

A RECONNAISSANCE SURVEY
OF THE
DISTRIBUTION OF NATIVE SPRUCES
IN THE
HARVARD FOREST AND ADJACENT AREA

by

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INTRODUCTION

Several contributions have been made to knowledge concerning the natural growing conditions of native spruces in the Harvard Forest. The Forest was founded in 1908 and as early as 1910 a student report was written by Joseph A. Fufts concerning spruce in the Tom Swamp tract. Professor John G. Jack (1911) in his Trees and Other Woody Plants Found in the Harvard Forest mentioned that Picea rubens, Sargent (1898) red spruce, and Picea mariana, (Mill) B.S.P. black spruce grew in the Harvard Forest. Three other student reports written by W. Shepard (1911), H. B. Shepard (1912), and H.W. Hall (1913) dealt with the occurrence of spruces over the Forest, their growth-rate, reproduction, and sites. A management plan of 1927, mentioned in the first Harvard Forest Bulletin, proposed an eighty year rotation for spruce stands on the Forest.

All the above authors agree that spruce in the Harvard Forest occurs primarily in swamps but may also, as on Prospect Hill, occasionally grow on hilltops. Works of R.T. Fisher (1921), H.W. Remp (1941), and S.H. Spurr (1951) corroborate these observations. Spurr found red spruce growing in the Prospect Hill tract and black spruce in the Tom Swamp tract.

In light of the early and continued interest in spruce at the Harvard Forest this paper has a two-fold purpose: (1) to describe the geographic distribution of native spruces in the Harvard Forest and adjacent areas, and (2) to see if the pattern of occurrence and the growing conditions described can lead to a more complete understanding of the

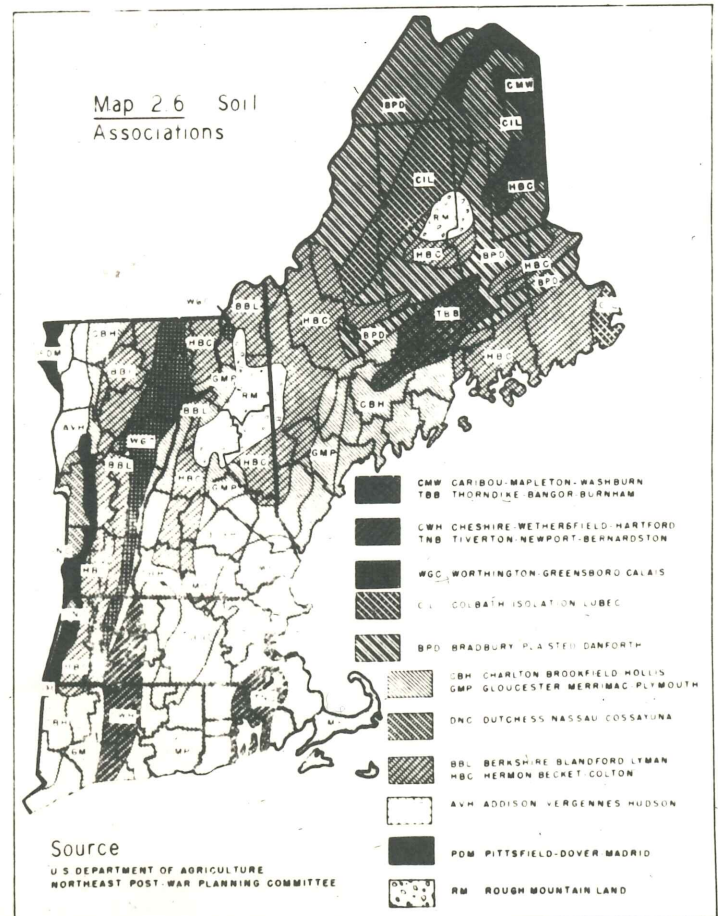
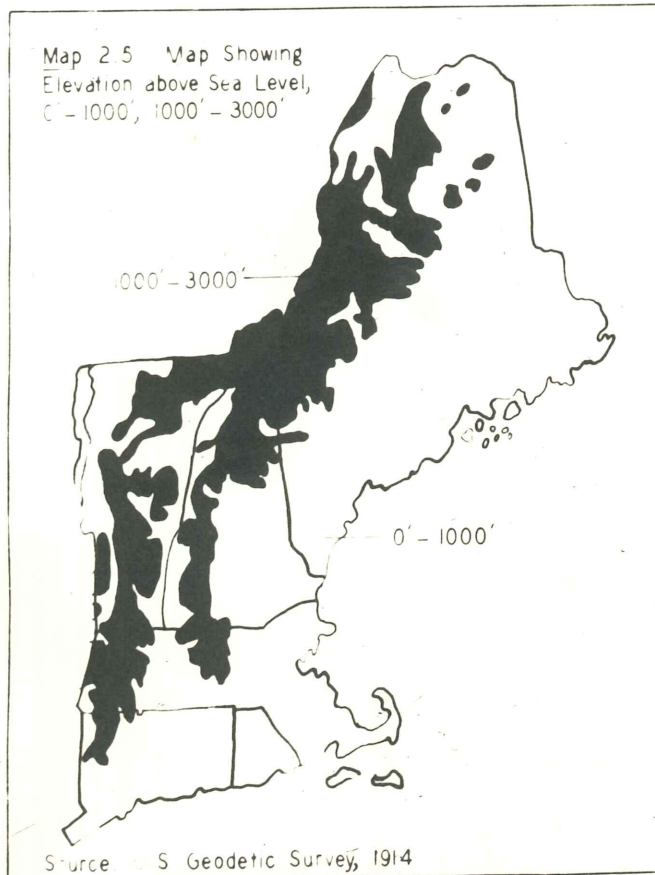
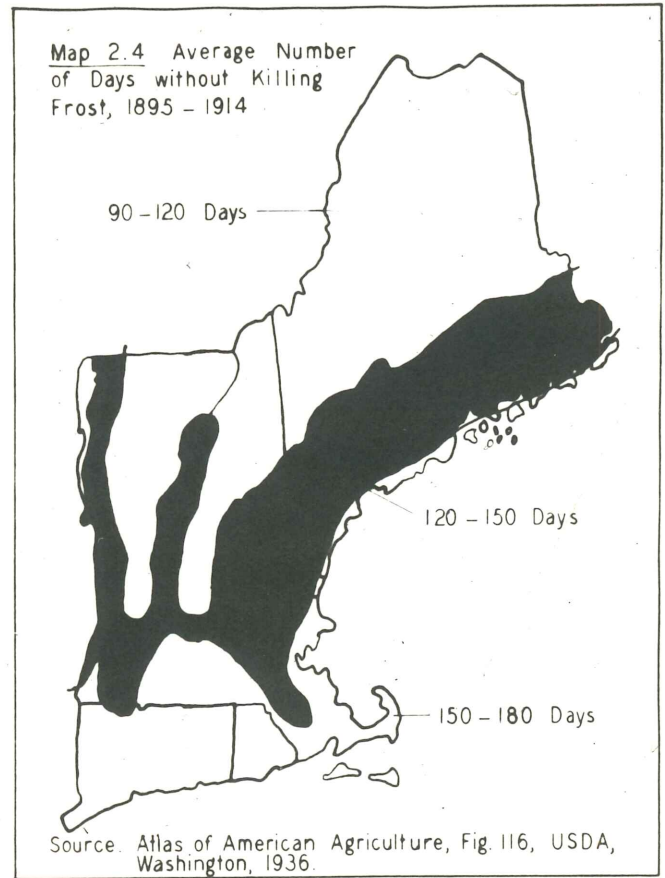
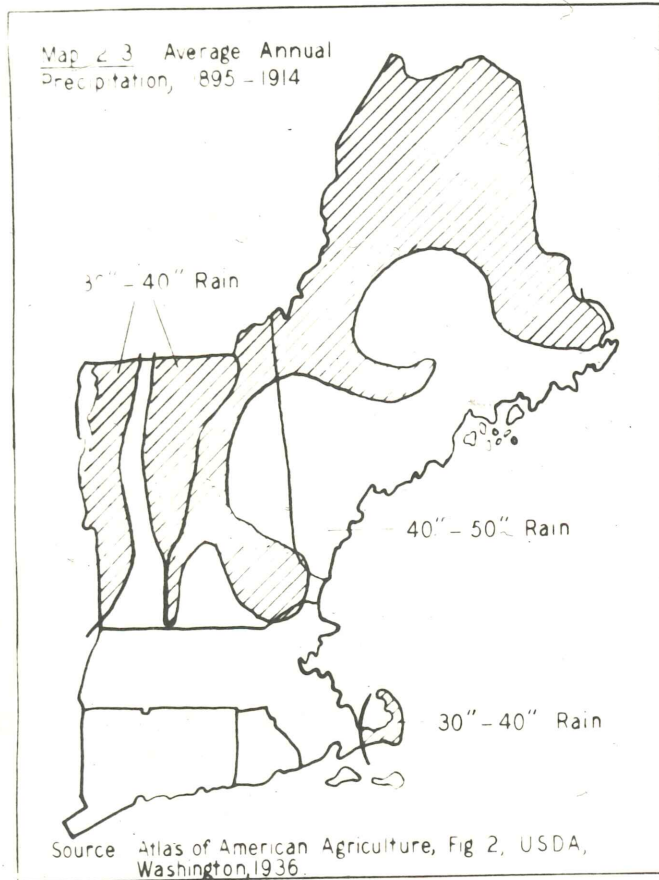
silvical requirements of spruce. This may suggest steps for the management of natural spruce stands in the vicinity and give some idea about the possibility of successfully establishing and maintaining plantations.

The field work was carried out during April, May, and June 1953, mostly in the company of Morris S. Clark, graduate student at Harvard Forest. The writer is indebted to Mr. Clark who was of great assistance in the many difficulties involved in the field work and who helped to shorten the long hours in the field. The writer wishes to express his appreciation to Director and Staff Members of the Harvard Forest for their assistance in both the field work and the preparation of this paper. Without their material support and stimulating suggestions this paper could not have been completed. Further, thanks are due to Mr. R. Wa. Glasheen of the Athol Water Department for his personal assistance in the field work, and to Mr. Roy Kimball of the Metropolitan District Commission who made a survey of the Quabbin Reservoir area possible. The writer is grateful to all farmers, lumbermen, and landowners in the area of this investigation, who were always ready to share their knowledge of local tree growth and roads and were of great help in making the field work easier.

Area of study.

The investigation was begun in the Harvard Forest. After locating all the natural spruce occurrences in the Harvard Forest itself, the survey was then extended over the adjacent area.

FIGURE 1.



The adjacent area includes the Athol quadrangle map and its eight adjoining quadrangles. These nine 7 1/2 minute U.S.G.S. maps have the following names (reading from west to east and from north to south): Mt. Grace, Royalston, Winchendon, Orange, Athol, Templeton, Quabbin, Petersham, and Barre.

The area includes a total of about 480 square miles. In general, it is made up of long, flat ridges running in a north-south direction. The ridgetop elevations range from about 1000 feet to 1200 feet above sea level. Their soils consist mostly of sandy loams. The valleys between the long ridges are frequently characterized (or plains with rather sandy soils) by a large number of gravelly or sandy knolls. The valleybottom elevations range from 550 feet to about 900 feet above sea level.

The whole area is part of the so called New England Peneplain, and probably represents its southernmost extension, as seen on figure 1. The average elevation of the peneplain is about 1150 feet above sea level. There are a few hills which emerge above this average elevation. Such hills are for instance, Mt. Grace with an elevation of 1620 feet, and Prospect Hill in the Harvard Forest with an elevation of 1380 feet above sea level. The elevation of the peneplain slowly decreases from north to south.

According to data from the Atlas of American Agriculture (Figure 1) the area seems to be uniform in its macroclimate, soils, and the growing seasons. Its vegetation is mapped as belonging to the transition hardwood-white pine type (Figure 2; by Soc. of American Foresters, modified by H.M. Raup). These illustrations are presented to show the relation of the study area to the forest types and to the geographic range of red

FOREST TYPES OF NEW ENGLAND

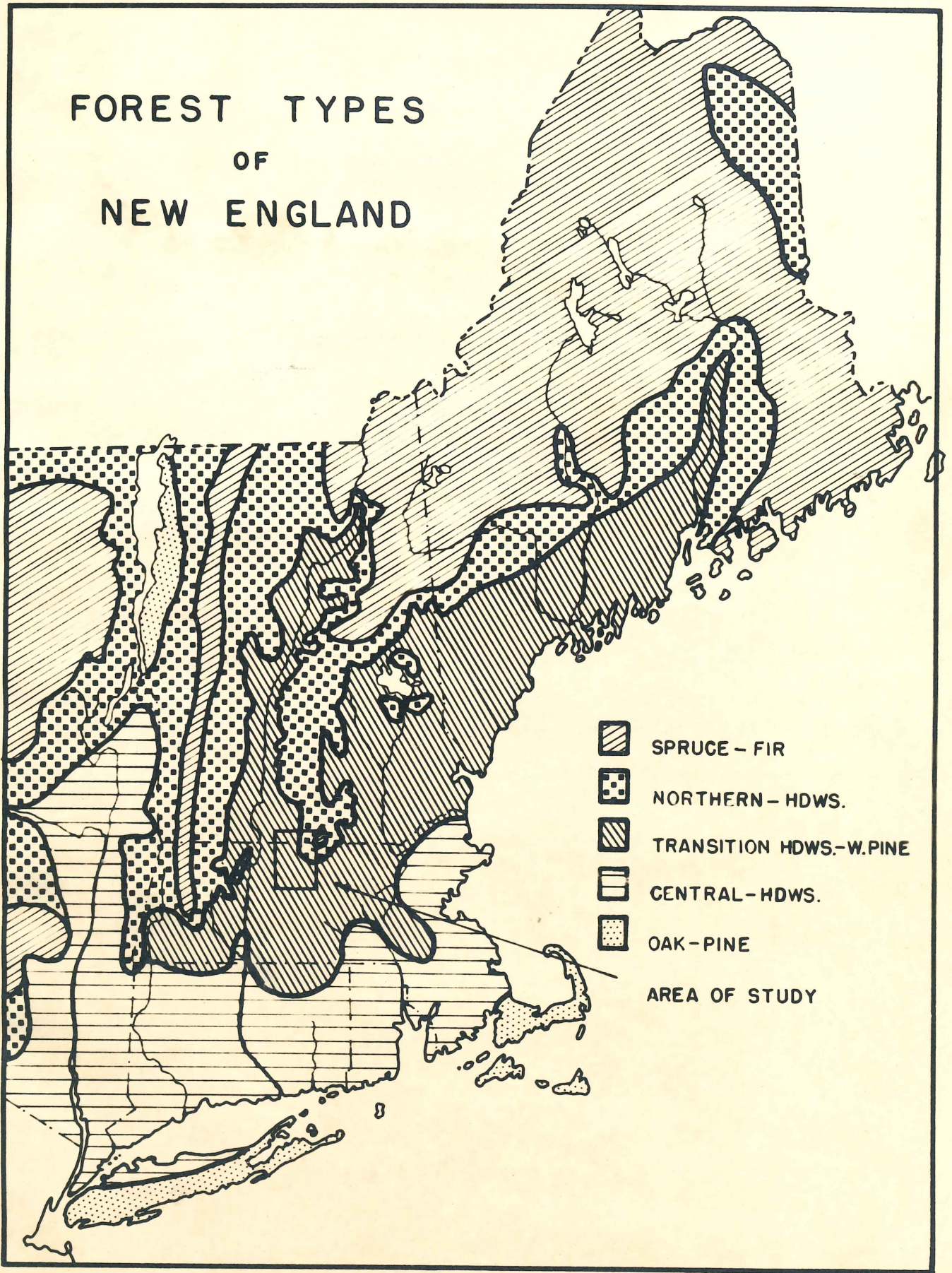


FIGURE 2.

and black spruce.

