max.																						
		Min.																						

STATIONS WITH NONSHELTERED MINIMUM THERMOMETERS

Prospect Hill	1383	Min.	29	37	48	31	30	28	19	19	16	12	6	6	
Brooks Hill	1250	Min.				31	30	27	17	19	15	12	7	6	5
Locust Opening	1200	Min.				29	28	28	18	19	12	11	7	5	4
Swamp Knoll	1140	Min.													
Pierce Road Swale	1100	Min.				21	24	25	15	17	9	5	-1	3	-1

APPENDIX B - WEEKLY READINGS OF MAXIMUM AND MINIMUM THERMOMETERS AUGUST 1947 THROUGH JULY 1948

1948. JANUARY				FEBRUARY				MARCH					APRIL				MAY				JUNE					JULY				
7	14	21	28	4	11	18	25	3	10	17	24	31	7	14	21	28	5	12	18	25	2	7	14	21	28	5	12	21	27	31
32	25 -2	32 -5	30 -6	27 -14	26 -6	48 8	45 7	41 4	41 -6	50 3	60 24	67 18	71 24	59 21	65 26	68 29	69 34	76 38	78 38	68 36	79 50	80 41	74 46	75 47	49	69 55	87 49	84 56	83 51	84 59
33 19	36 -6	33 -10	29 -18	29 -16	28 -16	48 2	43 -1	-6	-14	49 -3	61 17	65 16	71 24	61 19	65 19	69 26	70 27	79 37	81 36	69 35	81 45	82 36	75 45	78 41	43	90 49	90 47	85 48	83 46	84 55
32 19	36 -7	33 -12	31 -19	30 -15	28 -17	49 0	46 -5	41 -5	43 -15	49 -7	61 21	67 16	71 24	59 17	66 18	70 25	71 27	78 38	83 34	69 35	80 43	81 35	74 46	75 41	44	69 47	89 48	85 52	77 43	83 51
34 19	37	33 -7	31 -12	30 -15	28 -8	50	46 5	42 2	42 -6	50	63 19	65 14	70 24	60 21	66 21	69 28	70 33	78 38	81 38	69 35	81 45	81 37	75 45	78 44	44	69 47	90 50	86 51	82 45	84 56
33 19	38 -9	33 -17	32 -21	30 -15	28 -18	51 1	45 -3	44 -8	42 -19	49 -8	63 18	66 15	70 25	60 18	66 18	69 24	70 26	77 38	81 36	68 36	79 45	78 38	72 46	76 43	46	86 49	86 49	83 51	78 48	81 55
35 19	38 -6	33 -13	31 -19	29 -15	27 -18	50 2	46 -2	42 -5	41 -15	50 -6	63 20	66 16	71 26	61 19	67 19	69 27	70 28	77 40	81 37	68 38	79 46	80 37	74 48	76 42	84 46	88 49	88 50	86 54	85 48	87 57
																							73 46	72 46	49	83 54	84 49	80 54	75 52	79 59
																						83 38	76 45	78 43	49	90 48	90 50	86 53	81 50	85 55
																						78 38	71 46	74 44	50	85 53	85 50	80 50	75 52	
																										86 47	90 48	84 51	81 44	85 51
																											88 48	84 49	82 47	
18		-5	-7	-11	-7	8	6	4	-7	2	23	17	24	21	24	28	33	38	38	36	51	41	46	47	48	56		56	53	59
19	-3	-6	-9	-13	-7	8	6	3	-5	2	22	17	24	20	22	28	32	37	38	33	47	39	45	46	48	51	49	51	49	58
19	-3	-6	-10	-14	-8	7	5	2	-5	3	20	17	24	20	21	25	33	38	38	35	45	39	46	46	45	49	50	53	45	55
														16	18	24	28	36	34	35	43	35	46	42	44	47	48	51	44	54
				-17										17			25					35							43	

APPENDIX B - WEEKLY READINGS ON MAXIMUM AND MINIMUM THERMOMETERS AUGUST 1947 THROUGH JULY 1948 (CONT'D)

TOM SWAMP TRACT

STATIONS WITH THERMOMETERS IN SHELTERS

APPROXIMATE WEEKLY PERIODS ENDING

STATION	ELEV. IN FT.	1947:	AUGUST				SEPTEMBER					OCTOBER				NOVEMBER					DECEMBER		
			4	11	18	25	1	8	15	22	29	5	13	20	27	3	10	17	24	30	8	15	22	29
East Hill	950	Max.	89	90	94	95	96	88	87	81	64	73	79	85	82	79	61	47	49	40	50	42	50	
		Min.	45	52	51	60	47	56	53	36	28	28	33	43	28	28	28	19	19	14	12	6	5	
Trail Fork	860	Max.	90	89	93	93	98	86	87	82	65	72	79	86	82	78	59	49	48	41	50	43	50	33
		Min.	43	51	51	61	47	55	54	36	27	27	32	40	25	25	27	19	18	13	11	5	5	1
Fisher Stand	860	Max.																			51	44	51	31
		Min.																			9	3	4	-1
Stream Crossing	840	Max.									63	73	81	85	62	79	62	47	48	42	49	43	50	33
		Min.					31	38	44		20	20	23	31	15	20	24	15	12	5	2	-4	-2	-12
Hemlock Base	850	Max.	88	89	93	92	92	85	88	83	63	72	79	85	82	80	61	46	47	42	50	43	51	31
		Min.	39	48	49	59	49	51	50	33	22	23	26	36	20	23	25	16	15	10	8	1	2	-7
Harvard Hill	900	Max.	89	90	98	96	97	88	90	85	61	73	77	86	83	81	61	46	49	41	51	44	51	31
		Min.	45	53	52	59	49	57	55	33	26	30	33	42	29	28	30	18	19	15	11	5	4	4
Chestnut Grove	820	Max.																						
		Min.																						
Gravel Hill	800	Max.	89	88	93	93	92	84	87	80	61	69	77	82	80	76	60	45	47	41	51	44	51	
		Min.	43	52	53	61	49	55	54	35	27	29	31	39	23	25	30	20	18	9	7	2	4	
Mill Point	760	Max.	86	85	92	89	91	82	85	80	60	68	76	82	78	78	60	44	47	41	49	41	49	29
		Min.	43	51	52	60	47	54	53	36	26	28	30	37	21	24	28	20	17	8	6	5	5	-12
Riceville Pond	755	Max.																						29
		Min.																						-19
Fay Loc Terrace	780	Max.																						32
		Min.																						-13
West Boundary	900	Max.																					51	31
		Min.																				5	6	3
West Terrace	770	Max.																					51	32
		Min.																				-5	-4	-16
Tom Swamp	756	Max.	89	89	94	94	93	58	89	84		73	75	88	83	82	63	48	52	43	51	44	52	31
		Min.	33	41	46	53	36	45	43	29	18	22	27	28	13	18	25	13	11	3	1	-5	-3	-14

STATIONS WITH NONSHELTERED MINIMUM THERMOMETERS

STATION	ELEV. IN FT.	1947:	4	11	18	25	1	8	15	22	29	5	13	20	27	3	10	17	24	30	8	15	22	29
Red Pine Ridge	925	Min.					45	52	51	33	26	27	30	39	24	25	27	18	17	10	9	4	4	2
Hemlock Grove	840	Min.					44	52	51	33	24	24	28	37										
Blowdown	840	Min.					43	51	47	31	23	23	27	36	20	23	24	15	15	9	7	2	1	-9
White Ash Swale	885	Min.																						
Fisher Stand	860	Min.					47	53	53	35	26	27	31	38	22		26	16	17	11	8	3	4	-2
Mill Pond Flat	835	Min.																						
Fay Terrace Edge	780	Min.																						
Tom Swamp Bush	753	Min.	28	35		46	27	37	34	20		17	24	26	10	15	21			-1	-7	-11	-6	-19

1948	JANUARY				FEBRUARY					MARCH				APRIL					MAY				JUNE				JULY			AUGUST
5	12	19	25	2	9	16	23	1	8	15	22	29	5	12	19	26	3	10	17	24	31	7	14	21	29	5	12	21	27	1
	38	34	32		30	44	50	41	41	48	65	64	72	72	62	72	69	74	82	68	86	85	78	81	87	90	92		83	87
	-6	-8	-13		-6	-13	7	2	-5	3	22	18	26	23	24	30	30	39	39	38	51	38	47	44	46	51	50	51	50	57
37	39	33	32	29	30	44	50	42	42	48	66	65	72	72	61	72	72	76	83	68	85	85	78	80	87	90	91		87	86
3	-7	-11	-13	-15	-10	-14	8	0	-9	0	19	18	25	21	22	30	29	38	38	38	50	38	47	44	45	51	49	51	50	57
36	39	34	32	30	29	45	50	42	39	48	63	63	71	71	62	70	68	71	82	69	81	81	73	76	84	89	90	84	80	84
4	-10	-13	-15	-19	-12	-17	7	-3	-11	-2	18	17	25	21	21	29	29	36	37	38	50	37	47	43	44	49	48	40	49	55
35	40	35	33	35	33	43	53	42	42	52	62	61	75	75	63	75	69	73	79	70	84	87	76	79	90	91	93	90	84	90
1	-18	-25	-24	-27	-22	-27	2	-12	-23	-12	13	14		15	15	22	22	29	30	35	43	32	44	36	38	44	43	45	43	50
35	40	36	33	34	32	44	52	42	44	48	65	64	73	73	62	72	68		83	69	81		76	76	87	87		87		84
2	-18	-13	-21	-22	-15	-22	7	-7	-16	-4	17	16	26	19	18	26	27		31	36	44	31	45	36	37	44	48	44	43	50
35	40	35	32	31	30	45	51	42	42	48	63	63	73	71	61	71	68	71	83	69	83	83	77	78	85	90	92	86	84	85
4	-4	-7	-10	-13	-3	-11	8	1	-5	4	21	17	26	24	23	32	30	38	39	37	51	38	46	45	45	51	50	50	51	58
	37	33	33	29	30	44	48	42	39	46	59	59	71	70	60	72	68	73	82	66	82	84	72	76	84	87	90		82	84
	-10	-14	-13	-16	-13	-17	7	-5	-15	-2	19	17	26	20	20	28	28	35	36	36	48	36	47	41	33	49	47	49	48	49
	39	32	32			45	50	43	38	48	62	61	70	70	61	69	63	72	81	67	84	83	76	79	84	89	91		86	85
	-11	-17	-21			-23	8	-7	-23	-4	18	17	27	21	21	28	30	36	36	39	46	38	48	43	46	51	50	52	51	57
33	36	28	32		28	43	48	41	40	47	61	60	70	70	57	72	69		81	68	83	83	72	74	83	88	89		79	83
	-14	-23	-27	-23	-23	-25	3	-11	-26	-12	16	16	30	19	19	27	28		34	39	46	37	48	42	45	51	49	51	50	57
34	40	34	33		31	45	50	43	39	47	62	61	70	70	61	69	65	71	78	68	80	82	75	77	87	92	92		84	88
-1	-17	-31	-31	-27	-28	-28	1	-17	-31	-18	14	15	27	16	17	26	25	30	30	38	46	35	47	37	40	46	45	49	42	51
35	40	35	33		32	46	53	44	41	48	65	64	73	73	62	72	68	72	83	70	82	84	77	78	87	93	92	88	84	88
2	-16	-24	-27	-22	-25	-25	3	-12	-25	-13	13	12	26	13	13	22	22	26	27	35	43	31	45	33	40	42	41	45	39	48
34	40	34	32			45		44	40	45	64	63	71	71	62	70	67	72	80	68	79	79	72	73	81	87	86	82	78	82
5	-6	-8	-12	-13	-5	-12		0	-5	2	22	16	25	24	21	31	30	36	39	38	51	40	46	44		52	50	53	51	59
36	40	35	33		32	45	53	44	42	48	65	64	72	72	62	71	68	72	82	70	82	83	75	77	85	90	90		82	86
2	-19	-27	-29	-24	-27	-29	0	-14	-27	-15	13	11	25	13	13	20	21	27	27	35	43	29	45	33	36	41	41	43	40	48
35	40	35	32		30	44	51	43	40	45	64	63	73	72	62	71	66	72	81	70	81	82	76	77	84	91	90	85	82	85
0	-20	-29	-31	-27	-27	-30	0	-14	-28	-14	12	13	24	14	14	21	21	26	27	34	41	30	45	33	36	41	41	42	38	47
	-7	-10	-15			-15			-10				26	21	21	27	28	37	35	36	49	36	46	40	43	47	47	49	48	55
	-10	-15	-19						-24																					
													25	19	18	25	26	32	33	35	46	36	46	40	42	47	46	48	48	54
1	-10	-13																												
													25	15	15	21	23	28	29	35	39	33								
																										44	45	45	39	48
-4	-28	-16	-39		-33	-34	-6	-23	-35	-24	10	11		14	14	20	21	26	26	32	42	31		37	35	41	41	43	37	46

APPENDIX B - WEEKLY READINGS ON MAXIMUM AND MINIMUM THERMOMETERS AUGUST 1947 THROUGH JULY 1948 (CONT'D)