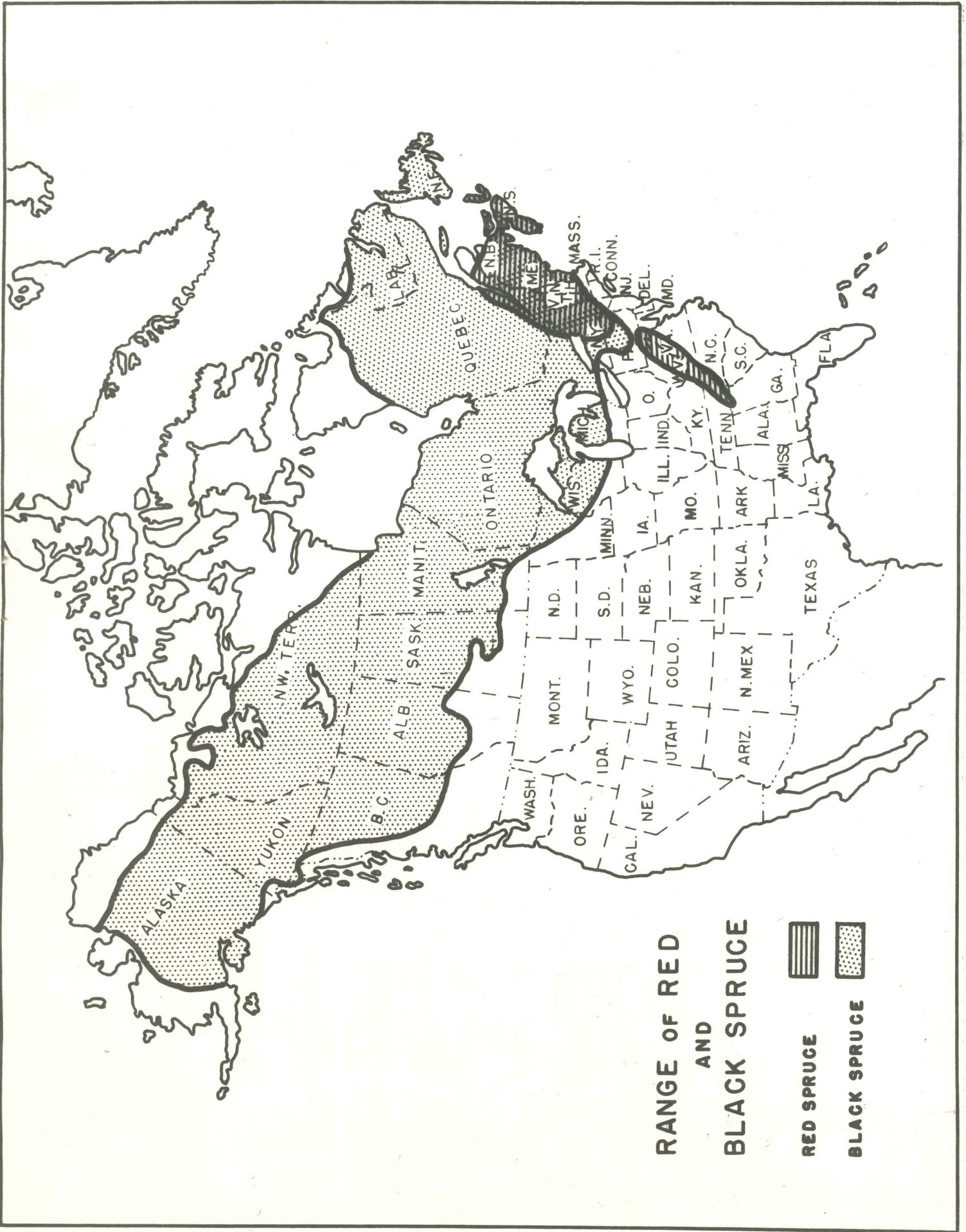
A closer observation of the foregoing information, however, shows that the lower isotherms from the north come very close to the study area, as do higher isotherms from the south and east. The area is mapped as transition hardwood-white pine type forest. Yet the map of forest types in New England shows that there are other types of forests close to the investigated area. Almost touching the area is the northern hardwoods type. From the south and west the central hardwoods come to within 60 to 70 miles of the area. An island of the spruce-fir type is found within the larger area of the northern hardwood type only 50 miles north of the study area near Mt. Monadnock.

We should not, - according to H.M. Raup, - expect to find the boundaries of climatic, soil, and vegetation types as clearcut lines (H.M. Raup per. comm. 1952). The boundaries will more nearly resemble a line painted with a wide brush than one drawn with a sharp pencil. Therefore the data presented on climate, soils, and forest types may suggest that in this area we are likely to find representatives of both southern and northern affinities in the vegetation.

Range and identification of red and black spruce.

The range of red spruce as given by Phillips A. Hayward (1930) is: "from Prince Edward Island southward to the coast of Massachusetts, and through New England and New York, and northern Pennsylvania to North Carolina and Tennessee. Range imperfectly known". From the same source the range of black spruce is given from: "Labrador to Mackenzie River, and northwestward into Alaska; southward through Newfoundland, eastern

FIGURE 3.



Canada, Michigan, Wisconsin, Minnesota to central Pennsylvania, and in the mountains to northern Virginia". This outline of the range of red and black spruce is essentially the same which was described by C.S. Sargent in 1905 and has since been used by various authors with little modification (R.S. Hough 1907, or G.R. Green 1933, or Harlow and Harrar 1950, and others)(see map).

Sargent (1905) was also among the first to distinguish between Picea rubens and Picea mariana. G.B. Emerson, who was commissioned in 1837 to describe the trees and shrubs of Massachusetts, mentions only the black or double spruce (Abies nigra, Michaux). Yet in his report he describes a "superior variety of the double spruce with red wood, often considered a distinct species, and called red spruce. The color is doubtless owing to some peculiarity produced by soil or exposure, as was confidently stated by Michaux".

According to C.E. Snow (1903) it is often difficult to distinguish between black and red spruce, for "red spruce (Picea rubens) resembles and is sometimes considered a variety of, black spruce".

H.H. Gibson (1913) recognized red spruce and black spruce as two distinct species. The main points of difference in the appearance of the two species are the size and shape of the cones and of the staminate blossom. Yet he mentioned that sometimes the red spruce is difficult to distinguish from black spruce. The same author described the fact that the cones persisting for several seasons as a characteristic of black spruce, while red spruce drops its cones during the first winter after they mature. Gibson also states: "Certain eminent botanists incline

to the belief that the two are different varieties of one species, inasmuch as even the timber of red spruce bears a close resemblance to that of the black spruce. Other botanists dispute this theory, saying that the trees are entirely different in appearance; that the red spruce is a light olive-green, while black spruce is inclined to a darker olive with perhaps a purplish tinge, so that when seen together they have no resemblance in point of color. They further say that the cones are not only different in size but that the scales are quite unlike in texture, those of the black spruce being much thinner and more brittle. The same authorities maintain that the tiny twigs of red spruce are more conspicuous on account of their reddish tinge".

Yet most authors agree that needle characteristics are extremely erratic due to difference in site and genetics. Similarly, the twig color, pubescence, and bud structure seem to be subject to variations. Recent studies by A.G. Gordon (1952) propose a method for a more accurate identification based upon the nature of the twig surfaces. The surface of the twig is composed of a series of decurrent ridges which run longitudinally along the twig. According to A.G. Gordon: "Other characteristics, particularly size and colour and needle colour, will aid in identification of course, but the decurrent ridges appear to offer the most certain means of identification". ✓

✓ "Red and white spruce have ridges which are laterally rounded. However the twigs of white spruce are covered by relatively larger ridges which are quite glabrous compared to those of red spruce. Black spruce has decurrent ridges which are flattened and which give the twig an appearance of being an almost smooth cylinder from which project the pulvini and needles".

Quotation from A.G. Gordon Separation of black spruce (*Picea mariana* (Mill) B.S.P.) from red spruce (*Picea rubens* Sarr.) and white spruce (*Picea canadensis* (Mill) B.S.P.) by twig characteristics.

The oldest among local vegetation descriptions is that of Peter Whitney (1793), in his "History of the county of Worcester". In all the towns included in the present investigation, spruce was mentioned by Whitney only in the town of Royalston. He said: "The natural growth of wood is of various kinds, as oak, chestnut, beech, ash, white, black, and yellow birch, maple, or sugar tree, bass, alder, and the evergreens, as pine, hemlock, hemstuck and spruce, &c."

Emerson mentions the local range of black spruce only in very general terms in his Traces and Shrubs of Massachusetts. It is stated in this work that black spruce was found as far south as Asherst.

Hawley and Hayes (1925) mention the higher hills of central and western Massachusetts as the localities where red spruce can be found.

According to figure 3 the range of both black and red spruce includes the western and north-central part of Massachusetts. Since their location for large scale mapping purposes however, depends upon more exact identification than generally attends the construction of small scale range maps, considerable confusion was anticipated in making species separations in the area selected for study.

In the course of preliminary investigation in the Harvard Forest, so-called red spruce was found in the bouldery wet sites and upland swamps, and what generally passes for black spruce according to classical definition was found in the deep sphagnum bogs. This pattern of occurrence was later found throughout the entire study area of which the Harvard Forest is a part. It was obvious, however, that these sites supported variations of both species. In fact, in terms of relative

abundance, the "variation" was exceedingly extensive. Whatever the causes were for this apparent confusion of identifying characters, it was felt that their classification fell beyond the scope of this investigation. It was therefore decided to limit the study to the distribution of "spruce", alone, being in this instance a general category containing the two species native to this area, Picea rubra and Picea mariana.

Method of study and field work.

The 7 1/2 minute quadrangle sheets of the United States Geological Survey were used as base maps. In the course of the study all roads marked on the base maps were covered by Jeep. Farm and logging roads not marked on the maps were also covered in the same way. In all cases the objective was to get as good a coverage as possible of the area in which we were. It was often necessary to leave the vehicle behind and cover several miles a day on foot. Doing so, gave a better picture of the whole terrain, than was possible to get simply by looking at the roadsides which in many cases did not give a true picture of the total vegetation. Inaccessible places such as bluffs and steep hillsides were surveyed with a 15 power telescope on a tripod. With the help of this instrument it was possible to distinguish spruce at a distance of about two miles, especially in the early morning hours of clear days when the air was free of heat vibration. The investigation was carried out over the whole area of study according to the same principles in order to get comparable data.

Whenever spruce was found it was marked on the map. If by ocular estimate the spruce seemed to make up at least 50 percent of the trees

in a stand, the area covered by such a stand was encircled. If a lesser number of spruces was found in a stand, in groups or as scattered individuals, it was marked with a dot on the map. The limited time available for the field work did not permit the establishment of sample plots to determine the amount of spruce in the stands in which it had been found. Therefore, it cannot be said from the number of dots how many trees were in each location.

It was decided that one dot would represent from one to twenty trees on the map. The position of individual trees or groups was located as accurately as possible within the scale of the base maps.

The pattern of occurrence over the whole study area seemed to be about the same as that found in the Athol quadrangle. In this quadrangle, which was the first one covered in the field work, every place in which spruce was found was described in detail. These descriptions are enclosed in the appendix of this paper.

GEOGRAPHIC DISTRIBUTION OF SPRUCE

The following section is presented to amplify the information shown on figure 4. The distribution of Red and Black Spruce. This map indicates only the outline of the U.S.G.S. quadrangles and the arrangement of the distribution pattern of spruce. The exact location of each spruce occurrence is marked on the quadrangle sheets which are attached to the appendix of this paper.

In order to give a better illustration of the distribution pattern

each quadrangle is described separately. The quadrangles are listed in the same sequence as they are on the map from west to east and from north to south.

Mt. Grace quadrangle

There are two concentrations of spruce occurrences in this quadrangle. The first one is in the central part of the quadrangle, and the second one is located in the northeastern part. Besides these two places in which the distribution pattern of spruce is dense, the quadrangle has almost no spruce occurrences at all.

The northwestern corner of the quadrangle shows three dots. In each of the cases represented by the marks there were only one or two trees found. In the southern part of the quadrangle there is only one dot, and it represents only a single tree. In both the northwestern and southern parts of the quadrangle, spruce was found only in bogs. These trees did not appear to be vigorous; the height growth was poor, crowns ragged, and the general impression was that the trees did not enjoy the high state of health of spruce observed in other localities.

The distribution pattern in the central part is denser. Yet the number of trees represented by each dot does not exceed two or three. As a whole there are only very few spruces in this part of the quadrangle.

There are not only more spruces in the northeastern portion of the quadrangle but the number of trees represented by each dot is greater also. Although here spruce still grows primarily in the swamps it was found often on the edges of the swamp, outside of the swamp proper. The

vigor of the trees seemed to be better in this general area. There were some well formed spruces found on some of the swampy edges. The trees were free of branches for about two thirds of their total height and had a long taper.

No spruces were found on Mt. Grace itself, which is the highest point in the whole investigated area. Neither was there any spruce found in the southeastern part of the quadrangle which appears to be the beginning of a gradual decrease in elevations from about 1100 feet to 500 feet above sea level in the Orange quadrangle.

Royalston quadrangle

Compared to the one previously described, the Royalston quadrangle has a much larger number of spruce occurrences. The spruce in some parts of the quadrangle is marked not merely with dots, but by encircled areas. This indicates that the spruce makes up at least an estimated 50 percent of the trees in the stand.

The greatest concentrations of spruce were found in the northern and central parts of the quadrangle. Spruce stands of considerable extent were located south and west of Sportsman Pond. The eastern edge of the quadrangle showed somewhat lighter distribution, though still denser than the Mt. Grace quadrangle.

There were only a few scattered spruces found along the broad valley of the Tully Brook in the western part. The soils in this valley are sandy and gravelly, and the forests in this part of the quadrangle consisted chiefly of white and pitch pine with an occasional red pine.

Occasionally along the valley there were open, grassy bogs sometimes of several acres in extent, and in the valley spruce was found only in these bogs.

A look at the map will convince the reader that spruce here is still growing primarily in swamps. However in the northern part of this quadrangle it is sometimes found on leamy soils also, on hillsides as well as valleys, not necessarily swampy or imperfectly drained land. In contrast to this, in the central part of the area spruce again is limited to swamps, bogs or rocky moist uplands.

Balsam fir seems to be the almost constant associate of spruce in the northern, central and eastern parts of this quadrangle. Especially in the central and northern parts balsam fir often occupies whole hillsides. Yet in the western part of the quadrangle it is absent, or at least has not been found by the writer in that part.

Winchendon quadrangle

From the whole investigated area spruce was found most frequently in this quadrangle. This was true for both the number of spruce occurrences and the areal extent of mixed and pure spruce stands. The whole quadrangle probably could be divided into the following subareas according to the pattern of spruce distribution.

The part west of the new route 202 in Massachusetts is occupied mostly by the flat and in many parts swampy lands adjacent to the Millers River, Otter River, and Priest Brook. It is in this part of the quadrangle that the largest, almost pure, stands of spruce are found. These stands

are growing in swampy places and the outlines of their occurrence coincide very well with the contour lines indicating low swampy land on the map.

Along highway 202 spruce is often seen to grow on other than swampy land. However all these locations are bordering on swamps and the groves located outside of the swamp proper are nothing but a few trees growing on the area adjacent.

The higher ground in this part of the quadrangle is occupied almost exclusively by white pine, and occasionally by pitch pine. The soils are mostly sandy and gravelly. It is interesting to observe a striking change from pine to hardwoods whenever the sandy plains or knolls are replaced by a rocky, leamy ridge.

The distribution in the northern part of the quadrangle, in New Hampshire, seems to be somewhat different from the one just mentioned. Spruce is still found primarily in swamps. However its tendency to grow over the edges of the swamps may be stronger than in the southern part of the quadrangle. Yet it would be difficult to find a measure for this tendency. One indication for this may be the fact that moist flat areas, not necessarily characterized by the presence of sphagnum, often support scatterings of spruce. Balsam fir is very frequently found with spruce in this part of the quadrangle. In swamps and on the areas adjacent to swamps it was observed that balsam fir was able to grow well over the edges of the swamps proper and occupy there a larger area than spruce does. The number of balsam fir occurrences seems to be rather limited until one reaches the northern part of the quadrangle.

In the southern part of the quadrangle spruce is still growing

primarily in swamps. It is also found on the edges of swamps, and sometimes on the edges of brooks whenever they have a wide, swampy floodplain. If there is no swampland on the edges of brooks then usually hemlock is the dominating species. Pure stands are formed mainly in places which have stagnating moisture, and where usually at least part of the groundcover is made up of sphagnum. Good examples of this are found in the extreme southeastern corner of the quadrangle. Similar to the previously described Royalton quadrangle, it has been noted in this one too that in some places spruce was found on sites which are not poorly drained. Also in other places spruce had been found in depressions which resemble swales rather than swamps.

On well drained, gravelly-sandy soil dense groups of red spruce saplings were found. Such a place is between the Riverside cemetery and Lake Martin, north of the Millers River. The trees are now about 10 to 15 feet high. They are growing in the open. The area must previously have supported a fairly closed stand of trees about 14 to 16 inches in diameter at the stump. The groupwise arrangement of the reproduction may have resulted from some large spruces growing scattered on this area. Other species growing here at the present are white pine and hemlock. All the large trees however were blown down in the hurricane of 1938. It is not impossible that the groups of young trees have been established artificially. However it seems unlikely that a group underplanting would have been established in such dense groups as were seen here. There was spruce found in the swamps along the Millers River and also in another swamp to the north of this place. It seems likely that sometime in the

past seedling established themselves here. The groupwise arrangement may be a result of: (1) large scattered spruces or (2) openings in the residual stand in which spruce found favourable conditions for its establishment. Since the wood of the stumps was not examined it cannot be said whether the first or the second theory has more weight in explaining the origin of these reproduction groups. This place is so well drained that it stands in sharp contrast to other spruce stands which in general are on very moist ground. Even if it cannot be proven satisfactorily that spruce has or will grow up here to commercial maturity, its presence on this site shows that it is able to grow under a wide variety of soil conditions.

Orange quadrangle

The area of the Orange quadrangle can be divided into two major parts according to elevation. The eastern part has elevations ranging from 550 to 950 feet above sea level. The western part has elevations from about 950 to 1200 feet above sea level. The soils in the eastern part are mostly sandy and support stands predominantly of white pine with some pitch pine. The western part seems to have predominantly hardwood forests.

The only spruces found in this quadrangle are in the eastern part. The occurrence of spruce is limited to bogs, most of which are bordering lakes. In some places on the edges of these bogs a few trees were found with 4 to 5 inch diameters breast height. However, the extent of their occurrence on the edges of the bogs is not large, and only a few scattered

trees are found here and there.

The spruces on the bogs are apparently growing very slowly. On the bogs themselves no large trees were located; therefore it seems questionable whether the spruce will ever be able to grow to trees of 3 to 5 inches d.b.h. under such conditions. In the bog the only species associated with the spruce is tamarack. Closer to the edges of the bog it is often found in the company of hemlock and white pine.

No spruce at all was found in the northern part of the quadrangle or in the western part, both of which have higher elevations. In areas where one would expect to find spruce according to the observations made in the previous quadrangles, the presence of hemlock was noted.

It would be interesting to find out whether there are any spruce occurrences at all between this quadrangle and the Connecticut River, or whether the few occurrences found in the quadrangle really represent the western limit of spruce distribution in the study area.

Athol quadrangle

For the purpose of describing the spruce distribution in it, the Athol quadrangle could be divided into three major parts. The first is west of highway 32, extending to the Millers River. The second could be east of highway 32 and south of highway 2. The third part could be the area north of highway 2.

In the first part spruce was located almost exclusively in swamps and bogs. There seem to be only two exceptions to this rule.

The two exceptions, represented by numbers 53 and 54 on the Athol

quadrangle may could be the results of planting. The trees are growing on a westerly slope. The soils on the slope seem to be of the sandy loam type. The stand in which spruce was found consists almost entirely of hardwoods with a little white pine. There is almost no shrubby undergrowth present. The stand is estimated to be approximately 55 to 60 years old and is very dense. Only a few spruces were found in this location. They are about 15 feet tall and seem to be growing well. Whether planted or not these trees are proof of the ability of spruce to become established on this type of soil as well as in the swamps if there are suitable conditions for its establishment. Since only small trees were found it cannot be said with certainty how they will perform in the future if left without treatment to compete with the hardwoods.

Compared with the eastern part of the quadrangle, the elevations here in the western part are somewhat lower. They range from 650 feet to about 1100 feet above sea level, with an average of about 850 feet. The soils are apparently of the sandy loam type, except in the long north-south valley between highways 32 and 122, where they are gravelly and sandy. It seems that here also, similar to findings in the previously examined quadrangles, the broad valley is favourable for the development of bogs of large extent. It is in these bogs that we find spruce in the western part of the Athol quadrangle.

The second part of the quadrangle has a larger number of spruce occurrences than the first part. The average elevation is about 1150 feet above sea level with Prospect Hill in the Harvard Forest rising to 1382 feet. Some of the occurrences are found in almost pure stands of

spruce while others represent scattered trees in mixed stands of red maple, hemlock, or white pine. The largest spruce growing in the whole investigated area, about 2 1/2 feet d.b.h., was found in this part, south of Reservoir Number 2 of the Athol Waterworks. Also in this part spruce is found to grow on a bouldery wet site along Bakers Lane in the southeastern corner of the quadrangle. Spruce was also found high on the eastern slope of Prospect Hill. This occurrence of spruce is described in more detail under the chapter on the Harvard Forest.

The small scattered occurrences along highway 2 are found mostly on edges of brooks, together with white pine, hemlock and red maple. There was no spruce found along Popple Camp Creek, which farther south becomes the east branch of the Swift River. The growth along this brook consists mainly of hemlock, white pine and red maple, the scattered spruces which were found along highway 2 under similar conditions, are absent here.

The third part of the quadrangle shows quite a number of spruce stands and scattered trees in its eastern part. Yet in the western part there was no spruce found at all. The highest elevations of this part (1200 to 1282 feet) are found near its center. From here the elevations decrease to about 530 to 550 feet toward the west. Also the soils become sandy. Toward the east the elevations, although lower, do not show great differences and seem to level off at an average elevation of about 1150 feet. The soils in the central as well as in this eastern part are of the sandy loam type. The forests in the central and eastern part consist of hardwoods-hemlock-white pine while in the western part white pine and

frequently pitch pine are the dominant species.

In general the distribution pattern of spruce shows a decrease from east to west in the number of occurrences. Detailed descriptions of all spruce occurrences in this quadrangle can be found in the appendix.

Templeton quadrangle

Highway 2 divides the Templeton quadrangle into two parts, a northern and a southern part. The elevations in both the northern and the southern part are about 1150 feet above sea level, except along the Otter River and the Burnshirt River. The soils seem to be mostly of the sandy loam type on the uplands while the valleys and their adjacent low lands are gravelly and sandy.

In the southwestern part of the quadrangle spruce was found under the same general conditions as in the Athol quadrangle. That is, it was found primarily in bogs, swamps, and bouldery moist uplands. It occurs either scattered or in pure stands. Its associated species are white pine, hemlock, red maple, yellow birch and tamarack; their combination varies with the particular conditions of the spruce site.

In this part of the quadrangle balsam fir was found at one of its southernmost occurrences. It is interesting to note that even here balsam fir was able to grow well over the edges of the swamp proper and occupied a greater area than did spruce.

There was no spruce found along the Burnshirt River south of Stone Bridge Pond. But scattered and also in small groups it was found

growing on the bog north of Stone Bridge Pond. The elevations are about 900 feet along the river and at the level of the bogs.

There was spruce found in almost all of the swamps in the middle of the southern part of the quadrangle. However, in addition to growing in bogs and swamps, spruce was found also in moist depressions or flats which sometimes were not even marked as swamps. Also it seems that spruce occupies larger areas on the edges of swamps than it does farther toward the west at the same latitude. A good example of one of the flat moist places where spruce was found growing is between Dolbier and Canasto Hills. The place is marked as a large flat area on the map with a pond in its middle. There is no standing water on the surface of the ground where spruce is growing. The usual sphagnum from the groundcover is absent, instead the ground is covered with a litter of leaves. Associated species of the spruce in this place are red maple, red oak and yellow birch. On the whole the stand gives the impression of a hardwood swale.

Immediately east of the area described above there is another place which seems somewhat different from the occurrences described heretofore. Although at an elevation of 1140 feet above sea level, this place resembles the bogs which tend to form in the broad valleys at lower elevations. While in most swamps on the uplands the deposits of peat are shallow, exposing rocks here and there, the layer of peat is deeper in this locality. There are only scattered trees on this bog. Other species growing here beside spruce are tamarack and red maple. All trees seem to have been growing rather slowly. Trees which have attained a height of about 20 feet are almost all dead. Most of the spruces have kept their

last year's cones still on the twigs. This is often regarded as a characteristic of black spruce. The cones collected from these trees show features typical of black spruce, yet the twig characteristics are definitely those of red spruce.

In the long valley which runs parallel with the western edge of the quadrangle spruce was found mostly scattered. Only in one place did it form a small stand of almost pure spruce. The soils in this valley are mostly sandy and the occurrence of spruce is limited to the bogs which tend to form generally under these conditions. Although it was found to grow also on the edges of the bogs, the area occupied by spruce on these edges is not nearly as great as it was around upland swamps.

In general the spruce occurrences of the northern part of the quadrangle are about the same as in the southern part. Large pure stands of spruce are found in the swamps along the Otter River and Trout Brook to the northwest and southwest of Baldwinville. Otherwise the usual pattern is found; that is, spruce in swamps, bogs, rocky uplands of brooks, and swamps. Species growing together with spruce are white pine, hemlock, red maple and tamarack.

The most vigorous growth and best form of the spruce seem to be produced in this quadrangle in the upland depressions and in the surrounding areas of upland swamps. Spruce was often found to form almost pure stands in such locations. The stands are not uncommonly found to have A or B density.^{1/} The live crown is small and does not make up more

^{1/} A, B, C, and D densities refer to percentage of crown closure and not to number of stems per acre. A-80 - 100% closure; B-60 - 80% closure; C-30 - 60% closure; D-less than 30% closure.

than one third of the total height. There usually is an abundant reproduction setting in after such stands are cut.

In the lower situated and often sandy areas spruce seems to be generally more limited to the bogs. It is found occasionally also on the edges and over the areas surrounding bogs. Under certain circumstances it seems to be able to form stands of almost pure spruce. The most commonly found form of its occurrence on the bogs is in small groups or scattered. The trees on the bogs are apparently much slower growing than those in the upland depressions or at the edges of swamps. The crowns are bushy and the yearly height growth is hardly noticeable.

Quabbin quadrangle.

Approximately half of the area of this quadrangle is occupied by the waterbody of the Quabbin Reservoir. Except for a narrow shoreline, this waterbody takes up all of the eastern part of the quadrangle. The western part consists of the Prescott Peninsula. There are some islands of various sizes emerging from the reservoir.

The soils are mostly of the sandy loam type over the whole area of the quadrangle. The level of the reservoir is at about 520 feet above sea level. The elevations range from about 520 to 1261 feet, the latter being the highest point of the quadrangle. In general the elevations decrease markedly from north to south. The average elevation of the north-south ridge of the Prescott Peninsula is about 1000 feet. Outside of this ridge, the average elevations seem to be in the vicinity of 700 to 900 feet.

Spruce was found in a few places on the Prescott Peninsula and in one place in the northeastern corner of the quadrangle.

Going from south to north the first spruce occurrence is in a bog surrounding a pond. The pond appears to be a natural body of water. Spruce is scattered over the eastern part of the bog. It is not found growing near the edge of the bog or growing over its edges. There are not many trees on the bog, most of its surface being covered with blueberry and other high shrubs. Most of the trees are about 10 to 15 feet high and do not seem to be growing vigorously.

The next locations where spruce was found are somewhat similar. In both cases it is in wet, poorly drained places in the vicinity of a swamp. On the swamps themselves however no spruce could be located. In both cases one large spruce was found with several smaller ones growing around it. It should not be overlooked that the large trees could have been planted, although they could very well have seeded in from the adjacent swamps at a time when there was spruce in those swamps. Artificial ponding could have created unfavourable conditions for the spruce in the swamps, but the trees growing on the edges would have been able to grow undisturbed.

The big trees found in these locations seem to have been growing in the open all their lives. They have full crowns reaching almost to the ground. Some of the smaller individuals have been cut back for Christmas trees, and a side branch has taken over the role of the leader. Similarly, as these trees here are now used for Christmas decorations, it is possible that those on the swamp have also been eradicated as a result of this

custom since spruce is so rare in this part of the investigated area.

One single spruce was found about 500 yards northeast from one of the swamps. The ground on which it was found is bouldery and moist. The difference in elevation between the tree and the level of the swamp is ca. 20 feet. About half of the total height of the tree is free of branches. This could be an indication that it was growing in a fairly closed forest. Other species growing on the same site are white pine, hemlock, red maple, and gray birch. It is not unreasonable to believe that spruce has found suitable conditions here for its establishment. But it would be difficult to determine just what could be the limiting factors of its environment.

Other swamps on the Prescott Peninsula support mostly stands of red maple, white ash, alder, and hemlock. The compositions of these stands may differ in various swamps from almost pure red maple to pure hemlock. Compared with the Royalston, Winchendon, Athel, and Templeton quadrangles, where spruce was found in the greater part of the swamps, the Quabbin quadrangle seems to be on the opposite side. The most commonly associated species of spruce, - red maple, hemlock, alder, and white pine - are still found here, but spruce is absent.

In general on the Prescott Peninsula the abundance of hardwoods is notable. This seems to be even more true as one proceeds farther south. White pine grows in pure stands in some of the old fields, but among the hardwoods it is only found scattered. Hemlock is found to grow near the ridges, in coves and gorges. Toward the southern part of the Peninsula one finds stands in which black oak, chestnut oak, scarlet oak, and sassafras make up the majority of the trees. Flowering dogwood is very

commonly found over the whole area of the quadrangle.

In the northeastern part of the quadrangle an almost pure stand of spruce was found. Other species growing with spruce in this location are red maple and hemlock, with hemlock being more abundant. The ground-cover consists mostly of sphagnum. The groundwater is standing on the surface in depressions and in the pits of uprooted trees.

The trees closer to the edges of the swamp or growing on somewhat elevated spots seem to be growing vigorously. There are some larger trees in this location which have diameters of about 6 to 8 inches at breast height.

Some of the trees still had some cones on their twigs. The cones collected from these trees resemble those of the black spruce; however the twig characteristics of the same trees are those of the red spruce.

In summary it can be said of this quadrangle that there are very few spruce occurrences in it. There are, on the other hand, stands of hardwoods of southern affinity. It may be only a coincidence, but perhaps it could be said that where the pattern of spruce occurrences fades out, the southern hardwoods appear in greater quantities.

Petersham quadrangle.

Without exception, spruce was found in swamps, bogs and their adjacent areas in the Petersham quadrangle. There is not one place where spruce is found in a pure stand, but is found scattered among white pine, hemlock, red maple, tamarack, or balsam fir.

The elevations show a marked decrease from east to west and north to south. The northeastern part of the quadrangle is about 1000 to 1150 feet above sea level. Thence it drops to about 550 to 750 feet in the western part and to about 700 to 950 feet in the southern part of the quadrangle.

The fact that spruce occurs only in swamps makes this quadrangle similar to the Quabbin. The behavior of the species usually found together with spruce is also much the same as in the Quabbin quadrangle.

The vigor of the spruces in bogs or swamps is similar to that of spruce on similar sites in previously described quadrangles.

There are however two spruce occurrences which are somewhat different from the general rule. The peculiarity of the first occurrence is that spruce occupies a bouldery, very moist upland pasture adjoining a swamp. Spruce here is accompanied by tamarack. All the trees found are small. It is possible that spruce here was able to occupy such a comparatively large area because the soil conditions were favourable for its establishment, and there was sufficient seedsource nearby.

The peculiarity of the other occurrence is that spruce is accompanied by balsam fir. This is one of the southernmost occurrences of balsam fir on the area of study. Yet balsam fir was noticed occupying a much larger area outside the swamp proper than spruce. The former stand in the swamp, and the adjacent area, was blown down by the hurricane of 1938. As a result of the blow-down no large firs or spruces could be located here.

There is no marked decrease in the number of occurrences from

is found. Its associated species are red maple and hemlock with some white pine. Near the northern border of the quadrangle balsam fir is found occasionally, but it is not found farther south. The occurrence of the balsam fir in this quadrangle is at the same latitude as in the Petersham quadrangle.

Summarizing the observations for the Barre quadrangle it may be said that spruce is found only in the swamps or bogs. In a few localities it was found in pure stands, but mostly it occurred scattered. Occasional trees were found on the edges of swamps.

Harvard Forest.

The outlines of the Harvard Forest are marked on the maps of the Athol and Petersham quadrangles as well as on the map showing the geographic distribution of spruce. This was done to illustrate the areal relation of the Harvard Forest to its surrounding area and the distribution of spruce.

In the Harvard Forest spruce was found in the Prospect Hill and Tom Swamp tracts. In the Prospect Hill tract it occurs in compartments II, IV, V, VI, and VII. In the Tom Swamp tract it was found in compartments VIII and IX.

Spruce in the Prospect Hill tract occurs in upland swamps and their adjacent edges, on bouldery moist sites. High on the east slope of Prospect Hill it is growing also on a bouldery moist site. This latter occurrence was mentioned separately because it was found to be the only case in the whole investigated area in which spruce was growing on a hillslope, on land which was at one time cleared for pasture.

north to south or east to west in this quadrangle. Yet, compared with the quadrangles to the north, it shows a much smaller number of spruce occurrences; and the number of trees in each place is fewer than farther north.

Barre quadrangle.