SLAB CITY TRACT

STATIONS WITH THERMOMETERS IN SHELTERS — APPROXIMATE WEEKLY PERIODS ENDING

STATION	ELEV. IN FT.	1947:	AUGUST				SEPTEMBER					OCTOBER				NOVEMBER					DECEMBER			
			4	11	18	25	1	8	15	22	29	5	13	20	27	3	10	17	24	30	9	16	23	30
Petersham [b]	1100	Max.	84			86	88	77	82	72	58								47					
	1055	Min.	48			56	49	56	55	38	30								20					
Hickory Hill Junction	1000	Max.																				50	48	31
		Min.																				5	5	2
Wildcat Hill	995	Max.																			49	50	46	30
		Min.																		11	12	7	6	3
Shelf Swamp	990	Max.																			49	50	48	30
		Min.																		7	4	0	1	-4
Coach Road	850	Max.																				52	51	32
		Min.																				0	1	-8
Burns Bridge	750	Max.																			52	52		32
		Min.																			5	-5		-23
River Meadow	725	Max.																						31
		Min.																						-18
South Boundary	850	Max.																				51	41	30
		Min.																				2	3	-7
Hemlock Knoll	795	Max.																			52	52	42	28
		Min.																		5	3	0	3	-8
Trailside Swale	750	Max.																						
		Min.																						
Transect Swale	748	Max.																			47	50	41	30
		Min.																		5	3		0	-12
White Pine Bottoms	690	Max.																			45	46	42	29
		Min.																		4	2	1	3	-11

STATIONS WITH NONSHELTERED MINIMUM THERMOMETERS

STATION	ELEV. IN FT.	1947:	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 22	Sep 29	Oct 5	Oct 13	Oct 20	Oct 27	Nov 3	Nov 10	Nov 17	Nov 24	Nov 30	Dec 9	Dec 16	Dec 23	Dec 30
Hickory Hill	1070	Min.									27	26	33	45	29	28	27	18	19	14	9	4	4	1
Shelf Swamp	990	Min.														22	27	18	17	9	7	2	2	0
Cave Road Swamp	930	Min.													22	23	28	19	17	10	10	5	6	1
Portal Swamp	920	Min.																						
Linden Terrace	860	Min.																						
Choate Farm Hill	930	Min.									26	27	27	35	12	22	29	18	15	8	8	7	7	-3
South Hill	1030	Min.														28	29		20					
Transect Knoll	760	Min.																						
Burns Bridge	750	Min.					35	46		31	19	20	24	30	14	20	25	11	12	4	2	-7		-17
Power Line Crossing	600	Min.											25	31	16	20	24	14	10	7	2	0		-8

APPENDIX B – WEEKLY READINGS ON MAXIMUM AND MINIMUM THERMOMETERS AUGUST 1947 THROUGH JULY 1948 (CONT'D)

1948	JANUARY				FEBRUARY					MARCH				APRIL				MAY					JUNE					JULY		
6	13	20	27	3	10	17	24	2	9	16	23	30	6	13	20	27	4	11	18	25	2	8	15	22	29	6	13	22	28	31
35	37	34	31	28	28	44	48			50	64	61	69	61		68	68	78	79	69	78	76	74	75		88	88		80	
7	-4	-6	-10	-13	-9	1	5	4	-6	2	22	15	21	21	24	29	30	39	39	37	47	37	46	47		49	51	53	50	60
35	38	33	32	30	30	44	50	41	40	48	64	60	71		61	70	66	79	82	71		81	74	77	89[a]	67	88	83	80	83
3	-8	-10	-15	-14	-10	-3	1	0	-8	1	21	16	26	21	21	26	28	39	37	37		37	49	42	55	48	48	55	48	56
34	36	34	32	32	31	43	45		39	50	63	61	72		62	73	69	80	84	71		86	77	79	92[a]	90	92	89	83	88
8	-5	-7	-15	-12	-9	-2	1	2	-5	3	22	16	26	22	21	28	29	40	39	37		40	46	45	51	50	49	50	49	59
34	38	34	32	31	29	44	50	41	40	51	64	61	71		60	69	66	79	82	72		81	75	78	90[a]	88	90	86	83	85
4	-15	-19	-21	-21	-17	-13	-5	-7	-16	-8	16	14	25	16	17	23	25	36	33	37		33	46	38	48	45	44	48	44	52
37	39	35	33	32	32	46	52	42	42	50	66	64	72		63	71	68	80	84	74		84	78	80	92	89	91	87	84	87
5	-15	-19	-24	-20	-23	-16	-10	-7	-23	-8	15	13	26	14	15	22	23	36	28	35		32	47	36	48	43	43	46	42	53
35	39	35	33	30	30		51	42	44	52	66	62	70	62	60	69	70	79	81	70	81	81	76	78	91	88	90	86	83	85
-1	-22	-30	-29	-27	-30	-21	-14	-12	-28	-14	12	13	26	14	15	22	21	35	27	32	38	31	46	34	44	42	42	45	40	52
36	40	35	33	30	31	46	52	42	40	50	66	63	72		61	70	67	81	83	71		81	76	79	91	89	90	85	83	86
1	-21	-30	-29	-27	-31	-21	-13	-16	-28	-15	12	12	25	14	15	21	21	35	27	32		32	46	35	44	42	41	43	40	50
37	38	34	33	30	29	46	51	42	45	50	63	63	72	62	61	69	70	79	82	71	81	81	76	77	90	88	89	85	82	85
6	-13	-18	-21	-17	-21	-14	-6	-7	-20	-7	16	15	27	16	16	24	25	36	32	36	41	35	47	39	49	45	45	47	45	54
34	38	34	32	29	28		51	42	42	51	64	61	70	60	59	68	66	78	81	69	79	79	73	76	87	86	67	82	80	83
7	-15	-20	-25	-20	-22	-16	-9	-5	-22	-8	16	14	27	17	18	25	25	38	30	37	41	34	47	37	48	45	45	47	43	54
								39		48	52	57	69	62	61	70	69	77	81	68	77	78	69	73	79	82	83	80	75	79
							-9	-6		-8	16	16	27	17	19	25	25	38	30	37	42	[illegible]	47	38	48	45	45	48	44	54
35	37	34	32	30	31	45	50	42	43	50	57	60	73	63		72	73	80	85	70		61	72	76	85	84	87	82	78	82
	-17	-22	-24	-21	-25	-15	-10	-8	-22	-8	16	15	26	17	16	24	24	36	29	35		34	47	37	48	44	45	47	43	52
33	36	35	32	28	29		49	41	39	45	60	57	69	60	57	68	66	77	80	68	78	78	71	74	82	83	84	80	77	77
4	-16	-23	-24	-22	-25	-17	-9	-7	-23	-8	16	16	27	18	19	26	26	38	30	35	42	34	47	38	48	45	45	47	44	55
7	-7	-7	-10	-13	-9	2	4	3	-5	3	21	15	24	22	23	28	29	39	38	36		37	46	43	50					
6	-12	-14	-16	-17	-13	-8	-2	-2	-10	-3	10	14	24	18	19	25	27	37	34	36		34	46	39	48					
7	-7	-10	-18	-15	-15	-8	-3	-4	-9	0	19	17	26	21	21	27	28	37	36	36		38	46	43	50	47	49	49	47	57
													25	17	18			37	28	35		34	46	37	46					
													25	15	15		22	36	28	33		31		35	48	43	43	45	40	52
			-19	-17										18																
															18	25	25	37	30	36		34		38	48	45	45	48	44	53
1	-21	-28	-28	-25	-28		-13	-11	-27	-14		14	26	15	15	22		35	27	32	37	31	46	34	45					
0					-27																									

a Readings taken June 30

b Readings for Jan. 20 and after are from station at High School

Appendix C-I DAILY MAXIMUM AND MINIMUM TEMPERATURES (°F) RECORDED ON THERMOGRAPHS - AUGUST 1947 THROUGH JULY 1948

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Means
AUGUST 1947																																	
Harvard Hill	Max.	79	81	82	65	88	90	83	84*	77*	82*	91	93	90	94*	95*	73*	66	83	90	82	73	90	93	86	96	85	75	78	81	73	85	85
	Min.	48	45	57	59	60	62	63	69	61*	63	53	63	69	72*	77*	64*	51	52	65	63	60	61	65	65	68	70	58	54	59	57	61	61
Tom Swamp	Max.	79	79	81	94	85	89	84	86	77	79	88	91	94	92	93	71	67	83	88	80	73	87	89	93	93	84	76	77	77	76	82	83
	Min.	44	33	43	48	47	51	49	69	60	63	41	49	61	59	65	60	55	46	57	63	59	58	53	56	58	41	58	44	51	47	59	[illegible]
SEPTEMBER																																	
Harvard Hill	Max.	85	77	83	87	79	85	86	75	85	81	85	87	89	73	84	73	75	73	70	65	65	70	57	61	57	54	56	62	68	55		74
	Min.	51	61	58	58	58	61	65	67	54	54	64	69	65	62	64	61	48	50	48	56	44	53	31	40	47	33	28	29	39	40		57
Tom Swamp	Max.	83	80	82	86	79	84	86	80	85	85	83	85	88	79	85	73	75	70	71	64	64	70	59	62	57	55	56	62	67	52		76
	Min.	39	48	47	45	49	53	57	60	48	43	55	68	62	62	61	43	33	37	44	28	31	54	27	28	43	28	18	18	21	39		44
OCTOBER																																	
Harvard Hill	Max.	57	63	67	72	73	79	79	71	64	66	74	76	58	77	80	85	83	80	72	75	71	77	82	60	64	74	83	73	67	57	62	71
	Min.	30	42	35	40	53	52	53	58	41	33	41	44	47	51	44	57	55	50	63	57	56	43	52	33	30	47	53	52	31	41	37	47
Tom Swamp	Max.	57	58	66	72	72	78	79	70	63	65	73	74	70	78	77	84	83	82	74	77	70	72	71	56	62	73	83	73	67	49	43	72
	Min.	21	20	23	26	38	39	37	39	30	30	25	27	27	43	28	33	34	45	59	41	36	22	29	28	11	27	31	35	59	40	35	33
NOVEMBER																																	
Harvard Hill	Max.	54	62	62	50	57	46	49	53	54	47	43	43	35	35	38	40	39	40	38	37	39	43	48	39	41	40	34	38	35	32		44
	Min.	32	30	34	44	42	42	44	41	32	31	24	29	19	23	21	27	28	30	24	20	26	21	35	27	34	30	19	23	21	16		28
Tom Swamp	Max.	52	63	63	51	56	47	49	52	53	46	45	45	42	35	34	43	39	40	38	39	40	41	51	40	42	42	37	43	34	34		44
	Min.	23	17	16	36	29	33	40	38	24	24	16	31	17	13	16	27	28	30	15	12	17	11	35	19	33	22	13	11	8	3		22
DECEMBER																																	
Prospect Hill	Max.									34	28	29	29	25	25	37	48	34	31	23	24	31	28	33	22	26	22	25	24	17	21		20
	Min.									19	13	19	16	15	5	18	32	22	14	6	6	17	15	16	14	7	13	19	16	6	5		8
Harvard Hill	Max.	36	38	50	48	23	27	39	43	38	33	35	33	30	31	37	49	35	33	17	28	34	32	22	25	29	24	28	20	19	24	26	[illegible]
	Min.	15	25	33	23	15	15	14	30	23	15	21	14	17	5	18	34	24	15	4	5	15	16	18	17	3	12	21	15	6	4	7	16
Tom Swamp	Max.	38	40	52	48	20	27	42	45	40	34	36	36	32	33	42	51	37	35	27	29	37	33	23	25	31	25	28	30	19	24	22	34
	Min.	2	9	31	17	13	4	1	31	22	7	22	-3	-1	-6	0	32	19	15	-5	3	1	9	8	15	-17	-10	22	-3	7	4	0	8
White Pine Bottoms	Max.								38	38	32	31	32	28	26	34	43	37	34	25	25	32	31	24	24	22	25	27	21	20	25	25	
	Min.								31	25	12	23	4	6	1	4	30	27	19	4	8	7	14	14	19	-11	-3	22	5	9	-3	4	
JANUARY 1948																																	
Prospect Hill	Max.	28	24	30	28	29	31	26	29	34	28	20	27	31	29	14	24	31	27	14	25	29	27	18	5	17	17	18	17	23	18	15	24
	Min.	21	18	21	23	23	23	20	18	29	3	-3	11	25	14	-5	2	21	7	-5	6	18	15	7	-6	3	4	8	-2	7	-14	-8	9
Harvard Hill	Max.	26	26	35	30	32	35	28	34	37	31	25	29	32	31	16	25	33	28	20	29	31	28	19	7	23	24	22	21	27	20	19	26
	Min.	22	20	22	25	24	23	20	18	18	4	-5	5	29	14	-7	1	21	9	-8	7	18	17	6	-10	5	2	8	-2	7	-14	-12	9
Tom Swamp	Max.	27	26	36	31	33	37	30	35	19	32	25	30	33	31	16	25	34	20	16	28	31	29	15	7	24	23	22	19	27	30	19	27
	Min.	20	21	23	23	22	22	20	7	2	5	-21	-19	28	-2	-19	-23	10	8	-29	-4	-1	6	-3	-31	4	-26	-15	-9	-5	-24	-15	-1
White Pine Bottoms	Max.	27	26	32	30	32	31	29	29	35	30	20	29	33	33	10	24	31	29	12	23	31	19	16	8	18	18	23	16	24	20	16	25
	Min.	21	20	22	24	23	24	22	11	6	4	-16	-11	28	0	-13	-14	10	9	-22	-5	0	15	3	-24	6	-19	-7	-2	-2	-17	-19	3
FEBRUARY																																	
Prospect Hill	Max.	22	27	24	9	23	22	25	25	16	18	21	34	26	41	27	34	47	43	40	44	25	30	24	27	41	38	36	31	26			29
	Min.	3	10	9	-1	5	7	4	17	-3	-6	5	19	17	28	8	13	12	30	17	22	9	14	7	9	19	27	23	19	14			13
Harvard Hill	Max.	25	31	25	11	25	27	27	28	19	22	23	38	30	43	27	36	51	45	42	46	27*	25*	27*	32	40	38	39	32	28			32
	Min.	-8	8	11	0	6	6	4	19	-4	-10	4	20	13	29	10	11	35	29	19	23*	10*	17*	9*	1	21	26	24	21	16			13
Tom Swamp	Max.	28	30	23	8	27	26	27	28	17	22	24	38	29	44	29	36	52	45	41	46	29	26	31	31	43	38	40	29	29			32
	Min.	-28	-16	5	-12	5	-13	-25	13	-22	-30	-21	14	-7	29	11	-4	35	19	13	24	1	16	-3	-13	22	21	16	18	17			3
White Pine Bottoms	Max.	21	26	20	9	23	22	22	27	17	17	24	34	28	37	29	33	48	44	40	39	24	23	25	28	38	36	36	28	27			28
	Min.	-22	-9	7	-5	7	-6	-18	11	-22	-25	-16	19	-2	28	12	1	32	22	19	24	7	17	0	-9	21	21	19	20	16			6
Burns Bridge	Max.				9	27	26	27	27	16	20	25	37	30	44	29																	
	Min.				-10	7	-12	-23	6	-30	-31	-21	18	-8	29	9	-4																
Stream Crossing	Max.																	50	44	41	43	29	25	28	36	42	39	41	30	31	35		
																		34			24	3	16	5	-7	21	21	15	19	18	-9		
Riceville Pond	Max.																	50	42	41	46	27	23	28	32	43	41	35	30	29			
	Min.																	35	22	15	23	4	16	1	-10	23	24	17	21	18	-15		