Similar to the Peterham quadrangle, there is also in the Barre quadrangle a marked decrease in elevations from the north to the south. Elevations in the northern and northwestern part of the quadrangle are about 1100 feet, while in the southern part they range from 600 to 900 feet above sea level. The soils in the southern part of the quadrangle are gravelly and sandy. Also along the eastern boundary sandy soils are frequently found. The rest of the quadrangle has soils belonging to the sandy loam type.

Spruce was found in the swamps along the eastern boundary. These swamps occupy almost one continuous line and have connections with the swamps and bogs in the southeastern part of the Templeton quadrangle. Only in two places was spruce found to form pure stands in this part; usually it is scattered. The most common species found with spruce are white pine, hemlock, and red maple.

Although there are swampy areas of considerable extent in this part of the quadrangle, spruce does not occupy much of the swamps. Much of the swamp is covered with blueberry and other high shrubs. Often large grasslands are found in or near these swamps.

In the northwestern part of the quadrangle only scattered spruce

One of the early Harvard Forest records mentions a spruce stand of about one quarter acre here on Prospect Hill. Today there are only a few trees left (Plate 10). It is evident from the map that the seed-source of this stand could well have been in one of the many swamps nearby. In these swamps spruce is still found. It is possible that after the slope was abandoned as a pasture, spruce found suitable conditions there to become established and eventually to form a stand.

Spruce in the Tom Swamp tract is found in a bog. The site resembles the localities in the Royalston, Winchendon, Templeton, and Barre quadrangles where spruce was found in bogs which tend to form in broad valleys. Here in Tom Swamp too, spruce occurs scattered with tamarack over the deep deposits and seems to grow very slowly. Closer to the edges it forms a pure stand which can be very dense. Trees of 6 to 8 inches diameter breast height are not uncommon. According to Harvard Forest records, most of the spruces in this bog are black spruce (*Picea mariana*).

Concluding the description of spruce occurrences in the Harvard Forest it can be said, that all ecophic types found in the investigated area are well represented in the Harvard Forest. Spruce is found in upland swamps, in bogs, and on bouldery moist sites; it is found on areas adjacent to bogs and swamps and along the edges of a brook. It is also growing on a hillslope on formerly cleared land, a phenomenon which was not found elsewhere in the study area.

GROWING CONDITIONS

The purpose of this section is to discuss some of the growing conditions under which spruce was found to occur in the area investigated. Obviously all of the conditions affecting growth could not be measured, indeed many may not be known, but at least some of the gross characteristics of the various sites could be noted in a survey of this type.

The pattern of observed growing conditions established in the Athol quadrangle seems to hold true for almost all the study area, with the possible exception of the northern parts of the Royalston and Winchendon quadrangles. Any conditions different from those of the Athol area, however, have already been discussed in the preceding section. A detailed description of all the locations in the Athol quadrangle is included in the appendix to this paper.

According to the growing conditions observed on the field spruce was generally found on the following types of habitats:

Bog.

This type seems to prevail in locations where the conditions are and have been favourable for the formation of deep peat deposits. Such places are commonly found in the broad valleys which often have gravelly, sandy soils. A good example of this type is the bog in Ten Swamp VIII and IX.

Beside other variables, which may also have some influence in it, the height of the water table or the depth of the peat layer may have



Plate 2. Shows seedling from plate 1 before it was lifted from ground. Note water standing in pit of uprooted tree. Seedling grew on elevated ground.



Plate 1. Adventitious root system grown by spruce in bog. Roots are dead on the side which was in contact with permanently high water table.

considerable effect on this type. It seems that a deep peat deposit, as we find it in parts of Tom Swamp brings about a rather stunted growth of the spruce. Soundings made by Wm. Benninghoff (1947) in that part of the swamp have shown a 25-30 foot depth of peat. In other parts of the swamp on the other hand, parts which are closer to the edge and do not have deposits quite that deep, the growth of spruce is much better. It is usually in such locations that it is able to form almost pure stands and reach a height of about 35 to 45 feet in about 50 to 60 years. The water table ^{1/} may still be high in such locations, but spruce is able to compensate for the high water table by growing adventitious roots as shown in plate 1. From the observations made during the fieldwork it cannot be said how fast the trees are able to grow these adventitious roots if the water tables would gradually rise. In several cases spruce stands were found which were formerly growing in bogs under conditions similar to the ones described above, and were drowned out by the sudden rising of the water table.

The reproduction becomes established usually on fallen logs, stumps of cut trees, on the roots of uprooted trees (Plate 3.) or in other spots which are not on the level of the standing water (Plate 4.). The seedling shown on plate 2 was established on the elevated spot created by the uprooting of a tree. As soon as the roots reached the stagnating water they died on the side which came in contact with it (Plate 1.). Probably the new root system was formed under the influence of a gradually rising water

^{1/} "Water table" - refers to level of standing swamp water.



Plate 3. Spruce seedling growing on the uprooted roots of a tree tilted by the hurricane of 1934. Note water standing on the surface.



Plate 4. Seedling established on the root collar of standing tree. Seedling straightened up after large tree was blown down. Note curvature of the stem of the seedling near the ground.

table. It is possible that the standing water has a similar effect on the large trees too, and the stagnation in their growth or the cause of their death in many cases could be the high, stagnating [✓] water table which they can endure only for a certain length of time.

In such locations tamarack, hemlock, and an occasional white pine or red maple are found to grow together with spruce. It is possible that some of the spruces found in such locations are black spruce. Although this cannot be said with certainty for all the places where similar conditions were found it seems that there are many trees which resemble black spruce very much in the appearance of their cones and needles.

Upland swamps.

Similarly, as bogs suitable for the growth of spruce can be found in the broad sandy valleys, swamps suitable for its growth can be found in the uplands. The main difference between the two, the bogs and the upland swamps, seems to be the condition of the topography in which they develop. It is possible that some of the other variables which make these two sites different are related to topography also. One of the variables may be the thickness of the peat layer. While in the bogs it is not uncommon to find this layer 10 to 20 feet thick, in the upland swamps its thickness seldom exceeds one foot and in general is about five to six inches. Boulders sometimes protrude to the surface of these swamps, and

✓ "Stagnating" - refers to little fluctuations in swamp water level.

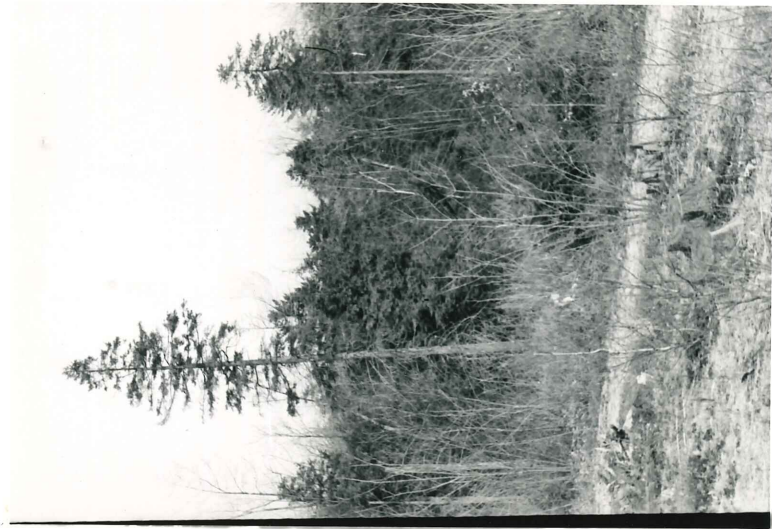


Plate 5. Mixed stand of spruce and hemlock. Note good forms and small crowns of spruce.

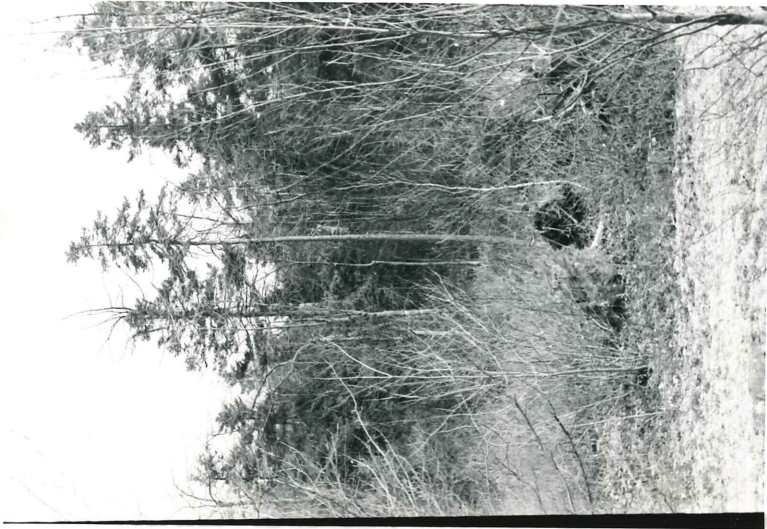


Plate 6. From "Big Spruce Swamp" in Prospect Hill tract of the Harvard forest. Deciduous trees in center background is black gum.

there are small humps of dry land emerging over the level of the swamp.

Under the influence of various factors, among which the depth of the peat layer and the height of the standing water could be of importance, spruce seems to grow in an association of red maple, yellow birch, black gum, hemlock, and white pine, although the latter never seems to occur in large numbers.

Certain circumstances seem to favour the predominance of red maple on these upland swamps. Spruce is found scattered in such stands. It is usually established on low elevations above the level of stagnating water. It is able to find such places on the rootcollars of the maples, fallen logs, or on the stumps of felled trees. It is not uncommon to find trees 5 to 6 inches d.b.h. which still make a yearly heightgrowth of about 4 to 5 inches. The trees seem to grow vigorously. They have a full crown even after they have attained a total height of about 15 to 20 feet. The groundcover consists of tall swamp grasses and various mosses among which sphagnum seems to be the dominant one.

Again, other circumstances seem to be more favourable for the development of a stand in which spruce grows together with hemlock. The main apparent difference between this type and the one described above seems to be a lower water table in the latter type. A good example of this is the mixed spruce-hemlock stand on the northern point of Thousandacre swamp in the Athol quadrangle. Certain favourable conditions seem to create an almost pure stand of spruce on such sites. The so called "Big Spruce Swamp" in the Prospect Hill tract of the Harvard Forest could belong to this type, together with two other swamps found south and east of Prospect

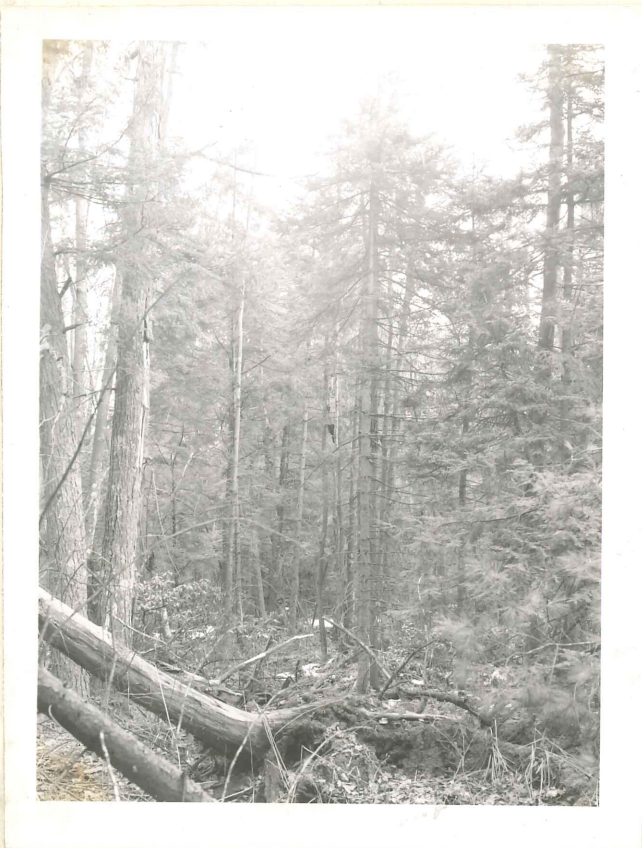


Plate 7. Pure stand of spruce and hemlock. Stand is very dense. Hardwoods in minority. Picture taken in "Big Spruce Swamp" Prospect Hill tract of Harvard Forest.



Plate 8. Scattered occurrence of spruce. Majority of trees consists of red maple, yellow birch, white birch, black birch and hemlock. Note the rising ground from left to the right side of the picture. Spruce standing near right edge of picture is growing about 100 feet away from swamp (see also plate 7). Picture taken in compartment IV Prospect Hill tract Harvard Forest.

Hill. The groundcover consists mainly of mosses and ferns, and here also sphagnum is the dominant species. Highbush blueberry (Vaccinium corymbosum) is commonly found in openings.

The areal extent of these types varies a great deal. Often it was found that the swamp types coincided with the contour lines of the topographic sheets. Within the swamp it is not uncommon to find stands that are predominantly hemlock and others that are predominantly spruce. Sample plots in the "Big Spruce Swamp" on Prospect Hill show the variation in composition rather well. In some of these sample plots spruce takes up as much as 70 percent of the basal area whereas in others it is as low as 2 percent and hemlock becomes the main species.

Plates 5 and 6 illustrate the general appearance of the upland swamp type in which spruce and hemlock occur in varying amounts. Some of the trees are very well formed and the live crowns are reduced to about one third of the total length of the trees. Plate 7 shows a rather dense stand of spruce as compared with the more scattered spruces of the stands in which red maple is the predominant species (Plate 8.).

Bouldery moist upland.

One of the features which makes this type different from the swamp type is that it is able to develop without having a direct continuation into a swamp. It is found on hillslopes or hilltops and also on flat sites. The ground is characterized by a large number of boulders on the surface. The depressions between the boulders are moist and are often filled with various kinds of mosses among which sphagnum seems to be the



Plate 9. Group of spruce on eastern slope of Prospect Hill in the Harvard Forest. Note large branches extending all the way to the ground. Trees probably grow up in open field. Ground is very bouldery and moist in places.



Plate 10. One of a few large spruces growing in a red maple red oak stand near Reservoir No. 2, in the Athol Quadrangle. Diameter breast height is about $\frac{3}{4}$ feet.

most frequent. Examples of the growing conditions of spruce under such circumstances are found on top of Prospect Hill and in Compartment IV of the Prospect Hill tract, also in a stand near Reservoir Number 2 in the Athol quadrangle (see no. 36), and in the southeastern part of the Athol quadrangle along Bakers Lane.

Plates 9 and 10 show that on these sites spruce can develop into trees of remarkable size (1 to 2 1/2 feet d.b.h.) compared to the stunted forms found in bogs. Plate 9 shows the spruces on the top of Prospect Hill. Large branches are extending practically to the ground. Thus it could be possible that these trees grew up under very open conditions, a hypothesis which is corroborated by the landuse records of this area, which show that the land was cleared for pasture. Plate 10 shows a spruce with similar branch development. This tree is about 2 1/2 feet d.b.h., and is the biggest spruce found in the whole investigated area. Plate 11 shows spruce in Compartment IV of Prospect Hill. The live crown here does not extend over the whole length of the tree; thus it is possible that this tree has grown up in a closed stand. Plate 12 shows saplings of spruce, reproduction under dense shade of hemlock, yellow birch, white birch, and red maple.

Although not swamps, these places are still rather wet throughout the year. Spruce is usually found scattered on these sites. The pure groups on Prospect Hill may have been results of land use.

Well drained soils.

Similar to the spruces growing on the bouldery moist sites, those



Plate 11. Spruce in compartment
IV Prospect Hill tract, Harvard
Forest. Note clear length of
broken tree. Reproduction in
foreground is spruce and has
look.

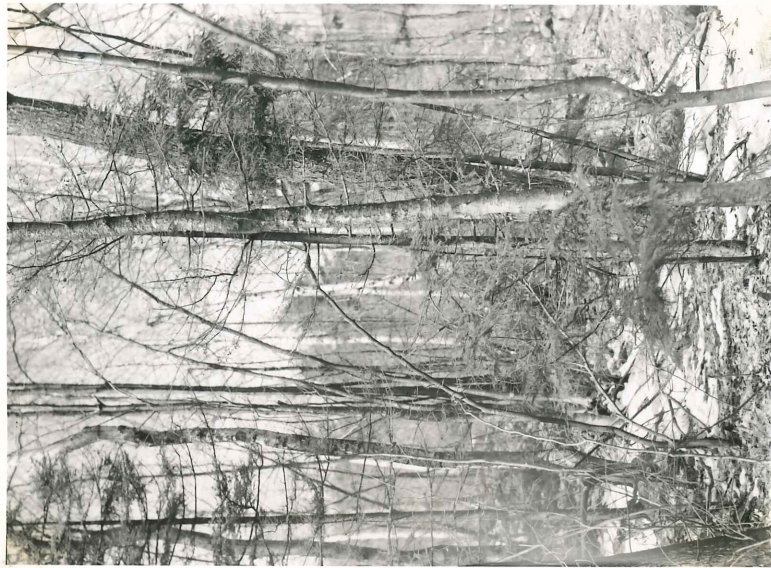


Plate 12. Spruce saplings growing
in the shade of red maple, red
oak, white birch, black birch.
Compartment IV Prospect Hill tract,
Harvard Forest.

found on the well drained soils are described here as a separate type because they do not have a continuous connection with a swamp or bog. It is not uncommon to find spruce growing on the edges of bogs or swamps, on whatever soils these edges might have. In these cases, spruce is usually found most abundantly in the swamp itself and its occurrence fades out farther from the swamp. The type of occurrence described here does not have a continuity. It seems uncertain whether it can be called a type or not for it is found under stands of various composition. It occurs only in the northern part of the Winchendon and Royalston quadrangles. Instead of calling it a type it would probably be better to say that under these conditions spruce was found not merely in certain poorly drained areas but was also found in flat moist locations, and on hillsides or ridges as well. The writer has not been able to locate trees larger than 4 inches d.b.h. growing under such conditions. It cannot therefore be said with certainty that these trees will survive and will not later in their lives be seriously affected and eventually killed by the surrounding or overtopping hardwoods.

It would also take a more detailed investigation in this type before it could be said that spruce is growing on well drained soils and not in the minute depressions of the microtopography which tend to be more moist than the surrounding higher areas.

It was noted on a trip to Mt. Washington that the pattern of spruce distribution from north to south seems to follow three steps. First, in northern New Hampshire, it is found in valleys, slopes and hilltops up to the timberline. Second, around Mt. Monadnock it disappears from the

slopes at least in noticeable quantities and remains only on the tops of hills in the form of spruce caps and in the moist flats, swamps, and bogs. Third, south of Mt. Monadnock, it disappears from the hilltops and continues the other phases of the pattern southward to the vicinity of the Harvard Forest by remaining in the swamps, bogs and, in general, places which are poorly to moderately drained. It is possible that the spruces found on apparently well drained soils in the northern part of the investigated area were the first noticeable representatives from south to north of the second major step in the distribution pattern, in which some spruce is found on the hillslopes.

Along moving waters.

Another site on which spruce is frequently found is along moving waters. The locations marked near the Phillipston Four Corners in the Athol quadrangle are good examples of such types. In general, narrow valleys do not seem to be favourable for the development of this type, for in such cases the spruce is not present and the stands bordering the edges of such waters are mainly of hemlock. If, however, the valley is wider and has a tendency to form a floodplain, it is on the higher elevated edges or islands of such plains where spruce is found.

The floodplains themselves are usually occupied by tall grasses with an occasional alder or red maple, but woody vegetation is often not present at all. It is on the edges of these grassy plains where spruces grow. It is not uncommon to find them 4 to 10 feet above the level of the plain itself. Often the ground is well drained. The groundcover here



Plate 14. Spruce on well drained land. Pictures was taken from the level of the swamp.



Plate 13. Spruce along the edge of a brook. Note scattered grasses among hemlock and white pine.

does not consist of grasses but mostly of ferns, and is often completely absent in which case the ground is covered only by a litter of needles and leaves.

In the previously described types white pine has not had great significance. Hemlock, tamarack, and red maple were said to be the associated species of spruce. In this type white pine is one of the major species to be found with spruce. The drainage appeared better adjacent to the river in this area than in any previously discussed type. This factor may contribute to the total condition responsible for the frequent occurrence of white pine.

Plate 13 shows the characteristic arrangement of this type. In the foreground of the picture the open water is visible. The water is bordered by flatland on which grass is growing; closer to the edges alders can be seen. The edges of the plain rises about 10 feet above the general level of the plain, and the other species with which spruce is growing can be seen well.

The plate also shows the number of spruce which occur in this type. Compared with the spruce swamps in which spruce can make up as much as 70% of the basal area these occurrences seem to be insignificant. Nevertheless they suggest the adaptability of spruces to various conditions of the environment. The trees found in such places are growing rather vigorously and may be able to develop into trees of the size as found on the bouldery uplands. The reproduction was abundant. In many cases it was found under the dense canopy of hemlock or under the shade of the mother trees.

Edges of swamps.

In most cases except the very localized occurrences in the southern and western part of the study area, spruce was found not only in the swamps, bogs or other poorly drained places but also on the moderately well to well drained edges of such places. It has been mentioned previously that the conditions of spruce growing on well drained soils and the ones growing on the edges of the swamps are very similar at least as far as the soils are concerned. It could be questioned however, whether spruce could grow on any of the edge habitats if it had not a seed source in the swamps.

There was a great variety of conditions under which spruce occurred on the edges of swamps. It was found in boulderfields bordering a swamp, on sandy loams, and even on loamy sands as in the Adams Fay Lot of the Harvard Forest.

Plate 14 taken in Tom Swamp VIII shows how high above the level of the swamp it is able to become established. In the same general area it was seen growing on gravelly sand with very little organic material on the surface. Similar conditions exist in one of the locations mapped in the northeastern part of the Athol quadrangle, where it is growing not only in the swamp but also on the sandy knolls emerging from the lowlands.

Plates 15 and 16 have been taken on the edges of the "Big Spruce Swamp" in the Prospect Hill tract of the Harvard Forest. The best growth is attained by the trees on the edges of the swamp, not only in this location but under the same conditions in general. The reproduction seen in plate 15 is very dense and if able to survive should certainly insure



Plate 15. Dense spruce reproduction on the edge of "Big Spruce Swamp" Harvard Forest. Reproduction is growing under the shade of hemlock.



Plate 16. Reproduction on the edge of "Big Spruce Swamp". Trees are growing about 60 to 80 feet away from the swamp, and about 6 to 8 feet above the level of the swamp.

a dense stocking. The young trees shown on plate 16 show that spruce is able to grow even at a distance of about 60 to 80 feet away and about 6 to 8 feet above the level of the swamp proper.

Pattern of growing conditions.

In the majority of cases the spruce occurrences can be classified into one of the above types. It should be stated, however, that often the occurrences seem to resemble different types in their various parts, and also that often the border between the types is not clear. Yet an estimated 95 percent of all the cases belong to the bog, swamp, and other poorly drained types, and only the remaining 5 percent can be classified into moderately or well drained types, both by the number of occurrences as well as by their areal extent.

POSSIBLE ORIGIN OF SPRUCE

Before an attempt is made to interpret the present day distribution and edaphic requirements of spruce in this area, the circumstances of their establishment and past distribution should be mentioned briefly. As a point of departure we may regard the period following the retreat of the last ice sheet in this region. The age and duration of periods since the retreat of the ice have long been subject to investigation by many people, and have been interpreted in various ways. Devey (1949) lists five climatic periods, based upon the analyses of pollen bogs: (1) a cool period, characterized by spruce and fir pollen, (2) warm and dry, with

pine pollen conspicuous. (3) warm (and moist) with predominance of beech and hemlock. (4) warm and dry, with a maximum of oak and hickory, a period often called the Xerothermic and. (5) the present, cooler and moister, with spruce returning in some northern States.

The spruce which is the subject of this investigation has been found in the lowest layers of bogs; that is, in layers which enclose representatives of the cool period.

The advance of the ice cap brought about a retreat of northern species into the ice free areas south of the glacial border. Spruce and fir pollen from bogs in Texas, Louisiana, and Florida seem to show how far south these species were capable of migrating. The question of where the southern species persisted during the glaciation and subsequent cool climate has been interpreted variously by different students. Decey's hypothesis states that "glacial chilling in the southeastern States must have been fairly extensive and that the warmth-loving species, including many or perhaps most of the 'Miocene relicts', survived in peninsular Florida and in Mexico, and have subsequently migrated to their present localities".

According to E. Lucy Braun (1951) there is no evidence to support the hypothesis that the 'Miocene relicts' lived in Florida during the Pleistocene. In Florida's post deposits, pollen of pines, oaks, hickories, grasses, ferns, palms etc., are found along with spruce and fir pollen (Davis 1946), but pollen of mesophytes and Appalachian species are absent. Neither is there evidence of a Mexican abode, says Braun in the same paper. Braun (1951) believes that: "as spruce and fir forests

now occupy the summits and upper slopes of some of the Southern Appalachians, and the Tertiary relics are there, too, it is reasonable to believe that such a combination of species could have been present in glacial ages, and could have persisted since Tertiary time". In a footnote to this sentence Braun says that the spruce (Picea rubens) is not a constituent of the boreal forest.

These hypotheses are presented here as concerning the possible refuges from which the species which are found today in our area made their advance after the retreat of the ice. Concerning the climatic conditions found by the advancing vegetation, recent studies of glacial geology suggest (H.M. Raup 1937) "that parts of central New England were not covered by the last ice invasion (Bryan 1936) however, the climate (Bryan 1928) during this late period must have been exceedingly rigorous". So even if the vicinity of the Harvard Forest was not glaciated during the last ice advance it is possible that due to the rigorous periglacial climate such processes as cryoplanation, solifluction and congeliturbation had a significant part in forming, and subsequently modifying the soil structures, surficial deposits, and land surfaces.

H.M. Raup describes various phenomena such as boulder streams and stone rings, resulting from intense frost action, that are characteristic of many parts of arctic and subarctic land. Features ascribed by C.S. Denny to periglacial action in Potter County and elsewhere in Pennsylvania, resemble those described by Raup from southwestern Yukon and are believed to have similar origin.

H.M. Raup (1951) concludes that: "though these processes are now largely confined to boreal and alpine regions, they were formerly effective

far southward, and at low elevations, even beyond the boundaries of the glacial ice. Their effects here upon soils and surfaces were so extensive that they still obtain and are strongly reflected in the nature and distribution of our natural vegetation*.

The landscape in the vicinity of the Harvard Forest shows phenomena similar to those found in Pennsylvania by Denny and in the Yukon by Raup. Recent studies of Stout (1950) reveal that the microtopography of slopes is composed of broad terraces, strongly reminiscent of those seen on arctic slopes (Raup 1951) and are backed by masses of boulders on their fronts. Rock fields, boulder streams, and stone rings have also been found on the Harvard Forest.

The similarity of periglacial phenomena on the assumed glacial border in the neighborhood of the Harvard Forest and in regions where periglacial action is still active seems to be strongly suggestive. Still an interpretation of our modern vegetation in terms of the periglacial climates should be approached, according to Raup (1951) "circumspectly, and with full understanding that even in the Arctic where congeliturbation is still active and a major factor, its relation to vegetational dynamics is very imperfectly known". This shall be kept in mind when in the following paragraphs an attempt is made to explain the present distribution of spruce in the Harvard Forest and its surrounding area.

Observations of G.S. Denny and J.W. Sticht (1950) in the Yukon suggest that most congeliturbation and related frost processes take place in areas devoid of trees. By analogy, when such periglacial phenomena were actively forming on the surrounding area of the Harvard Forest, the area

could have been essentially treeless.

Assuming that it was a treeless landscape into which the trees from their southern refuges migrated one may ask whether there was another vegetation already preceeding the arrival of trees in this area. H.M. Rump (1951) mentions certain facts and suppositions which suggest that "the region of the glacial border here in eastern America had no arctic tundra in the strict sense of the term during glacial or postglacial time". According to Potzger (1951) the pollen records do not reveal evidence of a tundra having bordered the ice sheet. In most bogs and lakes which he studied, vegetation begins with pollen of forest trees. Potzger believes that: "the most important pioneer tree as shown by all bogs, was Picea. In some instances it had no associates, at other locations Abies was an associate". Soundings taken by Wm. Benninghoff (1948) in a bog in the Fox Swamp tract of the Harvard Forest brought up spruce pollen from the bottom of the bog, a depth of about 30 feet. This is suggestive that, as shown by observations elsewhere, here too spruce seems to have been the pioneer species.

The question of whether spruce invaded the area at the same time the hardwoods did cannot be answered with the present amount of evidence. Further it is not certain at all whether spruce has occupied the uplands as well as swamps in the course of its northward migration. Till now no spruce pollen has been found in the buried soil profiles on uplands, whereas in bogs its presence seems to be uninterrupted.

If we accept the hypothesis that this area was within the region of periglacial frost action, we may well try to find a suggestion for the

distribution of spruce in the vegetation patterns of areas where frost action is active at the present. Rocky stream channels and gullies are commonly regarded as the most unstable plant habitats in our temperate region. Observations of H.K. Raup in the southwestern Yukon on the other hand suggest that: "such stream channels, though they are very poorly represented, turn out to be the most stable habitats, for the presence of even a small running stream has a tendency to lower the water table slightly and so cut the supply of water to the surface soils immediately along its banks. The principal effect of this is to lessen the activity of frost so that the materials along the banks of the stream actually stay in place for longer time than those on surfaces without streams". It has been observed in the Harvard Forest and its surrounding area that the occurrence of spruce was mostly connected with rocky, bouldery places such as are formed under frost action. Often such places are found along moving water below swamps or bogs through which a stream is flowing. Even in completely ponded areas the bottom is frequently found to be bouldery and it is not impossible that these places were once boulder-streams dissected by moving water and were only ponded by material which moved down the slope gradually.

It seems possible that at a time of intense frost action these places functioned similarly to the streams in the Arctic mentioned by Raup. These places may have supported the only forests in this area while the uplands were still affected by the action of freezing and thawing.

A gradual retreat of the glacier and subsequent amelioration of the climate could have brought about a further advance of trees from the

south. It has been mentioned before that there seems to be little evidence to back up hypotheses of spruce having occupied all the uplands in this region prior to the advance of hardwoods and having been restricted to bogs during the warm period of the postglacial optimum. But no matter what its behaviour might have been from the period of its establishment to the present it seems that spruce has been able to hold its ground in the localities where it is found today. The material gathered during the field work of this paper suggests that a trend toward a cooler climate could result in its spreading over the uplands from the presently restricted areas of its occurrence.

POSSIBLE VARIABLES OF PRESENT DAY DISTRIBUTION

In the preceding chapter a hypothesis was presented concerning the possible circumstances of the establishment of spruce in this area. It was supposed that after the last ice advance the spruce came into this area. It was supposed that after the last ice advance the spruce came into this area from the south, and also that at some time there was a continuous connection between the northern and southern occurrences of spruce. It would be difficult if not impossible to answer the question whether this connection was in the form of a spruce-fir belt at our latitude or not. Yet if there was a continuous connection it seems to have disappeared.

The map of New England forest types shows the spruce region in northern New England as about 70 miles north and about 50 miles west from the research area. The distribution toward the south follows the Appalach-

ian ridges as far south as North Carolina. The question now is, what are the possible causes of the present day distribution pattern in our area, and what seem to be the variables of spruce habitats in the investigated area? To help in evaluating and explaining the observations made in the field, the following comments are offered regarding the factors involved:

Physiography.

It is evident from figure 4 that the pattern of areal distribution of spruce fades out toward the south and west. A somewhat lighter pattern in the eastern part of the area is not so pronounced. It is possible that some of the following factors have an effect in this fading out of the distribution pattern.

The first one to be mentioned could be the Connecticut River which is in the quadrangle next to the western edge of the area of study. The map of New England forest types shows a transition hardwood-white pine forest type along the river valley, almost as far north as the Canadian border. The valley has a similar climate and lower elevations (200 feet above sea level) than the neighbouring uplands to the east and west (850-1150 feet above sea level). The presence of black oak, chestnut oak, sassafras, and hickory in the western Quabbin area might be a result of the same influence which is prohibitive to spruce.

The above hypothesis suggests an explanation for the distribution pattern along the western edge of the area. The fading pattern near the southern edge may be a result of a gradual decrease in elevation from

North to South. Elevations south of the area are even lower (Figure 1).

The pattern of distribution becomes denser toward the north. Among the five types into which spruce occurrences can be classified in this area it has been mentioned that in the northern part spruce can be expected to occur scattered on uplands. The forest type map seems to suggest, by the closeness of the spruce-fir island in the vicinity of Mt. Menadneck, and by the distance of about 70 miles to the spruce region, that probably the climate and soil conditions and related factors could be, in swamps and uplands alike, more favourable for spruce in the northern than in the southern part of the area.

The eastern edge of the distribution pattern is still very dense in its northern part. Toward the southeast it fades somewhat. The reason for this may be similar to those which bring about a fading of the pattern on the southern edge. It has not been investigated whether the pattern continues the same further east toward the coast. It is possible that lower elevations and oceanic influences have an effect on the density of the pattern. Spruce may be found occasionally farther south in Rhode Island, or in the Black Rock Forest in southeastern New York where the writer has seen it in a bog.

Topography.