*Interpolated Values

APPENDIX C-1 DAILY MAXIMUM AND MINIMUM TEMPERATURES (°F) RECORDED ON THERMOGRAPHS AUGUST 1947 THROUGH JULY 1948 (CONT'D)

MARCH 1948

Station		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Means
Prospect Hill	Max.	35	22	34	32	23	36	31	32	40	41	34	26	27	33	46	48	46	45	47	51	57	60	55	61	53	53	51	58	43*	57*	66	43
	Min.	4	15	20	22	-6	-1	23	25	24	31	17	4	8	14	24	41	35	24	30	40	41	47	31	29	24	27	45	26	19*	25*	34*	24
Harvard Hill	Max.	30	25	36	38	24	42	32	38	43	39	34	32	33	34	48	48	49	44	44	57	59	63	55	62	51	54	54	54	44	59	66	45
	Min.	4	18	22	24	-5	-5	23	26	27	24	18	3	6	8	24	42	34	20	32	40	36	50	32	30	23	29	44	27	16	26	33	24
Tom Swamp	Max.	32	25	35	35	23	41	33	37	42	41	34	32	33	34	51	48	48	44	44	55	58	64	56	63	53	55	54	54	46	61	60	45
	Min.	-14	5	22	23	-5	-21	5	23	20	15	10	0	-17	-13	10	29	30	12	17	43	22	29	31	31	23	18	46	27	13	27	24	16
White Pine Bottoms	Max.	22	24	35	32	24	34	31	34	40	35	32	14	27	33	42	44	39	43	42	50	47	59	44	54	45	50	49	49	41	54	41	40
	Min.	-4	7	24	24	-3	-42	13	25	23	22	17	-4	-6	-7	16	33	33	26	21	36	25	34	34	32	27	22	37	29	16	27	28	18
Fisher Stand	Max.									43	37	35	30	33	36	48	48	49	47	45	55	57	41										
	Min.									23	13	16	0	-3	0	25	42	35	18	27	41	30	43										
Pay Lot Terrace	Max.	34	36	37	37	23	41	34	40	48	41	36	32	33	36																		
	Min.		9	22	23	-6	-24	13	24	24	18	15	2	-23	-10	09																	
West Boundary	Max.															47	46	48	45	43	55	58	65	58	63	55	53	53	54				
	Min.																41	35	21	29	43	35	49	33	30	24	27	46	27	15			
Transect Swale	Max.									43	37				34	47	48	46	50	47	55	57											
	Min.										20	9	-2	-4	-7			34	25	20	39	34											
Chestnut Grove	Max.																							53	59	53	51	52	57	46	58	44	
	Min.																							32	30	23	25	44	27	15	26	29	

APRIL

Station		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Means
Prospect Hill	Max.	55	52	38*	53*	69*	63*	61	47	43	41	44	47	54	44	45	58	49	54	53	65	59	61	68	68	63	62	55	49	51	55	54
	Min.	45	35	37*	21*	45*	51*	40	33	38	20	24	33	39	30	30	32	28	34	29	38	53	38	36	43	44	33	19	31	35	38	35
Harvard Hill	Max.	57	53	40	53	71	65	61	49	46	45	46	59	55	45	46	54	50	57	55	67	62	63	72	71	66	67	59	43	53	58	54
	Min.	31	36	31	26	43	49	36	34	33	23	23	36	41	31	30	28	30	24	32	40	41	32	34	43	47	32	30	31	36	39	35
Tom Swamp	Max.	57	54	37	53	73	66	63	50	44	44	47	68	53	44	46	59	48	55	58	67	64	63	70	71	65	67	55	51	54	59	57
	Min.	31	30	31	26	25	34	21	31	34	23	12	36	34*	32	31	20	31	13	24	39	42	20	13	34	34	22	23	22	32	29	29
White Pine Bottoms	Max.	58	49	37	45	69	63	60	52	46	45	46	56	50	45	46	57	49	55	56	65	62	60	68	64	67	63	56	49	53	55	55
	Min.	47	37	30	27	29	39	29	37	34	25	18	30	39	33	31	24	32	19	20	39	43	17	28	38	41	26	29	24	34	34	32
Hickory Hill Junction	Max.										47	47	57	55	47	46	61	50	55	58	67	62	60	70	69	62	63	57	51	52	54	
	Min.											21	34	42	32	32	27	31	21	29	39	41	23	30	40	44	24	20	25	36	34	
Wildcat Hill	Max.						70	61	50	47	46	46	56	54	47	47	62	49	60	60	67	62	63	74	73	62	67	60	49	57	58	
	Min.						49	34	34	33	23	21	35	40	32	31	28	32	21	19	39	41	31	32	40	45	28	31	29	36	37	
Shelf Swamp	Max.										45	44	59	54	46	46	60	51	55	57	67	61	61	69	68	63	64	57	50	52	56	
	Min.											14	36	30	31	30	24	31	17	27	39	41	24	27	38	42	23	25	25	34	33	
Couch Road	Max.										47	47	57	53	46	48	62	50	57	57	66	62	64	72	70	64	68	63	53	55	58	
	Min.											14	36	38	33	32	23	32	25	29	40	41	22	25	36	39	22	25	26	35	33	
South Boundary	Max.										47	48	58	53	44	47	61	52	56	57	68	63	64	70	69	64	66	60	49	53	56	
	Min.											16	35	38	34	32	25	31	17	27	40	42	25	28	39	41	24	27	28	36	34	
River Meadow	Max.	57	54	40	52	72	68	67	51	47	47	47	61	54	47	49	61	52	54	57	69	65	64	70	69	64	66	62	51	53	57	57
	Min.	51	30	31	26	25	35	24	35	34	24	13	37	35	34	32	21	32	14	24	40	42	21	23	35	37	30	24	24	35	30	30
Transect Swale	Max.																		60	59	66	63	63	70	71	64	67	61	50	54	56	
	Min.																		20	28	40	41	25	26	37	40	24	26	27	35	33	

MAY

Station		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Means
Prospect Hill	Max.	51	44	63	49	60	66	50	44	68	74	76	78	60	43	53	52	58	57	56	56	46	52	67	64	63	66	70	78	77	70	63	62
	Min.	34	38	39	33	41	38	39	38	38	50	47	51	43	35	37	41	43	47	41	34	37	37	41	47	50	52	52	57	56	60	55	44
Harvard Hill	Max.	55	48	66	71	60	65	53	44	68	81	79	83	63	45	54	54	63	64	61	61	48	57	68	67	58	68	81	81	80	71	66	64
	Min.	35	33	37	38	40	39	40	39	40	52	49	51	45	42	39	42	46	49	43	37	39	39	43	49	51	52	52	60	59	61	56	46
Tom Swamp	Max.	55	67	67	72	62	66	52	47	67	81	79	81	61	45	56	55	65	65	62	59	49	58	70	71	68	69	81	81	80	73	78	66
	Min.	33	20	27	25	31	39	38	40	41	51	44	49	45	40	35	27	45	50	42	37	38	40	33	48	44	53	41	49	48	57	57	42
White Pine Bottoms	Max.	52	45	68	69	68	63	54	45	44	77	78	80	64	46	55	53	62	61	58	54	48	53	64	67	64	64	75	77	76	68	64	63
	Min.	33	24	34	30	38	38	40	41	41	49	49	49	46	47	38	30	46	50	43	35	37	40	35	48	48	54	45	54	52	59	54	43
Hickory Hill Junction	Max.	56	65	64	71	51	67	51	46	65	79	77	83	63	45	55	55	60	63	43	57	48	55	46	70	64	64	81	80	79	70	65	64
	Min.	34	29	36	33	3[illegible]	37	40	39	41	52	49	53	45	41	39	37	45	49	43	35	39	39	43	48	49	53	49	56	55	61	55	44
Wildcat Hill	Max.	57	70	66	77	60	67	58	47	67	80	77	85	63	43	54	54	41	66	64	60	47	55	64	69	65	66	83	84	84	71	66	66
	Min.	34	31	39	38	41	40	40	39	40	50	50	51	45	41	39	38	44	48	43	37	39	39	40	47	50	53	52	58	54	61	55	44
Shelf Swamp	Max.	54	66	64	71	61	64	50	46	66	78	76	82	63	44	54	54	62	63	60	54	48	56	67	70	66	67	77	81	79	71	64	64
	Min.	34	25	35	31	37	39	40	39	40	50	48	46	44	40	37	32	44	46	42	37	37	39	34	47	48	52	44	53	51	59	54	43
Couch Road	Max.	56	68	68	73	62	69	53	47	66	80	81	85	64	45	58	55	66	66	63	60	49	56	68	73	64	65	83	84	83	71	67	66
	Min.	33	23	34	28	37	37	41	40	41	52	48	48	45	42	38	28	45	49	39	35	37	40	36	47	47	53	44	53	52	59	55	42
South Boundary	Max.	53	67	65	72	62	64	54	47	48	79	78	81	64	46	58	55	63	42	67	56	49	57	69	71	66	66	79	81	77	70	64	65
	Min.	34	25	33	31	31	38	41	40	41	51	48	48	46	42	39	38	45	49	42	37	38	40	36	48	48	53	48	59	52	59	56	43
River Meadow	Max.	56	67	66	73	62	66	53	47	67	81	81	84	64	48	58	54	65	66	61	59	49	58	69	71	66	65	80	80	80	71	67	66
	Min.	34	21	31	25	35	37	43	41	41	52	48	47	46	42	37	26	46	49	41	36	37	41	31	48	45	51	45	51	49	58	56	42
Transect Swale	Max.	57	69	65	72	61	66	52	46	67	79	78	55	64	46	57	55	63	61	63	55	47	54	67	69	58	65	78	78	77	68	63	64
	Min.	33	24	31	29	36	35	38	39	40	49	48	45	46	42	38	29	46	50	40	37	31	39	34	47	47	52	45	53	52	58	54	42

*Interpolated Values

APPENDIX C-1 DAILY MAXIMUM AND MINIMUM TEMPERATURES (°F) RECORDED ON THERMOGRAPHS AUGUST 1967 THROUGH JULY 1968 (CONT'D)