Topographic features may also have an effect on the distribution. It has been noted that in about 95 percent of all cases spruce was found in swamps. The dense distribution pattern in the northern and central part of the area coincides with an abundance of swampy places. The western and

southern parts of the area, which seem to be at least locally the edge of the peneplain, have a smaller number of swamps.

Microclimate.

Investigations of S.H. Spurr (1950) and H.H. Rasche (1948) on the Harvard Forest suggest that variations in temperature over various land forms may have influence upon the distribution of local forest types. According to studies of Transeau (1943) "it is not improbable to think that the microclimatic factors have more to do with these dynamic inter-relations of the community mosaic than have the substrate factors".

Observations of Rasche (1948) show that convex areas tend to have a climate similar to the marine climates. Concave areas on the other hand resemble more the continentally influenced climate north of the Harvard Forest.

Applying these observations to the distribution of spruce, in almost all cases spruce was found in concave places. These places should have a climate resembling a northern climate. According to Rasche (pers. comm. March 1953) the extremes in temperature in concave areas are greater than those of the surrounding elevated lands. The span of extremes increases from the higher lands (1000-1100 feet above sea level) on the uplands toward the lower, concave areas at lower elevations (750- 850 feet above sea level). This phenomenon could be attributed to better air drainage and ventilation at higher elevations.

If the microclimatic observations made on the Harvard Forest could be accepted for the whole investigated area, it could be said that

localities in which spruce was found in an overwhelming number of cases tended to have a considerably lower minimum, but only slightly higher maximum temperatures than their surroundings. Despite of a suggestive coincidence between the microclimate and the spruce distribution, microclimate alone may not be regarded as the sole factor responsible for the presence of spruce. However, it could well be one of the important variables of present day spruce environment.

Although there is no evidence here to support the hypothesis it is still not impossible that under the influence of physiographic and climatic factors the ratio of precipitation to evaporation is different in various parts, notably on the edges of the area of study. If such influences do exist, they could probably be used to explain the fading out of the distribution pattern whenever it approaches areas of a supposedly warmer macroclimate. In the same way a denser pattern toward the north could develop as a result of approaching a colder climate. Quoting from H.N. Raup (1937): "one of the most significant correlations ever adduced between these (climate and vegetation) boundaries is that of Transsian for the ratio of precipitation to evaporation. A map of isoclimatic lines drawn up from this ratio was found to correspond remarkably well with the configuration of forest types in eastern North America. The correlation was somewhat improved by Livingston and Shreve (1921) with the insertion of a "duration factor" for the length of the average frostless days". It is not improbable to think that similar studies in this area would show some coincidences concerning the distribution of spruce.

Hydrogen-ion concentration of the soil.

The actual relationship between pH^{1/} and plant growth has been studied by many workers; yet it is not certain, from the viewpoint of plant physiology, whether the important factor is the soil reaction, its content of exchangeable bases, or its deficit from base-saturation (G.W. Robinson 1936).

In this study the pH values of the soils were not tested. Yet there may be some coincidence between the distribution and the growth of spruces and the pH values of their habitats.

As stated elsewhere in this paper, about 95 percent of all spruce was found in bogs and swamps. Parts of such bogs and swamps are covered with low shrubs and mosses, and the trees growing on them are usually dwarfed. The pH reaction in such localities may be around 3.9 or lower (Wilde 1946). The same source (Wilde 1946) gives pH 4.0 to 5.5 as the pH range of spruces in general, and labels black spruce as acidiphilous. A.A.J. de Sigmond (1936) states that: "high-moor^{2/} humus is poor in bases; consequently high-moor peats are usually very acid and deficient in plant nutrients".

The pH reactions of some upland soils on the Harvard Forest were tested by E.G. Griffith, E.W. Hartwell, and T.E. Shaw in 1930. In the course of their study 170 samples were analyzed. Seventy were from old field white pine stands and another seventy from hardwood stands. In the dark brown horizons under pine pH was ranging from 3.3 to 5.1, the light brown horizons from pH 4.3 to 5.7, and the O horizon from pH 4.6 to 5.8.

^{1/} Negative logarithm of the hydrogen ion concentration.

^{2/} Consisting mainly of various species of sphagnum and cotton grasses.

Under hardwoods the dark brown horizons vary from pH 3.8 to 5.4, the light browns from pH 4.3 to 5.2, and the C horizons from pH 5.1 to 5.6. The leached horizon under a pine hemlock stand had an acidity of pH 2.9, and under mixed hardwoods an acidity of 3.1.

Most of these data are within the range of the pH given by Wilde (1936) as the one required or tolerated by spruce. Some of the pH values are even lower, yet commonly there are no spruces found on the uplands. Lower pH reactions are probably more often found in swamps and bogs than on the uplands. It is possible that these lower pH values prohibit the growth of other tree species in bogs and swamps, yet in many cases do not provide optimum growing conditions for spruce, hence the dwarfed forms of spruces on bogs and better formed individuals on the edges of bogs and swamps, where pH may be somewhat higher.

According to some authors there is a mutual relationship between plant growth and soil acidity (Soil Survey Manual 1951). As cited by Aaltonen (1948), R.F. Chandler (1937) concludes from his studies that the type of humus layer is the direct result of the influence of the tree species.

Systematic studies on just how the type of the humus layer depends upon the ground-cover are very scarce (Aaltonen 1948). He says that: "for instance *vaccinium* is commonly accompanying *raw-humus*, but no matter how commonly *vaccinium* is associated with *raw-humus* it is uncertain, whether *vaccinium* should be regarded as the cause or the effect of *raw-humus*."

D. Fehér (1931) is inclined to believe that the soil acidity is chiefly a product of temperature and precipitation. It is possible that

Plate 17. Abandonment of spruce by
Junco hyemalis.



Plate 18. Small grass growing
under *Junco hyemalis*.



together with these factors, or as a result of them, the pH reaction of the soil is one of the important variables of the spruce distribution.

Hardwood competition.

The native hardwoods are able to grow faster on the uplands than are the spruce. The better growth of hardwoods becomes evident on the edges of swamps, where spruce, although able to become established and develop well in its youth, is often retarded by overtopping of long duration and is frequently killed by it. Another prohibitive effect of hardwoods is the abrasion of the growing tip of spruce by the neighbouring hardwood trees. Unlike the hemlock which with its flexible tip is able to work its way through the branches of overtopping hardwoods, the more rigid tip of spruce is very sensitive to abrasion. Plate 17 shows the tip of a young tree which had been subject to abrasion through several years. As a result of this the growth became stunted and after a while the tree dies.

It was mentioned in the description of the northern quadrangles that spruce was frequently found under hardwoods. Plate 18 shows spruce growing under hardwoods also. However, it must be remembered that in all these cases only small trees were found. Therefore it is not documented at all whether they will be able to grow up to become members of the high canopy. The large number of small dead spruces frequently found around swamps may be an indication that hardwood competition can be serious for spruce. Similar conditions were found under a large single tree which

was able to grow up in an old field. Despite the fact that this tree may have been there for at least 150 years, not a single one of its seedlings was bigger than 9 to 11 feet, and many small dead trees were found (Plate 19).

Root system.

The root system of spruce should perhaps be one of the variables which enable this tree to grow in poorly drained soil; on the other hand it may be prohibitive to its growth on excessively drained land.

The root system of spruce is very shallow, it seldom reaches down farther than one foot into the surface of the ground. This has been noted time and again on the root masses of uprooted trees. The root system was found to remain shallow under all soil conditions observed in this area. Plate 20 shows spruce on bouldery land which was not poorly drained, yet the roots seemed to be very close to the surface.

This shallow root system enables the trees to grow in the swamps and bogs. It was noted that the reproduction becomes established on fallen logs, stumps, and on root collars of standing trees rather than on the swamp level. The growing trees are able to develop in the substance above the water level of the swamp. The water level in swamps seems not to fluctuate as greatly as in swales or better drained areas. Measurements in the Slab City tract of the Harvard Forest in September and October 1952 showed a fluctuation of only 2 inches in a swamp as compared to 15 inches in a swale and 8 inches in a better drained soil. The slow raising or lowering of the water level is balanced out by the development of adventi-



Plate 20. Spruce has shallow root-system. The picture was taken from a tree growing on a hillside moist upland. Diameter of the tree is about 1 foot.



Plate 19. Only small reproductions are found around big spruce. Tree in background is about 2 1/2 feet diameter breast height.

tious roots on black spruce. A quick raising of the water table may result in drowning of the stand, as was found to have happened in some recently ponded areas.

Plate 1 shows a spruce seedling with three collars of adventitious roots. The plate also shows that the side of the root system which was reaching into the stagnating water is dead. It is possible that the apparently high mortality in some of the spruce stands is caused by high water tables which the trees cannot evade.

On well drained and especially on excessively drained lands spruce is often affected by drought periods. In the investigated area small trees have frequently been found on dry gravelly knolls adjoining swamps. Although these trees could eventually grow up to large size, there is no proof within the area that this has happened. A large number of small trees about 6 to 8 feet high have been found near the Riverside cemetery in the Winchenon quadrangle. The soil here is very sandy and gravelly and supports, predominantly, white pine stands. The spruce trees could have become established naturally here; nevertheless they seem to be growing very slowly, have flat bushy crowns, and do not look at all vigorous. It seems very doubtful whether these trees will ever be able to grow up to merchantable size, for they may be unfavourably influenced by droughts on this as well as on all similar sites.

The largest trees in the area were found on the edges of swamps or breaks, or in bouldery, rocky places. These places are better drained than the swamps and as a whole make up the transition from the swamps into the adjacent well drained soils. The competition of hardwoods here is

not so severe. As shown on Plate 15 the reproduction is most abundant in such places. It was noted by W. Shepard (1911) in one of the earliest silvical studies of spruce in the Harvard Forest that apparently it is in these locations where spruce finds optimum conditions in this area.

Windthrow.

Due to its shallow root system spruce is very easily blown down by wind. How much its present day distribution was modified or formed by blow down would be difficult to guess. Winds of high velocity are not uncommon in this neighbourhood. The hurricane of 1938 caused severe damage to the spruce stands in the Harvard Forest. Even if spruce had been present on the uplands before some major blowdown of the past, its reestablishment would probably have depended on factors which were enumerated in the preceding paragraphs of this chapter, namely physiography, topography, microclimate, hardwood competition, and characteristics of the root system.

Effects of human activity.

From contemporary descriptions it is known that the first white settlers found native Indians in this part of New England who were cultivating agricultural crops. Hence human activity as a factor modifying the distribution of vegetation was not initiated by the white man. The extent of cultivated land, however, was by far smaller than it was after settlement. Yet it is not impossible that parts of the land were cleared and later on

abandoned by the Indians as the producing capacity of the ground decreased or families migrated to other grounds.

Even if the extent of the land clearing was not significant compared with the clearing made by white settlers, there is the possibility that certain parts of the area were affected by the land use of the natives. In their clearing activity fire was often employed. It is mentioned in many of the early accounts of this country that Indians frequently set fire to the woods to chase out game. It would be difficult to say just which parts of the present forests have been subjected to burning by either the Indians or since the settlement by white men. One can find charcoal at almost any place in the woods in this area. It appears reasonable to believe that fires, caused either by Nature or man, have occurred in this area in the past.

Any interpretation of the significance of precolonial human activity upon the distribution patterns of vegetation in colonial times would need a great deal more evidence than could be given within the range of this paper. Nevertheless it is not impossible to think that the park-like arrangement of forests found by the settlers in this part of the country was at least to a certain extent a product of human activity.

Land use studies by R.H. Rapp and R.E. Carlson (1941) in the Harvard Forest suggest the human activity of the last 200 years to be one of the most powerful modifying factors in local vegetation patterns. These studies found the following major land use periods to have existed in the area: (1) homestead clearing, about 1740, production just enough for family consumption, most of the area was still forested, (2) peak of

agricultural activity around 1530, nearly 70 percent of the total area was cleared, (3) farm abandonment following 1850, the period of large migrations toward the West, (4) logging on the old field white pine stands which came up in the abandoned fields and reached merchantable size around 1910, (5) present period, after 1915, forests reverting to a mixed hardwood-white pine type.

When the Harvard Forest was acquired in 1907 it represented, as H.F. Fisher, its first director, said, merely what 150 years of ups and downs in rural colonization had done to the virgin wilderness (Fisher 1931). Indications of former agricultural land use over the whole area of investigation were found, such as stone walls, cellar holes and remnants of fences. This may justify the generalization of the land use studies in the Harvard Forest over the whole area.

The question is, how far did human activity modify the distribution of spruce? Was there any spruce growing on the uplands in pre-colonial times, or was it growing in such the same localities as we find it today?

There is little evidence available to answer this question. Pollen analyses and relic woodlands are about the only sources to draw from. Until now only a few pollen analyses have been made from buried soil profiles on uplands in the Harvard Forest. The samples did not contain spruce pollen. The relic woodlands, on those lands which were never cleared for agricultural purposes, may give another indication. Although never completely cleared these forests have probably been culled over frequently, which may have changed somewhat the precolonial con-

position. However, in none of the upland relic woodlands can spruce be found at the present, at least not in those which Bump and Carlson (1941) agree have never been completely cleared. The localities where spruce is found presently may never have been cleared either, for they were too swampy. These localities then could be regarded as relic woodlands in which spruce was able to perpetuate itself.

From the foregoing it cannot be said with certainty whether spruce was growing on the upland loamy soils in precolonial times or not. Whitney mentions spruce only in the Town of Royalston, where even today it is found to have one of the densest distribution patterns of the whole investigated area. It is entirely possible that it was growing there on uplands in precolonial times, yet it may not have been a major component of the forest. In the rest of the area it was presumably growing in its present well defined localities.

Following the abandonment of farms, white pine seeded in on old fields and pastures, but not spruce as one sees it farther north. In the whole area there are only two places with certain indications that spruce became established after the areas had first been pastured. One of these places is high up on the eastern slope of Prospect Hill in the Harvard Forest. Early Harvard Forest records give the extent of this spruce stand as about $\frac{1}{2}$ acre. Plate 9 shows the trees to have long crowns typical of open grown trees. Plate 10 shows the other field spruce occurrence which was found near Reservoir No. 2. in the Athol quadrangle (location number 35) and where spruce is growing on a rocky moist site. For the behavior of the spruce reproduction under these trees see paragraph

two on page 53 of this paper.

The fact that spruce-stands in the swamps have been logged repeatedly in the past was shown by S.R. Spurr in the "Big Spruce Swamp" in the Prospect Hill tract of the Harvard Forest (Location No. 52). Indications of cutting operations have been found in many of the spruce stands of the investigated area. These cutting operations could have altered the composition of some of the stand by favouring one or another component species. Since the original composition of these stands in precolonial times is not known, but could have shown considerable variation from place to place, it is possible that the effects of cuttings are likewise different in their results. It may be that spruce has been eliminated from some places by cutting, considering, however, the abundant reproduction usually found in spruce stands it is likely that at least a few small trees would be present now, perhaps some which have seeded in from some of the undesirable or small sized trees left over after logging.

In recent years much of the reproduction has been cut for Christmas trees. An old lumberman in the Petersham area pointed out some swamps in which about 60 years ago spruce was commonly found. Today it is very difficult to find spruce in these places because almost all young trees were cut down for Christmas decorations. Such, as a rule, is the case near settlements.

Artificial ponding is certainly one of the human influences which has eliminated spruce in some places. It has been mentioned that spruce is able to stand slow raising of the water table, but quick and long lasting changes in the water level may drown the trees. Many of the

depressions have been dammed up in this area for mill ponds or for log storage. The writer has seen spruce stands which died as a result of recent artificial ponding. It seems reasonable to believe that since the settlement of the white man the distribution of spruce has in some places been modified by artificial ponding. Similar phenomena could have occurred in precolonial times by the dam building of beavers.

As a summary of the effects of human activity it seems that although it may have considerably influenced the various spruce habitats, it apparently did not disturb the pattern of geographic distribution of the species a great deal.

TIMBERY ASPECTS OF LOCAL SPRUCE.

Several farmers and lumbermen were asked during the investigation for their opinion about the value of local spruce as a timber tree. Their answers almost invariably began with "This is not spruce country". Yet they all agree that although not in large quantities, local spruce timber has always been cut in this area.

Cutting methods.

In the course of the field work the writer visited several places in which spruce was being logged at the time. The cutting operations are almost invariably carried out in the winter. The ground is frozen then, and the spruce stands, which usually have pools of water standing on the

surface of the ground, are more easily accessible in this season. The stands are most commonly clearcut, leaving only an occasional badly formed tree or trees of unmerchantable size. It seems reasonable to believe that this method has been followed generally since the settlement of the region. The method seems to be suitable for the perpetuation of spruce.

A cutting method which leaves scattered seed trees seems not very practical. The trees, being very susceptible to windthrow because of their shallow root systems, may be blown down by winds of not unusual velocity. However, if one wishes to take this chance, this method of establishing reproduction may give satisfactory results.