JUNE 1968		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Means
Prospect Hill	Max.	73	76	73	81	72	66	62	56	59	57	75	[illegible]	65	70	70	66	70	71	67	73	74	73	61	82	77	75	70	85	[illegible]	85		71
	Min.	50	58	53	55	50	43	46	49	45	44	[illegible]	[illegible]	[illegible]	48	53	51	53	47	57	54	53	57	49	49	49	67	55	58	66	69		57
Harvard Hill	Max.	78	83	78	83	74	72*	57*	62	55	62	77	77	[illegible]	78	72	71	76	76	70	78	75	75	65	83	67	77	71	84	90	88		75
	Min.	46	49	48*	51	53	38	43*	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	52	56	45	46	45	55	48	52	45	50	49	43	56	45	57	64	58		51
Tom Swamp	Max.	80	84	79	83	74	72	65	61	57	62	76	75	[illegible]	78	73	69	74	74	65	78	81	76	84	84	83	80	74	85	72	89		75
	Min.	43	38	41	46	53	31	33	57	49	47	48	50	45	46	54	40	38	33	53	42	39	38	43	51	56	46	63	40	58	60		47
White Pine Bottoms	Max.	71	78	73	78	70	66	54	60	58	56	64	67	60	70	71	65	70	69	64	71	73*	69*	74	78	78	72	71	79	83	83		70
	Min.	47	42	46	47	63	34	39	51	49	47	47	51	49	50	53	46	43	38	54	45	42	41*	48	51	62	52	55	59	60	62		47
High Swamp	Max	77	82	77	84	70	70	60	56	53	54	70	69	53	76	71	69	75	73	75	74	78	72	63	83	81	74	70	84	90	83		72
	Min.	46	47	47	49	53	34	43	49	45	44	44	47	46	45	51	44	44	41	53	44	47	43	45	49	43	51	53	57	54	65		46
Town Line Swamp	Max.	75	80	76	83	74	68	63	57	54	56	71	66	57	74	71	67	72	70	66	74	75	78	66	82	80	75	71	83	89	84		74
	Min.	43	45	47	47	53	35	41	50	46	45	45	49	47	46	53	47	45	41	53	47	45	45	46	51	63	53	54	59	61	65		49
Locust Opening	Max.	76	81	75	80	73	58	63	58	53	57	72	70	59*	75*	71	68	73	[illegible]	67	77	78	77	64	82	81	75	72	83*	88	86		72
	Min.	46	47	47	48	52	37	41	48	45	44	44	46	47*	46*	52*	46	46	43	54	47	50	45	47	49	61	54	54	57	63	67		49
Lake Swamp	Max.	73	78	74	77	74	66	63	59	55	57	70	68	58	72	70	66	70	65	67	74	75	71	66	80	79	77	77	81	86	84		71
	Min.	46	47	47	49	51	38	44	51	47	46	47	49	47	48	54	46	47	47	54	48	50	48	50	51	62	55	56	60	64	65		50
Little Prospect Hilltop	Max.	71*	74*	70*	78	71	62	59	58	56	55	65	64	56	67	68	64	69	68	64	70	73	69	63	75	74	73	67	83	83	83		68
	Min.	49*	50*	53*	55	50	38	48	49	47	46	45	49	47	49	54	50	50	47	53	51	53	53	49	50	61	54	56	59	65	69		52
Northwest Midslope	Max.	79	82	80	84	75	71	67	59	54	60	75	72	55	77	73	70	74	73	68	77	78	75	65	84	81	77	76	85	90	87		74
	Min.	45	48	53	49	53	38	46	50	46	44	46	49	46	45	53	49	48	47	53	49	48	49	46	47	62	54	55	59	65	68		50
Lower Spruce Hardwood	Max.	73*	76*	72*	79*	70*	65	63	58	55	56	69	66	58	72	68	64	67	67	66	71	74	69	65	79	78	74	71*	80	85	84		70
	Min.	48*	51*	53*	50*	57	38	47	51	47	46	49	49	47	48	55	50	49	45	53	51	53	53	52	50	62	55	56	59*	65	68		52
JULY																																	
Prospect Hill	Max.	79	73	78	80	85	80	69	77	81	82	85	87	77	74	79	82	78	84	75	79	82	78	67	71	74	76	83	79	79	83	83*	79
	Min.	65	55	57	60	61	61	48	55	60	59	60	65	64	60	55	55	56	59	61	58	62	57	57	52	51	54	61	64	59	62	57	59
Harvard Hill	Max.	84	78	87	83	87	83	72	80	86	87	87	92	78	77	83	85	79	84	80	81	80	85	70	77	80	77	83	84	83	85	84	82
	Min.	65	52	51	56	54	63	51	50	55	59	60	66	65	61	50	55	57	51	61	54	62	58	60	55	51	56	63	65	58	55	60	58
Tom Swamp	Max.	83	78	83	85	87	83	72	79	83	85	86	91	77	77	83	84	79	85	79	79	83	82	77	75	77	78	83	83	82	84	83	81
	Min.	44	45	47	44	46	63	51	40	41	46	58	54	63	61	41	44	49	51	46	45	51	58	52	54	37	42	59	64	47	45	69	51
White Pine Bottoms	Max.	76	71	74*	77*	81*	78	69	77	78	79	81	84	76	74	75	78	76	79	73	74*	77*	77	67	70	73	72	74	78	78	79	80	76
	Min.	65	49	45	48	49*	64	52	45	47	51	53	58	66	64	47	47	55	59	56	57*	57*	58*	58	55	44	48	61	64	55	55	69	55
Big Spruce Swamp	Max.	82	79	81	84	86	81	74	82	83	86	88	89	79	80	82	82	78	85	79	79	80	81	67	74	78	78	82	81	83	85	83	81
	Min.	65	52	47	51	50	62	49	48	49	53	55	60	66	61	51	51	56	59	58	52	57	56	57	54	44	49	61	65	53	53	67	55
East Hill	Max.	86	81	85	87	89	85	74	83	86	85	91	95	83	82	85	87	87	88	82	82	84	85	72	79	[illegible]	79	83	86	84	87	85*	84
	Min.	66	53	51	55	53	63	51	49	53	56	58	64	68	67	50	56	58	61	60	55	61	58	60	55	[illegible]	54	62	67	56	57	60	58
Fisher Stand	Max.	81*	76*	78	81	83	81	70	80	82	84	85	90	78	74	78	82	77	83	75	77	78	80	69	74	75	76	80	81	80	83	82	79
	Min.	65*	52*	50	54	51	63	51	48	52	55	57	63	67	61	49	54	55	59	58	54	59	58	60	55	48	53	61	67	55	56	69	57
Stream Crossing	Max.	86	79	83*	85*	89	86	72	81	87	87	90	95	84	78	85	87	83	89	78	82	82	85	71	77	79	78	82	83	83	88	87	83
	Min.	66	47	44	46*	48*	64	52	43	46	51	53	59	66	63	45	48	54	55	53	49	57	59	54	55	43	48	60	67	51	53	68	54
Fay Lot Terrace	Max.	84	78	82	85	88	84	73	81	85	87	88	93	83	80	83	85	82	88	80	[illegible]	83	83	70	77	79	78	83	84	84	86	85*	83
	Min.	64	45*	42	44	46	62	51	42	44	48	51	57	64	62	45	46	52	53	51	46	53	57	53	54	39	44	59	65	47	49	68	52
West Boundary	Max.	78	72	75	78	82	78	70	76	79	82	84	86	80	73	76	78	76	82	74	75	78	76	68	71	74	75	79	79	76	80	78*	77
	Min.	65	54	52	57	54*	62	51	50	54	56	59	64	67	61	52	56	57	61	51	54	61	59	59	55	51	54	63	67	58	59	69	58
Hill Point	Max.	82	74*	79	80*	84	80	71	77	82	84	86	89	82	75	77	81	77	82	75	77	79	78	69	73	74	76	79	79	79*	81*	80*	79
	Min.	67	52*	51	54	52*	65	54	49	51	56	58	65	69	63	50	53	58	59	57	53	59*	60	60	55	48	53	63	66	54	56*	68*	57

* Interpolated Values

APPENDIX C-II TEMPERATURE AND PRECIPITATION RECORD, HARVARD FOREST HEADQUARTERS

READINGS TAKEN ONCE DAILY AT APPROXIMATELY 1300 HOURS

AUGUST, 1947

Date	Temperature (°F) Max.	Min.	Precipitation Amt. in Inches	Kind
1	82.5	46.0		
2	71.0	40.0		
3	75.0	48.5		
4	78.0	52.0		
5	81.0	53.0		
6	84.0	55.5		
7	85.0	55.0		
8	76.0	55.0	0.25	Thunderstorm
9	82.0	62.0	0.05	Drizzle
10	75.0	60.0		
11	83.0	47.0		
12	85.0	54.0		
13	93.0	67.0		
14	91.0	66.5		
15	95.0	68.5	0.15	Thunderstorm
16	90.0	68.0	2.43	Thunderstorm
17	66.0	60.0		
18	74.0	49.0		
19	83.0	54.0		
20	84.0	61.0		
21	70.0	57.0		
22	79.0	57.0		
23	85.0	59.0		
24	88.0	60.0		
25	96.0	64.0	0.10	Shower
26	90.0	67.0		
27	79.0	57.0		
28	75.0	49.0		
29	73.0	56.0		
30	75.0	53.0		
31	76.9	58.0		

SEPTEMBER, 1947

Date	Temperature (°F) Max.	Min.	Precipitation Amt. in Inches	Kind
1	71.0	44.0		
2	76.0	53.0	1.20	Thunderstorm
3	77.0	52.5		
4	79.0	51.0		
5	80.0	53.0		
6	75.0	55.0		
7	81.0	58.0		
8	82.0	62.5		
9	79.0	51.0		
10	77.0	51.0		
11	82.0	46.0		
12	81.0	67.0		
13	83.0	67.0	0.97	Thunderstorm
14	86.0	60.5	0.10	Intermittent rains
15	76.0	60.0	0.55	Thunderstorm
16	81.0	60.0	0.22	Thunderstorm
17	70.0	41.5		
18	72.5	46.5		
19	74.5	57.0	0.05	Drizzle
20	69.0	34.0	0.03	Drizzle
21	62.0	40.5		
22	69.5	56.0	0.65 0.19	Heavy rain, turning to Drizzle
23	61.0	29.0		
24	57.0	31.0		
25	59.0	44.5		
26	55.5	32.0		
27	53.5	27.0		
28	57.5	26.5		
29	63.0	31.0		
30	63.0	41.5	0.07	Light rain

OCTOBER, 1947

Date	Temperature (°F) Max.	Min.	Precipitation Amt. in Inches	Kind
1	49.0	26.5		
2	54.5	38.5		
3	59.0	36.0		
4	67.5	37.0		
5	69.5	52.0		
6	73.5	52.0		
7	76.0	51.0		
8	76.0	54.5		
9	69.0	41.5		
10	61.0	21.5		
11	67.5	25.5		
12	69.0	27.0		
13	72.0	37.0		
14	72.0	34.0		
15	74.0	30.0		
16	79.0	36.0		
17	83.0	39.0		
18	81.0	46.5		
19	78.0	54.0		
20	72.0	43.0		
21	73.5	43.0		
22	69.0	24.0		
23	76.0	36.0		
24	80.0	23.0		
25	55.0	23.9		
26	72.0	37.5		
27	73.0	58.0		
28	76.5	51.5		
29	72.0	60.0		
30	66.0	40.0	1.76	Heavy winds and intermittent rains breaking long drought.
31	44.0	35.0		

NOVEMBER, 1947

Date	Temperature (°F) Max.	Min.	Precipitation Amt. in Inches	Kind
1	48.5	32.0		
2	55.0	24.5		
3	60.0	25.5		
4	59.0	41.5		
5	54.0	41.0		
6	53.9	37.8		Trace of rain
7	48.0	42.0		
8	49.0	39.0	1.57	Rains with heavy winds
9	54.0	28.5		
10	43.5	28.5		
11	45.0	20.0		
12	44.0	31.5	1.33 0.65	Rain turning to snow (5 inches.)
13	35.0	19.0		
14	37.0	19.5		
15	35.0	20.0		
16	40.0	26.5		
17	39.0	26.5		
18	37.0	28.5		
19	38.0	22.0		
20	36.5	18.5		
21	36.5	22.0		
22	38.0	17.0		
23	47.0	33.5	0.36	Rain
24	48.5	26.0	0.56	Rain
25	41.0	33.5	0.04	Rain
26	39.0	26.5		
27	38.5	14.0		
28	38.5	20.0		
29	37.5	15.0		
30	29.0	9.5		

APPENDIX C-11 TEMPERATURE AND PRECIPITATION RECORD, HARVARD FOREST HEADQUARTERS (CONT'D)

READINGS TAKEN ONCE DAILY AT APPROXIMATELY 1[illegible]00 HOURS

DECEMBER, 1947

Date	Temperature (°F) Max.	Min.	Precipitation Amt. in Inches	Kind
1	33.0	7.5		
2	35.0	16.0		Trace of snow
3	44.0	31.5	0.05	
4	30.0	14.0		
5	-	-		
6	24.5	13.5	0.51	
7	35.0	5.0		
8	42.0	29.0	0.27	
9	39.0	27.0		
10	29.0	14.0	0.13	Dry, fluffy snow, two-day total: 2 in.
11	31.5	22.0	0.07	
12	32.5	6.0		
13	33.0	16.0		
14	29.0	3.0		
15	33.0	10.0	0.50	Warm, melting rain
16	50.0	33.0		Trace of snow
17	44.0	24.0		
18	34.2	18.2		
19	31.4	4.0		
20	26.0	4.0		
21	31.0	8.0		
22	34.0	11.0		
23	30.0	13.0	0.60	Snow, two-day total: 10 in.
24	24.0	16.0	0.06	
25	26.0	3.0		
26	29.4	1.0	0.45	Snow, two-day total: 8 in.
27	27.0	21.0	0.18	
28	29.0	7.0		
29	28.5	7.0		
30	22.0	5.0		
31	25.0	8.0		

JANUARY, 1948

Date	Temperature (°F) Max.	Min.	Precipitation Amt. in Inches	Kind	Depth of snow on ground, in inches
1	26.0	19.0			
2	26.0	20.0	0.47	Dry, blowing snow, total 9 in.	15
3	30.0	22.0			
4	33.0	24.0			
5	30.0	25.0			14
6	35.0	23.0			
7	31.0	21.0	0.14		
8	28.5	17.0			
9	33.4	8.5	0.33	Wet snow, rain	
10	37.5	13.0			
11	18.5	-5.5			
12	24.0	-5.5	0.06	Wet snow, rain	
13	33.0	25.5	0.27	Wet snow; 3 in.	
14	33.0	1.5			12
15	24.0	-9.0			
16	19.0	-9.0			
17	31.0	14.5			
18	31.5	14.5	0.57	Snow: 6 in.	
19	33.6	-12.5			
20	26.0	- 6.5			
21	30.0	20.0	0.44	Snow: 4 in.	17
22	31.0	14.5	0.04	Snow: 2 in.	18
23	24.5	9.5			
24	14.0	-18.5			
25	18.5	- 7.5	0.49	Snow: 8 in.	24
26	20.0	-11.0			
27	21.5	- 2.0			
28	23.0	- 2.0			
29	22.0	6.0			
30	1.5	-14.5			
31	12.0	- 8.5			28-30

FEBRUARY, 1948

Date	Temperature (°F) Max.	Min.	Precipitation Amt. in Inches	Kind	Depth of snow on ground, in inches
1	22.0	-13.0			
2	26.5	- 6.0			
3	29.0	14.0			
4	19.5	- 6.0			
5	22.0	6.5	0.10	Light, two-day snow, total: 3 in.	
6	25.0	- 4.0	0.03		
7	25.5	-10.5			
8	26.0	17.0			
9	27.0	-17.5			
10	14.5	-17.0			
11	21.0	-10.5			
12	35.0	7.5	0.24	Snow, 3 in.	
13	34.0	2.0			
14	44.0	24.5	0.85		
15	38.0	11.0			
16	31.0	2.0			
17	46.0	30.0			
18	56.0	30.5			
19	43.5	18.0			
20	46.0	27.0			
21	30.0	8.0			
22	27.0	15.5	0.10	Snow, 2 in.	8, in fields 24, in woods
23	23.5	7.5			
24	26.0	- 1.5			
25	35.5	20.0			
26	42.0	23.0	0.05	Snow, 1 in.	
27	38.0	16.5			
28	39.5	20.5			
29	23.5	16.0	0.95	Snow, 8 in.	

MARCH, 1948

Date	Temperature (°F) Max.	Min.	Precipitation Amt. in Inches	Kind	Depth of snow on ground, in inches
1	27.5	- 4.5			
2	28.5	12.5			
3	34.0	23.0	0.73	Snow, 8 in.	
4	35.0	22.5	0.07	Snow, 1 in.	
5	31.0	- 5.5			
6	29.0	-14.5			
7	39.0	19.5	0.39	Rain, turning to snow, 1 in.	
8	33.5	28.0			
9	-	-			
10	41.0	21.0	0.05	Rain	
11	40.5	16.5	0.42	Snow, 6 in.	10, in fields 30, in swamps
12	23.0	1.0			
13	29.0	- 5.5			
14	31.0	- 2.5			
15	45.0	26.0			
16	47.0	40.5	0.43	Rain	
17	50.0	35.5			
18	41.0	20.0			
19	46.0	24.0	0.14	Rain	
20	51.5	37.0			
21	58.0	29.5	0.74	Warm, melting rain	0-14 in woods Fields clear
22	62.0	50.5	0.28		
23	63.0	33.5			
24	60.0	32.0			
25	61.0	26.0			
26	55.0	28.0			
27	[illegible]	48.0	[illegible]	Rain	
28	[illegible]	30.5	[illegible]		
29	[illegible]	[illegible]			
30	[illegible]	[illegible]			
31	[illegible]	30.5			

APPENDIX C-II TEMPERATURE AND PRECIPITATION RECORD, HARVARD FOREST HEADQUARTERS (CONT'D)

READINGS TAKEN ONCE DAILY AT APPROXIMATELY 1300 HOURS

APRIL, 1948

Date	Temperature (°F) Max.	Min.	Precipitation Amt. in Inches	Kind
1	65.0	52.0	0.91	Rain
2	55.5	49.5	0.06	Drizzle
3	49.5	31.5		
4	50.5	26.0		
5	62.5	35.0		
6	70.5	49.5	0.25	Rain
7	59.0	31.5		
8	60.5	34.5		
9	47.0	39.5		
10	41.5	24.5		
11	48.0	19.0		
12	55.0	36.0	0.79	Rain and some wet snow
13	59.5	42.0		
14	50.0	33.0	0.85	Rain
15	45.5	32.0		
16	57.0	26.0		
17	56.5	30.5		
18	52.0	19.0		
19	55.0	29.5	0.05	Rain
20	60.0	41.0		
21	67.0	53.0		
22	59.0	28.0	0.08	Rain
23	68.5	30.0		
24	69.5	43.0		
25	69.5	45.0		
26	56.0	26.5		
27	64.0	29.0		
28	56.5	28.0		
29	50.0	36.0		
30	53.0	34.5	0.42	Heavy rain

MAY, 1948

Date	Temperature (°F) Max.	Min.	Precipitation Amt. in Inches	(All Rain)
1	58.0	36.0		
2	61.5	27.5		
3	65.0	34.5		
4	-	-		
5	70.0	37.5		
6	61.0	40.0		
7	63.5	42.0	0.50	
8	46.0	41.0	0.27	
9	59.5	42.0		
10	65.5	53.0		
11	77.0	49.0		
12	77.0	54.0	0.22	
13	80.5	51.0	0.07 0.03	
14	52.0	44.0		
15	49.0	40.5		
16	56.0	36.5		
17	55.0	47.5	1.27 0.73	
18	62.5	50.0	0.87	
19	60.5	42.5		
20	58.0	38.0	[illegible]	
21	55.0	39.5	[illegible]	
22	50.0	40.5	[illegible]	
23	62.5	39.0	0.02	
24	67.5	49.5		
25	68.0	51.5	0.33 0.25	
26	65.0	55.0	0.19	
27	77.0	47.5		
28	79.0	59.0		
29	79.0	58.5		
30	77.5	63.5	0.07 0.07 0.43	
31	66.0	58.0		

JUNE, 1948

Date	Temperature (°F) Max.	Min.	Precipitation Amt. in Inches	(All Rain)
1	73.0	46.0		
2	77.0	47.0		
3	79.5	51.0		
4	79.5	49.0		
5	80.0	56.5	1.25	
6	65.0	36.5		
7	66.0	42.0	1.00	
8	60.0	52.5	0.03 0.04	
9	61.5	49.5	0.11	
10	54.0	48.0		
11	69.0	47.5		
12	73.5	52.5		
13	73.0	49.5	0.76	
14	70.0	49.5		
15	75.0	57.0		
16	72.5	47.0		
17	71.0	46.0		
18	73.5	41.5	0.50	
19	72.5	57.0		
20	73.5	51.0		
21	75.5	47.0		
22	78.0	45.5		
23	75.0	52.0	0.15	
24	77.0	53.5	0.08 0.50	
25	83.5	66.0	0.10	
26	82.5	57.0		
27	78.0	59.0		
28	80.0	65.0	0.83	
29	87.0	64.0	0.10	
30	88.0	72.0		

JULY, 1948

Date	Temperature (°F) Max.	Min.	Precipitation Amt. in Inches	(All Rain)
1	87.5	68.5	0.25	
2	83.0	53.0		
3	79.0	49.0		
4	82.0	53.0		
5	82.0	52.0		
6	86.0	66.0	0.78 0.56	
7	83.0	54.0		
8	78.0	49.5		
9	87.5	53.0		
10	85.0	57.0		
11	87.0	59.5		
12	88.0	64.0		
13	88.5	72.0	0.05 0.23	
14	78.5	66.0		
15	79.0	55.5		
16	82.5	54.0		
17	84.0	62.0		
18	86.0	63.5		
19	86.0	62.0		
20	80.0	55.0		
21	83.5	61.5		
22	82.0	62.0		
23	83.0	61.0	0.15 0.20	
24	94.5	58.0		
25	72.0	48.0		
26	79.0	67.0		
27	85.0	72.0	0.20 0.55 0.15	
28	85.0	58.0		
29	85.0	58.0		
30	87.0	73.5		
31	85.0	57.0		

APPENDIX D

RANK OF MAXIMUM-TEMPERATURE STATIONS, IN SHELTERS

Table of weekly maximum temperatures, with stations arranged in approximate order from warmest to coldest, according to their monthly averages of weekly maximum temperatures, compared to monthly average of the highest weekly maximum temperatures recorded each week, regardless of station. Scale is in actual F degrees (in contrast to minimum-temperature scales in Appendixes E and F which are in tenths of total ranges). Each series of comparable readings is set off by vertical lines.

Figure 106 shows placement of all stations for all months of operation.

AUGUST, 1947

Dev. in F°	Date of Reading:	4	11	18	25
1°	Harvard Hill	89	90	98	96
	East Hill	89	90	94	95
2°	Tom Swamp	89	89	94	94
	Trail Fork	90	89	93	93
	Gravel Hill	89	88	93	93
	Hemlock Base	88	89	93	92
3°	Harvard Forest Hq.	86	85	95	96
4°					
5°					
6°	Mill Point	86	85	92	89

SEPTEMBER, 1947

Dev. in F°	Date of Reading:	1	8	15	22	29
1°	Harvard Hill	97	88	90	85	61
	Tom Swamp	93	88	89	84	-
	Trail Fork	98	86	87	82	65
2°	East Hill	96	88	87	81	64
3°	Hemlock Base	92	85	88	83	63
4°						
	Gravel Hill	92	84	87	80	61
5°	Harvard Forest Hq.	90	82	86	81	63
6°	Mill Point	91	82	85	80	60

OCTOBER, 1947

Dev. in F°	Date of Reading:	5	13	20	27
1°	Stream Crossing	73	81	85	82
	East Hill	73	79	85	82
	Harvard Hill	73	77	86	83
	Tom Swamp	73	75	88	83
	Trail Fork	72	79	86	82
2°	Hemlock Base	72	79	85	82
3°					
4°	Harvard Forest Hq.	70	76	83	80
5°	Gravel Hill	69	77	82	80
6°	Mill Point	68	76	82	78

APPENDIX D

RANK OF MAXIMUM-TEMPERATURE STATIONS, IN SHELTERS (CONT'D)

NOVEMBER, 1947

Dev. in F°	Date of Reading:	3	10	17	24	30
1°	Tom Swamp	82	63	48	52	43
	Harvard Hill	81	61	48	49	41
2°	Stream Crossing	79	62	47	48	42
	Hemlock Base	80	61	46	49	41
	East Hill	79	61	47	49	40
3°	Trail Fork	78	59	49	48	41
	Harvard Forest Hq.	77	59	45	49	41
	Mill Point	78	60	44	47	41
4°	Gravel Hill	76	60	45	47	41

DECEMBER, 1947

Dev. in F°	Date of Reading:	8	9	15	16	22	23	29	30	31
	Burns Bridge		52		52		–		32	
	West Terrace					51		32		
	Tom Swamp	51		44		52		31		
	River Meadow								31	
	Gravel Hill	51		44		51		–		
	Fisher Stand	51		44		51		31		
1°	Harvard Hill	51		44		51		31		
	Trail Fork	50		43		50		–		
	East Hill	50		42		50		–		
	Stream Crossing	49		43		50		33		
	Coach Road				52		51		32	
	Fay Lot Terrace							32		
	Hemlock Base	50		43		51		31		
2°	West Boundary					51		31		
	Harvard Forest Hq.	50		39		50				30
	Prospect Hill	49		42		50				27
	Locust Opening	50		40		50				28
	Hickory Hill Junction				50		48		31	
3°	Shelf Swamp		49		50		48		30	
	Mill Point	49		41		49		29		
	Town Line Swamp	47		42		49				28
	Wildcat Hill		49		50		46		30	
	Riceville Pond							29		
	Hemlock Knoll		52		52		42		28	
4°	South Boundary				51		41		30	
5°	Transect Swale		47		50		41		30	
6°										
7°	White Pine Bottoms		45		46		42		29	

APPENDIX D

RANK OF RAINFALL-TEMPERATURE STATIONS, IN SHELTERS (CONT'D)

JANUARY, 1948

Dev. in F°	Date of Readings:	5	6	7	12	13	14	19	20	21	26	27	28
	Hemlock Base	35			40			34			34		
	West Terrace	36			40			35			33		
	River Meadow		36			40			35			33	
	Coach Road		37			39			35			33	
	Burns Bridge		36			39			35			33	
	Stream Crossing	35			40			35			33		
1°	Fay Lot Terrace	35			40			35			33		
	Tom Swamp	35			40			35			32		
	South Boundary		37			38			34			33	
	Harvard Hill	35			40			35			32		
	West Boundary	35			40			34			32		
	Riceville Pond	34			40			34			33		
	Fisher Stand	36			39			34			32		
	Trail Fork	37			39			33			32		
	East Hill	-			38			34			32		
2°	Hickory Hill Junction		35			38			33			32	
	Transect Swale		35			37			34			32	
	Hemlock Knoll		34			38			34			32	
	Shelf Swamp		34			38			34			32	
	Harvard Forest Hq.			35			38			33			31
	Lake Swamp			33			35			33			32
	Gravel Hill	-			39			37			32		
	White Pine Bottoms		33			34			35			32	
	Chestnut Grove	-			37			33			33		
	Wildcat Hill		34			36			34			32	
	Locust Opening			34			37			33			31
3°	Town Line Swamp			32			36			33			32
	High Swamp			33			36			33			29
	Mill Point	33			36			-			32		
4°	Prospect Hill			32			35			32			30
5°													