Very dense reproduction after strip clearcutting is shown by one of the illustrations in the first Harvard Forest Bulletin. It is not stated there how the cutting was laid out; and today it would be difficult to trace its original location because all the swamp spruce stands in the Harvard Forest were severely damaged by the hurricane of 1938.

Uses of local spruce.

According to the first mentioned prevailing cutting practice, usually trees of about 6 to 8 inches in diameter at breast height are cut. The logs are commonly sawed into dimension stock.

A study of the pulpwood marketing possibilities in the Peterham area was made by Wm.H. Martin in 1948. According to his findings it would not be impossible to find customers for locally cut spruce. No operations

are being carried out at the present where spruce is cut exclusively for pulpwood. However, it is not impossible that some of the smaller trees cut may give a sufficient amount of pulpwood to make it worth while to operate them. There are several stands in the area which would supply considerable amounts of pulp.

The small trees are often cut for Christmas trees. This has been mentioned before also as one of the factors inhibiting the spread of the species. A study made in the Lake States region regards the growing of spruce for Christmas trees as one of the most profitable enterprises on swampy lands. Certainly this would seem to be feasible on many of the lands occupied by spruce in this area. Considering the high number of spruce occurrences here it is probable that the Christmas trees cut from them would supply the local market. If suitable methods can be found for the perpetuation of spruce on its present sites the sale of these trees could provide an additional income for the owners of swampy spruce forests.

Some of the larger spruce stands are found in places which belong to the watershed areas of reservoirs or flood control areas. Since no other trees are able to grow on most parts of these watersheds it seems that the most important role of spruce there is in watershed protection.

Improvement of spruce sites.

There is a great difference between the rate of growth of trees in bogs or places with very high water level, and in those places which have a lower water level or have better drainage. While trees on bogs

are frequently found to have only a diameter of 2 inches d.b.h. at an age of 50 to 60 years, on better drained lands they may obtain a diameter of 6 to 8 inches d.b.h. in the same amount of time. This suggests that perhaps drainage could improve some of the lands in which the growth rate is very slow. Experiments in Maine showed that the growth rate of black spruce in recently drained swamps increased considerably as compared with that in undrained areas (T. Grisez pers. comm. May 1953). It would be interesting to see what results the drainage would bring in this area. There are however, two questions which arise in connection with this problem: (1) whether the drainage would not favor eventually the growth of hardwoods which would in due time crowd the spruce out, and (2) whether these drainage operations would be economically feasible.

Planting of spruces.

Although this paper is primarily concerned with the natural occurrences of spruce, from the point of view of forestry it would also be interesting to see how artificially established stands of native spruce perform.

To begin with, over the whole area the majority of the artificially established stands consist of pine plantations, mostly of red pine. Only a few spruce plantations were found and they were almost exclusively of white or Norway spruce. There was only one red spruce plantation found and that is in the Harvard Forest. Red spruce frequently was found planted for ornamental purposes and in these locations seemed to grow well. This, however, should not be accepted as an indication that it would perform



Plate 21

Red spruce plantation. Note the effect of hardwood overtopping. Spruces not affected by hardwoods are much taller. Ruler on tree is 1 foot.



Plate 22

similarly under the growing conditions of a closed stand. No black spruce plantation was found in the whole area.

If we would try to apply the observations made on natural spruce stands to its planting then the first important matter would be the selection of the proper soil type. According to the observations the best growth is made in moderately well drained soils. However, there is not much known about planting on this type of land and probably it would take considerable experimentation before successful methods could be found. Other observations concerning the soil seem to show that spruce is able to become established on just about any kind of soil found in this area. Yet there were no large trees found on other than moderately drained land, which gives no guarantee of the survival to commercial maturity of the plantations on such sites.

As in natural stands, the competition provided by hardwoods also has to be considered in planting. Plates 21 and 22 show that overtopping by hardwoods may result in considerable differences in the growth of spruce. The plantation shown on these plates is evenaged, yet some of the trees are only between three and four feet high while others are 10 to 15 feet high. These differences can be attributed to the overtopping hardwoods which by shading and abrasion retard the growth of the trees.

To eliminate hardwood competition spruce plantations have to be weeded repeatedly under local conditions. The weeding has to be repeated at intervals of about 3 to 5 years if the plantation is to be kept free of the influence of hardwoods. Weeding methods using machete or axes require high labor inputs. Recently initiated methods of chemical weeding may prove to be a cheaper and more efficient method for the elimination

of hardwoods from plantations. It may be that chemical treatment of hardwood stumps or advanced hardwood growth prior to the planting of spruce would prove to be efficient in reducing later competition.

The material available for reasoning about the feasibility of spruce plantations is certainly not sufficient. One of the important factors, however, in every kind of planting is the origin of the seed from which the plantation is grown. It is reasonable, for example, to think that trees flourishing on the moderately drained edges of swamps would provide seed which would give satisfactory results if used in local planting.

SUMMARY AND CONCLUSIONS.

In light of the early and continued interest in spruce at the Harvard Forest this paper has a two-fold purpose: (1) to describe the geographic distribution of native spruces in the Harvard Forest and adjacent areas, and (2) to see if the pattern of occurrence and the growing conditions described can lead to a more complete understanding of the silvical requirements of spruce.

The geographic distribution of spruce is illustrated in Figure 4. The frequency of spruce occurrence is highest in the northeastern part of the study area. Thence the occurrence becomes less frequent toward the western and southern edge of the area, while along the eastern edge there is no pronounced decrease in the number of occurrences.

Spruce was found in six major types of habitats, namely, bogs, upland swamps, bouldery moist uplands, well drained soils, along brooks, and on the edges of swamps. An estimated 95 percent of all the cases belong to the bog, swamp, and other poorly drained types. Only about 5 percent can be classified into moderately or well drained types, both by the number of occurrences as well as by their areal extent.

An hypothesis is offered concerning the circumstances of establishment of spruce in the study area. According to this hypothesis, following the last ice advance, spruce became established in more or less the same localities where it is found presently.

Physiography, topography, microclimate, hydrogen-ion concentration of the soil, hardwood competition, root system, windthrow, and human activity are discussed as being variables which may have had an effect upon the development of present day distribution pattern and may have influenced the growing conditions of spruce habitats.

The writer visited several places where spruce was being cut for timber. It is also widely used for Christmas trees, and is highly regarded for watershed protection. Thus its role as an important forest tree in this area is established.

APPENDIX

OCCURRENCES OF SPRUCE IN THE ATHOL QUADRANGLE.

Numbers correspond with those on Athol Quadrangle map in Appendix.

1. In the northeastern corner of the quadrangle, along the Royalston Main Road, the wet places along Beaver Brook support hardly any woody vegetation at all, but there is a grassy cover. Only on the edges which are apparently somewhat elevated above the level of the swamp of the creek do we find scattered spruces with white pine, hemlock and red maple.
2. This place is located in the same general area as the last, but on the west side of the road. While on the elevated portion above the swamp on the east side white pine is dominant, here the dominating species seems to be red maple. Apparently it has been cut over repeatedly and presently gives the impression of a coppice stand. Some spruces and white pines are scattered in this stand of red maple. There is also plentiful reproduction present which could develop into some good trees if they are not retarded too long by the overtopping hardwoods. The spruces which are above the canopy of the red maple are about 25 feet tall and are apparently growing vigorously. They have a full crown which could be an indication that they developed in the open. No insect damage was noted on trees under shade, but open grown trees show signs of attack by gall aphids.
3. This area is located east of the Royalston Main Road on the edge of the Beaver Brook. The ground next to the brook is covered with

with grasses, similarly to the areas mentioned just before. The stand in which spruce was found seems to be somewhat elevated over the level of the plain of the brook. It is still rather moist; the groundcover consists of grasses and mosses, with sphagnum predominating. The stand is composed of red maple, alder, gray birch, aspen and hemlock. Spruce is scattered over the whole area. The largest ones are about 25-30 feet tall. The live crowns take up the whole length of the trees. In general they seem to be growing well and apparently are not infected with any insects.

4. On the northwest side of the Colony Road the most striking feature of the spruces is that they are not only found in locations which have the character of a bog, but also on the adjoining dry land. The boggy depressions have a ground cover of ferns and sphagnum, while the adjoining areas have a cover which is commonly found under hemlock-white pine stands in this region. The lot is just being logged, and most of the larger trees have been cut. The reproduction is, however, very dense in the bog as well as on the adjacent lands. Spruce, hemlock and white pine are present in about equal proportions.

5. The northeastern part of the quadrangle, south of the Colony Road, in general has the characteristics of the stand described under No. 6. and is therefore not described in detail here. If there is a difference between the two areas it is only that here the grassland occupies a somewhat larger area along the edges of the brook.

III.

6. Southeast from the area described previously, the lot is situated on both sides of the South Royalton Road. It has the appearance of a red maple swale with hemlock and scattered spruces. The ground is covered with red maple leaf litter. In open places grasses and ferns cover the ground. In depressions sphagnum is found. The two dots along the road near the swamp, indicated on the map, show locations where spruce was found growing outside of the swamp on places which are rather dry. Some parts of the swamp itself look very much like Prospect Hill swamp. Hemlock and spruce are the main species and red maple is in the minority.

7. This area is located near the so called Five Points on the southeast side of the Colony Road. The land next to the road is in cleared pasture. Along the brook which flows through parts of the swamp there is grassland and almost no woody vegetation at all. The stand in which spruce was found is composed of white pine, red maple, hemlock, gray birch, and tamarack. The spruce is found in both the high canopy and the undergrowth. It seems to be growing vigorously. The live crowns of the larger trees (6-8 in. d.b.h.) take up about $1/3$ of the total height. One half to $1/3$ seems to be the average for the stand. No apparent insect infection was noted. Small spruces are all growing under the full or partial shade of other trees.

8. This area is located on the northeastern tip of the Thousand Acre Swamp and is bisected by the Willis Road. The end of the swamp forms a depression between two knolls and is gently sloping toward the

south. Spruce occupies $1/3$ to $1/2$ of the total area of the stand. Other trees growing here are hemlock, white pine, and red maple. Hemlock seems to be the dominant species so far as numbers are concerned. The ground is bouldery, with the boulders covered by a thick mat of mosses. Sphagnum is the cover in depressions and wet places between the boulders. There is not much shrubby vegetation. The stand, presently being logged, must have been growing very densely, for the live crowns of the trees are often very small, taking up in some cases not more than $1/4$ to $1/5$ of the total height. Most of the spruces cut are about 8-10 inches d.b.h., and are being used for dimension stock.

9. Another swamp near Five Points, south of the South Royalston Road.

The principle species in this lot seem to be red maple and alder. The water table is high, and the groundcover consists mainly of grasses. Only scattered spruces were found here. Generally they occupy spots which are of a somewhat more elevated position over the level of the swamp. It did not look as though the trees would suffer from the hard-woods. They all seem to grow well, and have full crowns. Many of them are above the general canopy of the red maples.

10. Similar to a number of other places described in detail under numbers 20-23. These locations are near the edges of brooks.

The type is more or less characteristic of the occurrence of spruce in this part of the Athol quadrangle. In the case described under number 10, one finds spruce together with white pine, hemlock and red maple on

the edges of the Beaver Brook. On the plain of the brook itself grasses, ferns and a few alder bushes cover the ground. Sphagnum is also very common in the groundcover.

11. The area of this location covers the part of a swamp that lies on the east side of the South Road, north of Phillipston four corners. Here the spruces are found beyond the edge of the swamp. The reason for this may be that there is no moving water so that a permanently high water table is maintained, and objects like old logs on which spruce could get a foothold are not washed away. The best growth is produced on the edges of the swamp. Spruce is found here in the company of hemlock, white pine, and red maple. On the swamp itself red maple and alder are dominant, and in many places grasses occupy large areas. Sphagnum covers depressions and extremely moist places, and is present over almost all of the area. No soil analyses have been made but it seems that in this area, at least near the brooks, the soils are quite sandy, which however may be the reason of later water action.

12. Similar to the area described under number 10. Spruce occurs on the edge of a brook. A detailed description for this type of occurrence is given under numbers 20-23.

13. North of Phillipston four corners, west of the South Road, the area is similar to the other locations in which spruce was found to grow on the edges of swamps. Here, however, it is not only growing well over the edges of the swamp but the site occupied by it has been

under cultivation or in pasture. This is indicated by the large number of juniper bushes still present in places where they were able to persist under the cover of the old field white pine and hemlock. The largest tree found has a diameter of about 14 inches d.b.h. The reproduction is abundant and is found mostly under the shade of hemlock and the spruce itself. The whole area on which the trees are growing is about ten feet higher than the level of the swamp. The live crowns of the big trees extend well over $1/2$ the total heights. Large branches close to the ground may be an indication that at times these trees were growing under fairly open conditions. Perhaps they got established in the pasture while it was being used, or soon after it has been abandoned.

14. This area is similar to the one described under number 13. It is found on the edge of a brook and does not extend over the area of the swampy place.

15. On the opposite side of the road where spruce was found on the edge of the pond are only about 5 trees. Some of them have forked tips. Otherwise no visible insect injury was noticed. The trees are about 18 feet tall. They have a full, evenly formed crown. The ground is covered with highbush blueberry over most of the surrounding area, though in some places grasses form the groundcover. Sphagnum was found over most of the lot. The water table is high, and the trees are mostly growing on the edges of a depression which seems to be one of the inlets of the pond. Other trees growing with spruce here are white pine and red maple.

16. Spruce was found on the southern edge of a pond along Baldwin Hill Road. The belt in which it is growing is very narrow and occupies only the wet, moist strip between the pond and the adjacent higher land. The spruce is associated with red maple, hemlock and white pine. The groundcover consists of grasses in the more open spots. Sphagnum is found over most of the lot. There is a dense understory of hemlock and spruce reproduction. The surrounding area supports a stand predominantly of hardwood.
17. This location is in a swamp along Route 202. Red maple seems to be the dominating species, but there are also hemlock and white pine scattered over the area. A few trees were found growing over the edge of the swamp but the spruces were found in the swamp proper.
18. Spruce was found growing here on the edge of a brook, north of Phillipston. Again it is not growing near the running water, but is limited to the edges of land, which at times seems to be flooded by the brook. The flood or moist area itself supports a cover of grass and a few alder bushes.
19. This area, north of the Phillipston four corners, is very similar in its appearance to the Prospect Hill swamp of the Harvard Forest. Spruce was found growing here with hemlock, white pine, and some red maple. The groundcover is also very similar to the swamp mentioned above, and therefore is not described in detail. The ground is bouldery and seems not to have a deep layer of peat even in the depressions. The

VIII.

spruces are rather well formed and some of them have a d.b.h. of 5-6 inches. The reproduction is well distributed over the area and seems to be growing vigorously.

20, 21, 22, These places are located southeast and south of Phillipston
23, 24, 25, Four Corners. They are described under one paragraph be-
26, 27, 28. cause they are very similar in appearance and are located within the same general area, mainly along Beaver Brook. The plain of the creek itself has no trees on it. Grasses, or in some places shrubs, are found growing near the brook, often extending over large areas. This is well illustrated by a photograph of location 23. The brook is visible in the foreground, with the grassy and shrubby vegetation on its borders. Spruce and other trees are found only on the margin of such grasslands, never growing on the grassland proper. Other species found growing with spruce in these locations were hemlock, white pine and red maple. The first two seem to be predominant in numbers. The ground occupied can hardly be classified as rocky or bouldery, but often seems more to resemble the loams. The part of the area which is occupied by spruces, however, may be somewhat more moist because of its nearness to the swamp. It was often found here that spruce extends up as high as 8-15 feet above the level of the swamp. The picture of No. 23, shows this fairly well. The spruces in general seem to grow well here. They have well formed stems and are apparently healthy; at least no visible insect damage was noted. The reproduction is abundant and is often found under very dense hemlock and spruce growth. The young trees are found on stumps of cut

or fallen trees, situations which seem to be particularly favourable for spruce in the places where it was found in this quadrangle. It was also found frequently among the roots of standing trees. It grows very close to the stems of the trees among the roots of which it is established. It is possible that the water running down the stem of the tree adds considerably to the amount of moisture which is needed by the seeds for their germination and growth. Its great tolerance of shade is undoubtedly a significant factor in such locations, for without it the trees could not persist under the dense canopy. The groundcover near the swamp consists mostly of grasses, ferns and sphagnum. However, on the higher places often only a litter of needles is found, without any smaller plants at all. As said before, these latter places do not seem to be of the swamp type, and may have enough moisture only because they are so close to the water.