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FEBRUARY, 1948

Dev. in F°	Date of Readings:	2	3	4	5	10	11	16	17	18	23	24	25
	Fay Lot Terrace	-			32			46			53		
	West Terrace	-	32		32			45			53		
	Coach Road					32			46			53	
1°	Stream Crossing	33			33			53			53		
	Hemlock Base	34			33			44			53		
	River Meadow		30			31			46			52	
2°	Burns Bridge		30			30			-			51	
	South Boundary		30			29			46			53	
	Harvard Hill	31			30			45			51		
	West Boundary	-			-			45			-		
	Riceville Pond	-			31			45			55		
	Transect Swale		30			31			45			50	
	Wildcat Hill		32			31			43			49	
	Hickory Hill Junction		32			30			44			50	
	Shelf Swamp		31			29			44			50	
3°	Lake Swamp			32			28			51			46
	Tom Swamp	-			30			44			53		
	Trail Fork	29			30			44			52		
	East Hill	-			30			44			50		
	Locust Opening			30			28			50			46
	Hemlock Knoll		27			28			-			53	
	Fisher Stand	30			29			45			50		
	Gravel Hill	-			-			45			50		
	Harvard Forest Hq.			29			27			50			46
4°	Town Line Swamp			30			28			47			44
	White Pine Bottoms		28			29			-			49	
	Chestnut Grove	29			30			44			48		
5°	High Swamp			27			28			48			43
	Mill Point	-			28			43			48		
6°	Prospect Hill			27			25			46			46

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MARCH, 1948

Dev. in F°	Date of Readings:	1	2	3	8	9	10	15	16	17	22	23	24	27	30	31
	Burns Bridge		42			44			52			66			62	
	Coach Road		42			42			50			66			64	
	South Boundary		42			45			50			63			63	
	Trail Fork	42			42			48			66			65		
	West Terrace	44			42			40			65			64		
	Hemlock Base	42			44			48			66			64		
	Fay Lot Terrace	44			41			48			65			64		
1°	River Meadow		42			40			50			66			63	
	Hemlock Knoll		42			42			51			64			63	
	East Hill	41			41			49			65			64		
	Stream Crossing	42			43			52			62			63		
	Harvard Hill	42			42			48			63			63		
	Shelf Swamp		41			40			51			64				
2°	West Boundary	44			40			45			64			63		
	Tom Swamp	43			40			45			64			63		
	Fisher Stand	42			37			45			63			63		
	Wildcat Hill		-			37			50			59			61	
	Locust Opening			42			42			50			63			65
	Harvard Forest Hq.			42			41			50		63				66
	Hickory Hill Junction		41			40			48			64			60	
	Riceville Pond	43			39			47			62			61		
	Gravel Hill	43			38			48			62			61		
	Town Line Swamp			41			43			40			61			67
	Lake Swamp			41			42			49			63			66
	High Swamp			-			-			49			61			66
	Transect Swale		42			43			50			57			60	
	Prospect Hill			41			41			-			-			67
3°	Mill Point	41			40			47			61			60		
4°	Chestnut Grove	42			37			46			59			59		
	White Pine Bottoms		41			39			45			60			57	
5°	Trailside Swale		39			-			48			52			52	

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APRIL, 1948

Dev. in F°	Date of Readings:	5	6	7	12	13	14	19	20	21	26	27	28
1°	Stream Crossing	75			75			63			75		
	Hemlock Base	73			73			62			72		
	Fay Lot Terrace	73			73			62			72		
	Wildcat Hill		72			-			62			73	
2°	Transect Swale		73			63			-			72	
	Coach Road		72			-			63			71	
	East Hill	72			72			62			72		
	Tom Swamp	73			72			62			71		
	West Terrace	72			72			62			71		
	Trail Fork	72			72			62			72		
3°	Harvard Hill	73			71			61			72		
	River Meadow		72			-			61			70	
	West Boundary	71			71			62			70		
	Fisher Stand	71			71			62			70		
	South Boundary		72			62			61			69	
	Hickory Hill Junction		71			-			62			70	
	Harvard Forest Hq.			71			61			67			69
4°	Chestnut Grove	71			70			60			72		
	Town Line Swamp			71			59			65			70
	High Swamp			71			61			65			69
	Shelf Swamp		71			-			60			69	
	Locust Opening			70			60			[illegible]			69
	Lake Swamp			70			60			66			69
	Prospect Hill			71			59			65			68
	Trailside Swale		60			62			61			70	
	Riceville Pond	70			70			61			69		
	Gravel Hill	70			70			61			69		
	Burns Bridge		70			[illegible]			60			69	
5°	Mill Point	70			70			57			72		
	Hemlock Knoll		70			60			53			65	
6°	White Pine Bottoms		68			60			51			65	

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APPENDIX D

DATA OF MAXIMUM-TEMPERATURE STATIONS, IN SHELTERS (CONT'D)

MAY, 1948

Dev. in F°	Date of Reading:	3	4	5	10	11	12	17	18	24	25	31	June 2
	Transect Swale		73			82			85		79		-
	Coach Road		64			80			84		74		-
	Wildcat Hill		69			80			84		71		-
1°	Trail Fork	73			76			83		64		85	
2°	East Hill	69			76			82		64		86	
	River Meadow		67			81			83		71		-
3°	South Boundary		70			79			82		71		81
	Burns Bridge		70			73			81		70		81
	Stream Crossing	69			73			77		70		84	
	Fay Lot Terrace	68			72			83		70		82	
	West Terrace	68			73			82		70		82	
	Harvard Hill	68			71			83		69		83	
	Shelf Swamp		66			79			82		72		-
	Hemlock Dam	68			-			83		67		81	
4°	Mill Point	69			-			81		68		83	
	Gravel Hill	68			72			81		67		84	
	Chestnut Grove	68			73			82		66		82	
	Fisher Stand	68			71			82		69		81	
	Hickory Hill Junction		66			79			82		71		-
	Town Line Swamp			71			78		83		69		80
5°	Tom Swamp	64			72			81		70		81	
	High Swamp			70			79		81		66		81
	Locust Opening			70			78		81		69		81
	Hemlock Knoll		66			78			81		69		79
	Harvard Forest Hq.			70			77		81		68		77
	Lake Swamp			70			77		81		68		79
	Trailside Swale		69			77			81		68		77
6°	West Boundary	67			72			80		68		79	
	Riceville Pond	65			72			78		64		80	
	Prospect Hill			69			76		78		62		79
7°	White Pine Bottoms		66			71			80		65		78

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JUNE, 1948

Dev. in F°	Date of Reading:	7	8	14	15	21	22	28	29	30
	East Hill	85		78		81			-	
	Trail Fork	85		78		80			-	
	Stream Crossing	87		76		77			-	
	Coach Road		84		78		80			[illegible]
1°	Wildcat Hill		86		77		79			[illegible]
	Fay Lot Terrace	84		77		78				
	Harvard Hill	83		77		78			-	
	Gravel Hill	83		76		77			-	
2°	Northwest Midslope	83		76			78	85		
	Riceville Pond	82		75		77			87	
3°	High Swamp	82		75		78		87		
	West Terrace	83		75		77			85	
	Tom Swamp	82		76		77			84	
	Locust Opening	81		75		78			[illegible]	
4°	Hemlock Pass	-		76		[illegible]				
	Chestnut Grove	84		72		76			84	
	Fisher Stand	81		73		[illegible]				
	River Meadow		81		78		[illegible]			81
	Burns Bridge		81		76		75			[illegible]
	South Boundary		81		76		77			
	Shelf Swamp		81		75		76			[illegible]
	Harvard Forest Hq.	80		74		76			[illegible]	
5°	Town Line Swamp	81		74		75			83	
	Prospect Hill	80		74		75		83		
	Mill Point	83		72		74				
6°	Hickory Hill Junction		81		74					[illegible]
	Lake Swamp	78		72		76			[illegible]	
	Hemlock Knoll		79		73		76			
	Transect Swale		81		72		76			85
	Little Prospect Hill	-		73		72		79		
7°	West Boundary	77		72		73			81	
8°	Lower Spruce Hardwood	78		71		74		77		
9°	White Pine Bottoms		78		71		74			82
10°	Trailside Swale		78		69		73			79

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JULY, 1948

Dev. in F°	Date of Reading:	5	6	12	13	21	22	27	28	31	1
1°	Stream Crossing	91		93		90		84			90
	Fay Lot Terrace	93		92		88		84			88
	Riceville Pond	92		92		-		84			88
2°	Trail Fork	90		91		-		87			85
	Wildcat Hill		90		90		[illegible]		83	88	
	East Hill	90		92		-		[illegible]			87
3°	Coach Road		89		91		87		84	87	
	Harvard Hill	93		92		86		84			85
	Gravel Hill	89		91		-		86			85
	Harvard Forest Hq.	88		88		86		85		87	
	Tom Swamp	91		90		85		82			85
	West Terrace	90		90		-		82			86
	River Meadow		89		90		85		83	86	
4°	Northwest Midslope	90		90		86		81			85
	Shelf Swamp		88		90		86		83	85	
	Burns Bridge		88		90		86		83	85	
	High Swamp	90		90		85		83			84
	Locust Opening	89		90		86		82			84
	Hemlock Pass	87		-		87		-			84
5°	Fisher Stand	89		90		84		80			84
	South Boundary		88		89		85		82	85	
	Chestnut Grove	87		90		-		82			84
	Prospect Hill	89		87		84		83			84
	Big Spruce Swamp	86		90		84		81			85
	Nelson Brook Flat	-		88		84		82			-
	Mill Point	88		89		-		79			83
6°	Town Line Swamp	89		89		85		77			83
	Hickory Hill Junction		87		88		83		80	83	
7°	Hemlock Knoll		86		87		82		80	83	
	West Boundary	87		86		82		78		82	
	Lake Swamp	86		86		83		78		81	
8°	Transect Swale		84		87		82		78	82	
9°											
10°	Lower Spruce Hardwood	85		85		80		75			-
	Little Prospect Hill	83		84		80		75			79
	White Pine Bottoms		83		84		80		77	77	
11°	Trailside Swale		82		83		80		75	79	

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APPENDIX E

RANK OF MINIMUM-TEMPERATURE STATIONS IN SHELTERS

Consisting of tables of weekly minimum temperatures for stations where instruments were in shelters.

Stations are arranged in approximate order of rank from least cold to coldest.

Each series of comparable readings is set off by heavy vertical lines.

Scale is in tenths of monthly total of weekly ranges between least cold and coldest station. Stations in rank 1 are least cold; stations in rank 10 are coldest.

Example (Placement of Big Spruce Swamp for July, 1948; Page E-13.)

	Weekly range between least cold and coldest stations, in F degrees	Difference in F degrees: Highest weekly minimum minus Big Spruce Swamp minimum
1st week	14	8
2nd week	9	2
3rd week	14	5
4th week	14	8
5th week	12	8
Total	63	31

Total of $63^\circ \div 10$ (ranks) $= 6.3^\circ$ per rank.

Total of 31° for Big Spruce Swamp places it near bottom of 5th rank.

Minor adjustments in placement made upward or downward for reasons given in text, Chapter IV, Section 6. Figures 102 and 103 show placement of stations for all months of operation.

WEEKLY GROUND TEMPERATURES - AUGUST, 1947

STATIONS IN [illegible], IN APPROXIMATE ORDER FROM WARM TO COLD

Week of Month	1	2	3	4	5
Date of Reading	4	11	18	25	
Harvard Hill	41	57	[illegible]	[illegible]	
Gravel Hill	43	58	55	[illegible]	
Bush Hill	[illegible]	[illegible]	[illegible]	[illegible]	
Trail Fork	43	51	51	[illegible]	
Hill Point	43	51	[illegible]	[illegible]	
Hemlock Base	39	[illegible]	[illegible]	39	
Harvard Forest Hq.	[illegible]	47	[illegible]		
Tom Swamp	39	41	[illegible]	53	

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WEEKLY GROUND TEMPERATURES - SEPTEMBER, 1947

STATIONS IN [illegible], IN APPROXIMATE ORDER FROM WARM TO COLD

Week of Month	1	2	3	4	5
Date of Reading	1	8	15	22	29
Harvard Hill	[illegible]	57	55	33	[illegible]
Gravel Hill	[illegible]	59	56	35	27
Bush Hill	47	[illegible]	[illegible]	[illegible]	[illegible]
Trail Fork	47	51	54	36	37
Hill Point	47	54	53	36	34
Hemlock Base	49	51	50	33	23
Harvard Forest Hq.	44	52	48	36	37
Tom Swamp	36	43	43	[illegible]	18

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WEEKLY GROUND TEMPERATURES - OCTOBER, 1947

STATIONS IN [illegible], IN APPROXIMATE ORDER FROM WARM TO COLD

Week of Month	1	2	3	4	5
Date of Reading	[illegible]	13	[illegible]	27	
Harvard Hill	[illegible]	37	[illegible]	[illegible]	
Bush Hill	[illegible]	33	43	[illegible]	
Trail Fork	[illegible]	[illegible]	[illegible]	[illegible]	
Gravel Hill	[illegible]	31	[illegible]	33	
Hill Point	[illegible]	[illegible]	[illegible]	35	
Hemlock Base	[illegible]	[illegible]	[illegible]	[illegible]	
Harvard Forest Hq.	[illegible]	[illegible]	[illegible]	[illegible]	
Tom Swamp	[illegible]	[illegible]	[illegible]	13	
Forest Crossing	[illegible]	[illegible]	[illegible]	15	

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WEEKLY GROUND TEMPERATURES - NOVEMBER, 1947

STATIONS IN [illegible], IN APPROXIMATE ORDER FROM WARM TO COLD

Week of Month	1	2	3	4	5
Date of Reading	3	10	17	24	30
Harvard Hill	[illegible]	30	18	19	15
Bush Hill	[illegible]	[illegible]	15	19	14
Trail Fork	35	37	19	18	13
Gravel Hill	35	30	[illegible]	18	9
Harvard Forest Hq.	35	[illegible]	19	17	10
Hill Point	34	[illegible]	[illegible]	17	[illegible]
Hemlock Base	33	35	16	15	10
Forest Crossing	[illegible]	34	13	[illegible]	5
Tom Swamp	[illegible]	35	13	11	7

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Armed Services Technical Information Agency

ARLINGTON HALL STATION
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WEEKLY MINIMUM TEMPERATURES - DECEMBER, 1947

STATIONS IN SHELTERS, IN APPROXIMATE RANK FROM WARM TO COLD

Zone	Week of Month	1			2			3			4			5		
	Date of Reading	4	5		11	14		18	21		28	29	31			
1	Prospect Hill	-			8			6					5			
	Wildcat Hill		12			7			6			3				
	East Hill	13			4			5			-					
	West Boundary	-			5			6			3					
	Harvard Hill	11			3			4			4					
	Locust Opening	10			8			4					-			
2	Hickory Hill Junction		-			5			5			2				
	Trail Fork	11			9			3			1					
3	Fisher Stand	9			3			4			-1					
	High Swamp												8			
4	Harvard Forest Hq.	5			3			4					1			
	Gravel Hill	7			2			4			-					
	Lake Swamp												-1			
5	South Boundary					2			3			-7				
	Mill Point	6			3			5			-12					
	Hemlock Base	8			1			2			-7					
	Town Line Swamp	5			-1			8					-8			
	Shelf Swamp		4			8			4			-6				
6	Hemlock Knoll		3			0			3			-8				
	Coach Road					0			1			-8				
	Transect Swale		3			-			8			-12				
7	White Pine Bottoms		3			1			3			-11				
8	Stream Crossing	2			-4			-8			-12					
9	Pay Lot Terrace										-13					
10	Tom Swamp	1			-5			-3			-16					
	West Terrace	-			-5			-6			-18					
	River Meadow											-18				
	Mineville Pond										-19					
	Burns Bridge		5			-9			-			-23				

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WEEKLY MINIMUM TEMPERATURES - JANUARY, 1948

STATIONS IN SHELTERS, IN APPROXIMATE RANK FROM WARM TO COLD

Zone	Week of Month	1			2			3			4			5		
	Date of Reading	5	6	7	12	13	14	19	20	21	26	27	28			
1	Prospect Hill			-			-3			-5			-6			
2	Harvard Hill	4			-4			-7			-10					
	Locust Opening			19			-			-7			-12			
	Wildcat Hill		8			-5			-7			-15				
	West Boundary	3			-6			-6			-12					
	East Hill	2			-6			-6			-11					
3	Trail Fork	3			-7			-11			-13					
	Hickory Hill Junction		8			-8			-10			-15				
	High Swamp			19			-6			-16			-18			
4	Town Line Swamp			19			-7			-21			-19			
	Harvard Forest Hq.			19			-6			-13			-17			
	Fisher Stand	4			-10			-13			-13					
5	Chestnut Grove	-			-10			-14			-18					
	Lake Swamp			19			-9			-17			-21			
6	Gravel Hill	-			-17			-17			-21					
	South Boundary		6			-13			-18			-21				
	Shelf Swamp		4			-15			-19			-21				
	Hemlock Base	2			-18			-18			-24					
	Coach Road		3			-11			-19			-24				
	Hemlock Knoll		3			-21			-20			-25				
7	White Pine Bottoms		4			-16			-23			-24				
	Transect Swale		-			-17			-22			-26				
	Mill Point	-			-14			-22			-27					
8	Pay Lot Terrace	2			-14			-24			-27					
9	Stream Crossing	1			-18			-25			-24					
10	West Terrace	2			-18			-27			-28					
	River Meadow		1			-21			-30			-29				
	Mineville Pond	-4			-17			-31			-31					
	Tom Swamp	0			-20			-28			-31					
	Burns Bridge		-1			-22			-30			-29				

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WEEKLY MINIMUM TEMPERATURES - FEBRUARY, 1948

STATIONS IN SHELTERS, IN APPROXIMATE RANK FROM WARM TO COLD

Zone	Week of Month	1			2			3			4			5		
	Date of Reading	2	3	4	9	10	13	16	17	18	23	24	26			
1	Prospect Hill			-14			-8			8			7			
2	Wildcat Hill		-12			-9			-2			1				
	Harvard Hill	-13			-3			-11			8					
	Locust Opening			-15			-8			-			1			
3	Hickory Hill Junction		-14			-10			-3			1				
	West Boundary	-13			-5			-12			-					
	East Hill	-			-6			-13			7					
4	Trail Fork	-15			-10			-14			8					
	High Swamp			-16			-16			2			-1			
	Harvard Forest Hq.			-15			-16			2			-2			
5	Lake Swamp			-15			-16			1			-3			
	Town Line Swamp			-15			-17			0			-5			
	Chestnut Grove	-16			-13			-17			7					
	Fisher Stand	-19			-12			-17			7					
6	Shelf Swamp		-21			-17			-13			-5				
	South Boundary		-17			-21			-14			-6				
7	Hemlock Base	-22			-15			-22			7					
	Gravel Hill	-			-			-23			8					
	Hemlock Knoll		-20			-22			-16			-9				
	Coach Road		-20			-25			-16			-10				
8	Transect Swale		-22			-25			-15			-10				
	White Pine Bottoms		-22			-25			-17			-9				
	Mill Point	-25			-23			-25			3					
9	Pay Lot Terrace	-22			-25			-25			3					
	Stream Crossing	-27			-22			-27			2					
10	West Terrace	-24			-27			-29			0					
	River Meadow		-27			-32			-21			-13				
	Burns Bridge		-27			-30			-21			-14				
	Mineville Pond	-27			-26			-28			1					
	Tom Swamp	-27			-27			-30			0					

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WEEKLY MINIMUM TEMPERATURES - MARCH, 1948

STATIONS IN SHELTERS, IN APPROXIMATE RANK FROM WARM TO COLD

Zone	Week of Month	1			2			3			4			5		
	Date of Reading	1	2	3	8	9	10	15	16	17	22	23	24	29	30	31
1	Prospect Hill			6			-6			3			24			18
	Harvard Hill	1			-9			4			21			17		
	East Hill	3			-5			3			22			14		
	Wildcat Hill															
	West Boundary	0			-5			2			22			14		
2	Locust Opening			2			-6			-			19			14
3	Hickory Hill Junction		0			-8			1			21			16	
	Trail Fork	0			-9			0			19			16		
	Fisher Stand	-3			-11			-3			18			17		
4	Chestnut Grove	-5			-15			-2			19			17		
5	High Swamp			-6			-11			-3			17			15
	Harvard Forest Hq.			-5			-15			-6			20			16
	Town Line Swamp			-5			-15			-7			21			15
6	Hemlock Base	-7			-16			-4			17			16		
	Shelf Swamp		-7			-16			-8			16			14	
	Gravel Hill	-7			-23			-6			14			17		
	Lake Swamp			-8			-17			-8			14			15
	Trailside Swale		-6			[illegible]			-8			16			16	
	South Boundary		-7			-20			-7			16			15	
	Hemlock Knoll		-7			-22			-8			18			14	
7	White Pine Bottoms		-7			-23			-8			16			16	
	Transect Swale		-8			-22			-8			16			15	
	Coach Road		-7			-23			-8			15			13	
8	Mill Point	-11			-26			-12			16			16		
	Stream Crossing	-12			-23			-12			13			14		
9	Pay Lot Terrace	-12			-25			-13			13			12		
	Burns Bridge		-12			-26			-14			12			13	
10	Tom Swamp	-14			-26			-14			12			13		
	West Terrace	-14			-27			-15			13			11		
	River Meadow		-14			-24			-15			12			12	
	Mineville Pond	-17			-31			-16			14			15		

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WEEKLY MINIMUM TEMPERATURES - APRIL, 1964

STATIONS IN SHELTERS, IN APPROXIMATE RANK FROM WARM TO COLD

	Week of Month	1			2			3			4			5		
	Date of Reading	[illegible]	6	7	12	13	14	18	20	21	25	27	28			
1	Prospect Hill			[illegible]			25			[illegible]			[illegible]			
	Harvard Hill	[illegible]			34			39			34					
2	East Hill	[illegible]			[illegible]			34			[illegible]					
	East Boundary	31			34			[illegible]			[illegible]					
3	Trail Fork	31			31			32			30					
4	Gravel Hill	27			21			[illegible]			[illegible]					
	Wildcat Hill		[illegible]			[illegible]			21			[illegible]				
	Locust Opening			34			[illegible]			21			[illegible]			
	Fisher Pond	31			21			21			29					
	Hickory Hill Junction		34			21			21			34				
	Chestnut Grove	[illegible]			[illegible]			[illegible]			[illegible]					
5	Harvard Forest Hq.			[illegible]			19			19			27			
	Mill Point	20			19			19			27					
	High Swamp			34			19			18			[illegible]			
6	White Pine Bottoms		27			18			19			[illegible]				
	Hemlock Nose	[illegible]			19			18			[illegible]					
	Trailside Swale		27			17			13			[illegible]				
7	Lake Swamp			25			18			18			14			
	Town Line Swamp			24			17			18			25			
	Hemlock Knoll		27			17			18			25				
	Riceville Pond	27			14			17			[illegible]					
	Transect Swale		[illegible]			17			14			24				
8	South Boundary		27			18			18			24				
	Shelf Swamp		25			18			17			23				
	Stream Crossing	-			13			13			22					
9	Coach Road		16			14			15			[illegible]				
	Burns Bridge		[illegible]			14			13			23				
	River Meadow		25			14			13			23				
10	Pay Lot Terrace	[illegible]			13			13			22					
	Tom Swamp	34			14			14			21					
	West Terrace	35			13			13			20					

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WEEKLY MINIMUM TEMPERATURES - MAY, 1964

STATIONS IN SHELTERS, IN APPROXIMATE RANK FROM WARM TO COLD

	Week of Month	1			2			3			4			5		
	Date of Reading	3	4	5	10	[illegible]	12	17	18		24	25		31		
1	Prospect Hill			34			34		34			34				
2	East Hill	30			31			35			38			31		
	Harvard Hill	30			34			39			37			31		
	West Boundary	30			34			39			34			32		
	Locust Opening			33			34		38			35				
	Wildcat Hill		39			40			39			37				
	Harvard Forest Hq.			34		40			37			38				
	Trail Fork	39			38						38			30		
3	Fisher Pond	39			34			37			37			40		
	Gravel Hill	30			36			36			39			44		
	Hickory Hill Junction		[illegible]			39			37			37				
4	Chestnut Grove	38			32			36			38			42		
	Mill Point	38			-			34			39			44		
	Lake Swamp			34			34		36			36				
5	High Swamp			27			37		36			35				
	Town Line Swamp			27			34		36			35				
	Shelf Swamp		25			36			33			37				
6	Hemlock Nose	27			-			31			36			44		
7	Hemlock Knoll		25			38			30			37				
	Trailside Swale		25			38			30			37				
	Riceville Pond	25			30			30			38			44		
	South Boundary		25			34			32			36				
	White Pine Bottoms		24			38			32			33				
8	Transect Swale		24			36			29			35				
	Stream Crossing	22			29			30			35			43		
9	Coach Road		23			34			28			35				
10	Pay Lot Terrace	22			26			27			35			43		
	West Terrace	21			27			27			35			43		
	Tom Swamp	21			26			27			34			41		
	Burns Bridge		21			33			27			32				
	River Meadow		21			35			27			34				

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WEEKLY MINIMUM TEMPERATURES - JUNE, 1964

STATIONS IN SHELTERS, IN APPROXIMATE RANK FROM WARM TO COLD

	Week of Month	1			2			3			4			5		
	Date of Reading			2	7	8		14	15		21	22		28	[illegible]	[illegible]
1	Prospect Hill			50	41			46			47			49		
	Little Prospect Hill							46			46			49		
2	Wildcat Hill			-		40			44			45				51
	West Boundary				40			46			44				-	
	Lower Spruce Hardwood				38			46			44			50		
3	East Hill				38			47			44				46	
	Harvard Hill				38			44			45				45	
	Northwest Ridgetop				38			45			43			49		
	Gravel Hill				38			44			43				44	
	Trail Fork				38			47			44				45	
4	Harvard Forest Hq.			46	37			48			47			46		
	Lake Swamp			45	38			46			43				46	
	Fisher Pond				37			47			44				44	
	Hickory Hill Junction			-		37			49			42				55
	Mill Point				37			48			43				45	
	Locust Opening			45	37			45			44				44	
5	Chestnut Grove				36			47			41				43	
	High Swamp			45	36			45			41			43		
	Town Line Swamp			43	35			44			41				44	
6	South Boundary			41		35			47			39				49
	Trailside Swale			41		35			47			38				48
7	White Pine Bottoms			42		34			47			38				48
	Riceville Pond				35			47			37				40	
	Hemlock Knoll			41		34			47			37				48
	Transect Swale			-		34			47			37				48
8	Shelf Swamp			-		35			46			38				-
	Coach Road			-		32			47			36				48
9	River Meadow			-		32			46			35				44
	Stream Crossing				32			44			36				38	
	Hemlock Nose			- -	31			45			36				37	
	Burns Bridge			30		31			46			34				44
10	Pay Lot Terrace				31			45			33				37	
	Tom Swamp				30			45			33				36	
	West Terrace				29			46			33				34	

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WEEKLY MINIMUM TEMPERATURES - JULY, 1964

STATIONS IN SHELTERS, IN APPROXIMATE RANK OF WARM TO COLD

	Week of Month	1			2			3			4			5		
	Date of Reading	3	6		12	13		21	[illegible]		27	[illegible]		31	1	
1	Prospect Hill	55			49			54			53			59		
	Little Prospect Hill	54			49			54			57			59		
	Lower Spruce Hardwood	53			50			53			51			-		
2	West Boundary	57			50			53			51				59	
	Harvard Hill	51			50			50			51				58	
	Gravel Hill	51			50			52			51				57	
3	East Hill	51			50			51			50				57	
	Trail Fork	51			49			52			50				55	
	Harvard Forest Hq.	49			50			54			48			57		
	Mill Point	51			49			53			50				57	
	Wildcat Hill		50			49			50			49		59		
	Northwest Ridgetop	48			50			53			50			55		
4	Hickory Hill Junction		48			48			53			49		56		
	Lake Swamp	49			49			51			48			57		
	Locust Opening	47			50			51			45			56		
	Fisher Pond	49			48			49			48				55	
5	High Swamp	49			47			48			46			55		
	Town Line Swamp	47			48			52			43			54		
	Big Spruce Swamp	47			48			51			44			55		
	Chestnut Grove	49			47			49			48				49	
	Hollow Brook Flat				48			49			47					
6	South Boundary		45			45			47			45		56		
	Trailside Swale		45			45			48			44		56		
	White Pine Bottoms		45			45			47			44		55		
	Hemlock Knoll		45			45			47			43		54		
7	Riceville Pond	46			45			49			43				51	
	Shelf Swamp		45			44			48			44		52		
	Transect Swale		44			45			47			43		52		
	Hemlock Nose	44			48			44			43				50	
8	Coach Road		43			43			46			42		53		
	Stream Crossing	44			43			45			43				50	
9	Burns Bridge		42			42			45			40		52		
	River Meadow		42			42			43			40		50		
	Pay Lot Terrace	42			43			45			39				48	
10	West Terrace	41			41			43			40				48	
	Tom Swamp	41			41			42			39				47	

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APPENDIX F

RANK OF NONSHELTERED MINIMUM-TEMPERATURE STATIONS

Tables of weekly minimum temperatures for stations where instruments were not in shelters. Stations are arranged in approximate order of rank from least cold to coldest.

Scale is in tenths of the monthly total of weekly ranges between least cold and coldest station. Stations in rank 1 are least cold; stations in rank 10 are coldest.

<u>Example</u> (Taken from Fisher Stand, for October, 1947; Page F-3.)

	Weekly range between least cold and coldest station, in F degrees	Difference in F degrees between highest weekly minimum and Fisher Stand minimum
1st week	9	2
2nd week	13	6
3rd week	18	10
4th week	17	9
	57	27

Total of 57° for ten ranks equals 5.7° per rank.

Total of 27° at Fisher Stand places it near bottom of 5th rank.

Minor adjustments in placement made upward or downward, in some cases, for reasons given in text, Chapter IV, Section 6.

Figures 104 and 105 show placement of all stations for all months of operation.

Readings for Tom Swamp Bush thermometer (not at standard height) have been added at bottom of rank scale.

APPENDIX F. DATA OF NONSHELTERED MINIMUM-TEMPERATURE STATIONS

SEPTEMBER, 1967

	Week of Month	1	2	3	4	5
1						
2						
3	Hickory Hill					27
	Fisher Pond	47	33	33	39	28
4	Red Pine Ridge	43	34	32	39	26
5	Charlie Dunn Hill					26
	Hemlock Grove	44	50	31	33	34
6	Blackburn	43	51	47	31	23
7						
8						
9	Horse Bridge	39	46	-	31	19
10						
	Tom Swamp Bush	37	37	34	30	-

F-2

APPENDIX F. DATA OF NONSHELTERED MINIMUM-TEMPERATURE STATIONS (CONT'D)

OCTOBER, 1967

	Week of Month	1	2	3	4	5
1	Prospect Hill	29	39	48	31	
	Brooks Hill				31	
2						
3	Hickory Hill	26	33	43	29	
	Locust Opening				29	
4	Red Pine Ridge	37	38	39	34	
5	Cove Road Swamp				28	
	Fisher Pond	37	32	34	32	
6	Hemlock Grove	34	28	37		
7	Charlie Dunn Hill	27	27	35	19	
	Blackburn	23	29	36	20	
8						
9	Power Line Crossing		29	31	16	
10	Horse Bridge	30	34	30	14	
	Tom Swamp Bush	17	34	26	16	

F-3

APPENDIX F. DATA OF NONSHELTERED MINIMUM-TEMPERATURE STATIONS (CONT'D)

NOVEMBER, 1967

	Week of Month	1	2	3	4	5
	Date of Reading	3	10	17	24	30
1	Prospect Hill	37	38	19	19	10
	Snake Hill	28	39	-	30	-
	Brooks Hill	30	27	17	19	11
2	Hickory Hill	30	37	18	19	14
	Locust Opening	28	28	18	19	12
3						
4	Cove Road Swamp	23	28	19	17	10
	Red Pine Ridge	25	27	18	17	10
5	Wolf Swamp	22	27	18	17	9
	Fisher Pond	-	26	16	17	11
	Charlie Dunn Hill	22	25	18	13	8
6	Pierce Road Swale	24	25	15	17	9
7	Blackburn	23	24	15	13	9
8						
9	Power Line Crossing	27	34	14	10	7
10	Horse Bridge	30	29	11	12	6
	Tom Swamp Bush	15	21	-	-	-4

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APPENDIX F. DATA OF NONSHELTERED MINIMUM-TEMPERATURE STATIONS (CONT'D)

DECEMBER, 1967

	Week of Month	1		2		3		4			5
	Date of Reading	8	9	15	16	22	23	29	30	31	
1	Brooks Hill	12		7		4				3	
	Prospect Hill	12		6		4				-	
	Locust Opening	11		7		3				4	
2	Cove Road Swamp		10		5		6		1		
	Charlie Dunn Hill		8		7		7		-3		
3	Red Pine Ridge	9		4		4		2			
	Hickory Hill		9		4		4		1		
4	Fisher Pond	8		3		4		-2			
	Wolf Swamp		7		2		2		0		
5	Blackburn	7		3		1					
6	Pierce Road Swale	5		-1		3				-1	
7											
8	Power Line Crossing		2		0		-		-8		
9											
10	Horse Bridge		2		-7		-		-17		
	Tom Swamp Bush	-7		-11		-6		-19			

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APPENDIX F. [illegible] STATIONS (CONT'D)

JANUARY, [illegible]

Level	Week of Month / Date of Reading	5	6	7	12	13	14	19	20	21	26	27	28
	Week of Month	1			2			3			4		
1	Prospect Hill			10			-			-6			-7
1	Brooks Hill			10			-3			-6			-7
1	Locust Opening			10			-3			-6			-10
2	Hickory Hill		7			-7			-7			-10	
3	Red Pine Ridge				-7			-10			-11		
3	Cove Road Sump		7			-7			-10			-10	
4	Shelf Sump		6			-13			-16			-14	
5	Meadows				-10			-10			-10		
5	Pioneer Stead	1			-10			-10					
5	Chapts Farm Hill											-15	
6													
7													
8													
9	Power Line Crossing		8									-27	
10	Burns Bridge		1			-21			-20			-20	

Top Sump Rock: -4, -20, -14 (Under cover), -23

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APPENDIX F. [illegible] STATIONS (CONT'D)

FEBRUARY, [illegible]

Level	Week of Month / Date of Reading	2	3	4	9	10	11	16	17	18	23	24	25	1
	Week of Month	1			2			3			4			5
1	Prospect Hill			-11			-9			4			4	
1	Brooks Hill			-13			-7			4			4	
1	Locust Opening			-14			-8			7			3	
2	Hickory Hill		-13			-9			3			4		
3														
4	Shelf Sump		-17			-13			-8			-2		
4	Red Pine Ridge							-11						
4	Cove Road Sump		-13			-15			-8			-2		
5	Chapts Farm Hill		-17											
5	Pierce Road Swale			-17										
6														
7														
8														
9														
10	Burns Bridge		-19			-18			-			-13		

Top Sump Rock: -22, -14, -6, -23

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APPENDIX F. [illegible] STATIONS (CONT'D)

MARCH, [illegible]

Level	Week of Month / Date of Reading	1	2	3	8	9	10	15	16	17	22	23	24	29	30	31
	Week of Month	1			2			3			4			5		
1	Prospect Hill			4			-7			2			23			17
1	Brooks Hill			3			-5			2			22			17
1	Hickory Hill		3			-3			3			21			13	
1	Locust Opening			2			-6			3			20			13
2																
3	Cove Road Sump		-6			-9			0			19			17	
4	Red Pine Ridge				-10											
4	Shelf Sump		-2			-10			-1			10			14	
5																
6																
7																
8																
9	Burns Bridge		-11			-27			-16			-			16	
10																

Top Sump Rock: -23, -35, -36, 10, 11

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APPENDIX F. [illegible] STATIONS (CONT'D)

APRIL, [illegible]

Level	Week of Month / Date of Reading	5	6	7	12	13	14	19	20	21	26	27	28
	Week of Month	1			2			3			4		
1	Prospect Hill			24			21			14			30
1	Hickory Hill		24			22			23			28	
2	Brooks Hill			24			20			27			28
3	Red Pine Ridge	26			21			23			27		
3	Cove Road Sump		26			21			21			27	
3	Locust Opening			24			20			21			28
4													
5	Chapts Farm Hill					18							
5	White Ash Swale	25			15			18			25		
5	Shelf Sump		24			18			19			25	
6	Portal Sump		25			17			18			-	
6	Pierce Road Swale						17						
7	Sump Knoll						16			18			24
7	Transect Knoll								18			25	
8													
9	Burns Bridge		26			13			13			20	
9	Mill Pond Flat	25			15			13			21		
9	Linden Terrace		25			19			15			-	
10													

Top Sump Rock: -, 14, 14, [illegible]

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APPENDIX F. DATA OF [illegible]-TEMPERATURE STATIONS (CONT'D)

MAY, 1968 (JUNE)

	Week of Month	1			2			3			4			5		
	Date of Reading	3	4	5	10	11	12	17	18		24	25		31	1	2
1	Prospect Hill			33			38		38			36				51
	Locust Opening			33			38		38			35				63
2	Brooks Hill			38			37		38			33			.	47
	Hickory Hill		39			39			38			36				
3	Cove Road Swamp		38			37			36			36				
	Red Pine Ridge	40			37			35			36					
4	Swamp Knoll			38			38		36			35				43
	Shelf Swamp		37			37			36			36				
5	White Ash Knoll	36			38			33			35					
6	Pierce Road Knoll			35												
	Transport Knoll		35			37			38			36				
7																
8	Mill Pond Flat	33			40			39			35					
	Portal Swamp		.			37			40			36				
9	Linden Terrace		38			36			40			33				
10	[illegible] Bridge		-			39			37			32				37
	Ten Swamp Dam	31			36			36			38					

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APPENDIX F. DATA OF [illegible] STATIONS (CONT'D)

JUNE, 1968

	Week of Month	[illegible]														
	Date of Reading	7	8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	Prospect Hill	42		[illegible]				46								
2	Brooks Hill	33				38		48								
3	Locust Opening	39		46		46		43								
4	Cove Road Swamp		38		44		43					50				
	Hickory Hill		37		46		43					39				
5	Swamp Knoll	37		44		42		44								
6	Red Pine Ridge	36		46		40			43							
	White Ash Knoll	36		46		40			42							
	Pierce Road Knoll	35														
7	Shelf Swamp		36		46		39					48				
	Transport Knoll		34		-		38					48				
8	Portal Swamp		36		46		37					46				
9	Linden Terrace		31		-		35					48				
10	[illegible] Bridge		31		46		34					43				
	Ten Swamp Dam	31		-		37			35							

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APPENDIX F. DATA OF [illegible]-TEMPERATURE STATIONS (CONT'D)

JULY, 1968

	Week of Month	1			2			3			4			5		
	Date of Reading	3	4		10	11		17	18		24	25				
1	Prospect Hill	36			-			38			33					
2																
3	Brooks Hill	51			49			51			49					
	Locust Opening	49			50			53			45					
4																
5	Cove Road Swamp		47			49			49			47				
	Red Pine Ridge	47			47			49			48					
	Swamp Knoll	47			48			51			44					
6	White Ash Knoll	47			46			48			48					
7	Pierce Road Knoll										43					
	Transport Knoll		45			45			48			44				
8																
9	[illegible] Terrace Edge	44			43			45			39					
	Linden Terrace		43			43			45			40				
10																
	Ten Swamp Dam	43			43			43			37					

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