29. This number represents the occurrence of two small groups of spruce with hemlock, red maple, gray birch, and white pine on the edge of Dunn Brook. The hardwoods seem to be dominant in numbers. The site seems to be similar to the locations described previously where spruce was found on the edges of brooks or small creeks.

30. This area is south of Route 202 near Phillipston Four Corners. The site is very rocky and bouldery. The depressions and holes between rocks are filled with sphagnum; otherwise ferns are the most common plants in the groundcover. Other species growing here are hemlock and yellow birch. The spruces were found to be growing on the bouldery field well over the edges of the swamp proper.

31. In this swamp along Route 202 red maple seems to be the dominant species, growing with spruce, but there are also hemlocks and white pines scattered over the area. A few spruces were found growing over the edge of the swamp, but the majority of them are growing in the swamp proper.
32. Between Ward Hill Road and Bates reservoir, this area occupies the greater part of a swamp of which the remainder is covered with highbush blueberry. Other species found growing here with spruce were white pine and red maple.
33. On the tip of a peninsula in Reservoir No. 2. The upper canopy consists mainly of white pine and hemlock, but also has a few tall, rather well formed spruces in it. The understory consists of dense groups of hemlock, white pine, and some spruce.
34. In the same general area close to Reservoir No. 2. on the land of a Mr. Bassett who showed me over his place, there is only one dot on the map, but actually there are a number of spruces scattered under a canopy consisting mostly of hardwoods. This is illustrated in the picture which has the large red oak in the background (Plate 18). The trees range from 2 to 6 inches d.b.h., and seem to be well distributed over the area. The land was cleared at one time, as is evident from the large number of stone walls running all over the area in which the trees were found. In places the ground is very bouldery and shows much similarity to the top of Prospect Hill, or to the conditions under which we find spruce there. The depressions have some water standing in them

although no sphagnum was found in any of the holes. The water may have been high only in spring.

35. South of the Reservoir No. 2. an area supports an almost pure stand of spruce. Parts of this area had been logged in the recent past, and now support a cover of highbush blueberry. There is good reproduction of spruce present under the blueberry cover, and it is possible that with time these little seedlings will be able to work their way through the blueberries and form another stand. Other trees growing with the spruce are hemlocks which form a high canopy as well as occur in the understory.

36. West of the Ward Hill Road in the same general area where the other spruce occurrences described above were found are several large spruces. The d.b.h. is about 2½ feet, and heights were estimated to about 70 feet. The trees are about 250-300 feet away from the swamp and about 40-50 feet above the level of the swamp, on rocky and bouldery ground. The soil does not seem to be very moist, although there is a small creek flowing nearby. The trees have large branches that are visible in the picture taken here (Plate 19). The reproduction is prolific around the big trees to a distance of about 100 feet. None of the regeneration however has a diameter larger than 2 inches d.b.h. One small tree of larger diameter is dead, and may indicate that despite the fact that the seeds were able to germinate and even reach a considerable height they were not able to develop into trees of larger sizes. This may have been possible for the mother tree because it grew up under open conditions, as it is shown by the large branches all over the trunk.

37.a. This occurrence of spruce is found on the edge of the bog of Lake Ellis directly below the grounds of the Athol Gun Club. Only a few small groups of spruce are found here. They are between the bog itself and the adjoining slope, on the borderline of the two. The trees were identified as red spruces. Hemlock, white pine, and a few hardwoods such as red maple and grey birch are growing with them. The groundcover consists mainly of ferns and mosses with sphagnum predominating. The trees do not seem to be healthy, and may be growing slowly. The live crowns extend over almost the whole height of the trees. No insect infection of any kind was noticed.

37. In the area directly south of Lake Ellis there is a nearly pure stand of tamarack with scattered white pines, red maples and spruces. Similarly to location 39, no large spruces were found. It is possible that the larger individuals have been taken out in an earlier logging operation. The spruces in general are scattered over the area and do not form pure groups as they do in Tom Swamp. There is, however, maple reproduction which, if given a chance to grow up may provide seed source for further spreading. In open places the ground is occupied by highbush blueberry; otherwise there is the usual cover of ferns, tall grasses and sphagnum. The spruces have long crowns extending over the whole tree.

38. Spruce was found near a gravel pit southeast of Lyons Road. This area was dry in the wintertime, but in April was under water. Only one small tree was found, about 7 feet tall. It is possible that

the spruce once had a larger extent over the lot which is now occupied by the gravel pits. Also it is possible that many of the spruces were drowned following the damming up of the water by excavating operations in and around the gravel pits.

39. In the bog south of the Doe Valley Road some of the trees have been identified as red spruce. However, the majority of them are black spruce. The stand is very open. Large red maples are scattered over the whole area. There are not many large spruces standing, most being about three inches d.b.h. The largest tree found was a red spruce 14 inches in d.b.h. It looks as though the area has been cut over several times. Some old stumps have diameters of about $3 - \frac{1}{2}$ feet. In general the trees seem to grow slowly here. They are covered with lichens, and the appearance of the bark shows that they could be rather old for their small diameter. Many spruces found outside the swamp proper seem to be growing more vigorously than those in the swamp itself. Groundcover consists of *taxus canadensis*, ferns, laurels, and sphagnum. Reproduction now developing may well form a densely stocked stand similar to that in Tom Swamp. No gall aphid infection was noted at all.

40. This number represents the location of a spruce west of Doe Valley Road. The ground here is very rocky and bouldery, with water standing in depressions and between boulders. The groundcover consists of mosses and ferns. The whole site gives the impression of a rather moist location. Associated species are red maple, and white pine. The spruce itself is small, about $2\frac{1}{2}$ feet tall, and is rather well formed. No other trees are interfering with its growth as yet. It has a healthy

green color, and no insect damage was noticed. The tree is growing under the complete shade of the surrounding stand.

41. In the area located near the Lower Cemetery, northwest from Phillipston, spruce was found growing with white pine, hemlock, and balsam fir. It grows not only in the swamp proper but also on adjacent higher land. It is interesting to note that balsam fir occupies a much larger area and is also better represented in numbers on the edge of the swamp than red spruce. This phenomenon was later noticed also along the cemetery near the East Road in Peterham. Here too, balsam fir occupies a much larger area than the spruce and is also present in much larger numbers than the spruce. On the other hand, balsam fir is not found in as many places as red spruce. It is possible that the seed source available for balsam fir is, or was, more scarce than for the spruce.

42. One spruce was found in a swamp north of Phillipston, along the Baldwinville Road. Other trees growing here are gray birch, aspen, and red maple. Groundcover consists of grasses and sphagnum. The understorey is of shrubs.

43. On Prospect Hill Road north of Prospect Hill spruce was found in a small depression between two hills which rise about 10 feet above the depression. The ground is rocky with large boulders covered with moss, ferns and some grass. Sphagnum is present also. Spruce is growing here with hemlock, white pine, red maple and yellow birch.

Growth seems to be good and vigorous. Trees are about 25-30 feet tall. The live crowns extend down the whole length of the trees. Gall aphids seem not to be present in this location. In general the ground is moist, of which the occurrence of sphagnum is a good indication. The surrounding area supports a stand of red maple, white pine and hemlock. Parts of the area are cleared for pasture.

44. The location of this place is west of the Dee Valley Road. The position of the site where the spruce was found seems to represent a drainage channel between top knolls. The site is rocky and bouldery. In general it resembles a hemlock grove with white pine and red maple. The groundcover consists of ferns and mosses, with sphagnum in the depressions between rocks. Only one spruce was found here. It is about 30 feet tall and has a diameter of 6 inches b.h. The tree is growing on the stump of a tree which either has fallen or was cut down. It could not be said that the ground immediately around the spruce would be particularly wet. The groundcover is as described above, but large areas are covered only with a litter of needles and leaves. The tree seems to be growing vigorously. The live crown does not take up more than about 1/3 of the total length of the stem. No insect damage is apparent.

45. Along the Conant Road is a swale of red maple and red oak with a spotty understory of white pine on the small elevations. The upper canopy has an average height of about 50 feet, the pines are about 12 feet high. Spruces are scattered in the stand. Their heights range

from 2 to 18 feet. The live crowns extend practically over the full length of the trees. The tip of every branch is dead due to infection by gall aphids. The stand is fairly open, and it is quite possible that this has something to do with the high grade of infection among the spruce. The water table appears to be fairly high; and the water stands in the small depressions and in the pits of fallen trees. The groundcover contains a few grasses, but otherwise leaves of maple and oak cover the ground. Fences around this area indicate that it may have been cleared at one time. Also, these trees could have been planted. Some of the lower branches from a few trees were cut off, and also some small spruce stumps were found, probably cut for Christmas trees. It is possible that the owner of the woodlot merely planted some spruce to have a few trees for Christmas decoration or was trying to grow them for profit. The trees could well be all of the same age, in which case there could be little doubt that they were planted. There is no tree around this area which would provide a seed source; therefore it is difficult to explain its occurrence.

46. In compartment VI. of Prospect Hill Tract of the Harvard Forest.

Plate 10 gives a picture of the situation in which spruce is seen here. A description of the site in 1916 includes the following observations: "A part of an upland pasture, moderate to steep in slope, and very rocky. The (planted) area is flanked on the east and south by similar open land, rising southward steadily to the summit of Prospect Hill, 50 feet higher and 400 odd feet away. To west and south the open is being encroached on by brambles, sweet fern, and scattered red spruces,

pine, thorn-bushes, etc. Altitude, 1323-45 (Prospect Hill, 1995). Aspect, north. Slope, moderate to steep. Soil, sandy loam; soil moisture scanty. Rock, abundant, both boulders and small buried stones. Relief, somewhat uneven, but with very few spots likely to hold surface drainage. Ground-cover, light sod, sweet fern, hardhack, etc. Brush, scattered saplings of pine, red spruce, thorn bush, etc. High shade, none. Wind exposure. Area is exposed to all winds; hill breaks force of S.E., S., and S.W. winds. Quality low II. History. The land has been a cow or ox-pasture for a great many years. Unused for several years^o.

47. In Compartment IV. of Prospect Hill Tract of the Harvard Forest.

Plate 8 gives a view of the situation in which spruce is seen here. The location represented by the dot on the map is situated on the lower end of a slope which ends in a swamp. There are no large spruces in the swamp, but a few small ones are scattered. Mostly alder and red maple grow in the swamp. On the edge of the swamp on the other hand are several large (5-10 in.d.b.h.) spruces. Most of these trees are found on the lower half of the slope itself. The site is very rocky, bouldery and moist. Species growing with spruce are red maple, red oak, white birch, yellow birch, black birch, and hemlock. Plates 8, 11, 12, and 20 were all taken in this location, and illustrate the conditions under which spruce was found.

48. East of Prospect Hill and south of Lincoln Road there is a lot which supports an open growth of red maple, hemlock and spruce.

Water stands on the surface. Areas of several square yards are covered with pure sphagnum. The area adjoining of the swamp in which spruce is found was at one time cleared, and parts of it are still used as a pastured woodlot. Hoof imprints show that cattle frequently browse over parts of the swamp also. The tallest tree found was 15 feet high. The spruce reproduction seems to be growing well whenever it is able to get established, but the high water table, grazing, and probable other factors limit it to a comparatively small total area which occupies about half of the swamp. There are, however, spruces growing on the edges of the swamp, approximately 20-30 feet away and about 15 feet higher than the level of the swamp. These trees are about 55 feet tall and have a diameter of about 7 inches d.b.h. The live crowns take up about half of the total length of the trees. These trees grow in a dense stand of hemlock and red maple on a very rocky, bouldery site. The ground cover consists almost entirely of mosses. In general it seems to be rather a moist place. Reproduction is not prolific. Only a few small trees were found and they do not seem to grow very well, have small flat crowns and very light foliage. It is possible that they have been growing for several years under the dense cover of the hemlock and red maple understory, and have not been able to work their way through. There are also some Norway spruces along the west side of the road in Compartment V. of Prospect Hill Tract. There is no record that these trees have been planted. They may have seeded in from a plantation and may indicate that Norway spruce is able to reproduce itself naturally under favorable circumstances, a fact which is very significant in the further treatment of the present plant-

ations of the Harvard Forest and also for an eventual future planning of plantations in this area.

49. In the area located in a swamp on both sides of the Peterham -
and

50. Phillipston Road only small spruces were found scattered under a canopy of hemlock, white pine, red maple and aspen. The understory is a dense growth of hemlock with small hardwoods. Hemlock and red maple seem to be the dominant species in the rest of the swamp also. The area where spruce was found is characterized by a groundcover of mosses and ferns. The ground is moist to wet, with standing water in some places.

51. In compartment V. of the Prospect Hill Tract of the Harvard Forest spruce was found in a swamp south of Prospect Hill. The area was cut over some years ago and no large trees were found. There are also several spruces growing on the edge of the swamp. They show rather good vigor compared with those growing in the swamp. Species growing with spruce in this location are white pine, hemlock, and red maple. The groundcover consists of mosses and ferns among which, in the swamp, sphagnum seems to be the dominant species. There are also a few spruces found along the creek south of the swamp. These trees are growing under conditions similar to those described under numbers 30-35. The immediate vicinity of the creek is occupied by grasses and a few scattered red maples. On the edges one finds hemlock, white pine, red maple, and a few scattered spruces. In a few places spruce forms a continuous line along the creek.

52. In compartment II. of the Prospect Hill Tract of the Harvard Forest. Plates 5, 6, and 7 were taken in this location and illustrate the situation of spruce in this area. Except where it was opened up by the hurricane of 1938 the stand is very dense (Plate 7). Species growing with the spruce are hemlock, red maple, white pine, and an occasional black gum. The ground cover consists mainly of highbush blueberry and sphagnum. Spruce seems to attain its best growth near the edges of the swamp (Plate 5), and the reproduction is also most abundant here (Plate 15). The whole situation is typical of the upland swamp type with the spruce growing mainly in the swamp but also able to grow on and over the edges of the swamp proper. The peat deposit in this swamp is not deep.

53. This occurrence is located south of Leighton Road on a bouldery
and
54. westerly slope. It seems to form a little flat area where the spruce was found. Stone walls nearby are an indication that the area was once cleared for agricultural purposes. Only two spruce trees were found here. Both of them are about 15 feet tall and have a diameter of $\frac{3}{4}$ inches d.b.h. One of the trees is growing on a boulder and therefore could hardly have been planted. Other trees growing on the slope are yellow birch, black birch, red maple, etc., and some scattered white pines. This area is far from all of the swamps.

55. This is a flat area, with some depressions, on the east side of
and
56. Nelson Road. Parts of it seem to have been damaged by the hurricane rather severely. A few remaining trees and the stumps of the salvaged trees show that the stand was of mixed hemlock and white pine,

probably with some red maple. Presently there is a dense cover of pin cherry, gray birch, white pine and hemlock reproduction on the area where spruce also was found. The spruces are both (only two trees were located) growing on what seem to be mounds of an earlier blowdown. The trees are growing free from immediate competition but under the partial shade of a few large trees left standing along the roadside. Both trees are about 9 feet high. They seem to be growing vigorously despite the fact that some tips show signs of insect infection. The groundcover consists of ferns and mosses.

57. This area occupies the northern part of the swamp along the Poor Farm Road. It seems to have been badly damaged by the hurricane of 1938. The large trees, which seem to have been drowned by the raising of the water level in the swamp may not have died as a result of this. They may have been so badly hurt by the wind, falling trees that they could not survive. Some of these trees are spruces about 16 inches d.b.h. and about 65-70 feet tall. Their live crowns once covered about $1/2 - 2/3$ of the total heights. Reproduction is abundant and vigorous. Hemlock, red maple and gray birch are growing with the spruce; also some white pine. Among these species the hemlock is dominant in numbers. The groundcover consists mainly of ferns, and there are few shrubs. Sphagnum covers most of the ground in the lower spots. Scattered trees are growing well over the edge of the swamp proper. On the edge of the swamp the topography is gently sloping, and spruce is found about 3 feet above the level of the swamp on the moist mossy edge. There are stone walls about 60 feet away from the swamp indicating

that the area was once cleared. There is also an old field white pine stand about 60 years old. This stand extends to the edge of the swamp. Many large dead white pines suggest that with the building of the road the level of the swamp was raised and the pines were drowned. Besides the dead pines the cover in the swamp consists of alder bushes and red maple. Also in places in the swamp there is a dense understory of hemlock beneath the pines and hardwoods. The groundcover consists mostly of mosses and ferns. Sphagnum is abundant. Dry tips of the twigs of red spruce show that it is infected by aphids. The appearance of the trees is not healthy, and the needles are yellowish. Only small trees were found here.

56. The area located on the south side of the road to the Queen Lake almost at the edge of the Athol quadrangle looks very much like the lower slope of the stand in which spruce was found in Prospect Hill Tract, Compartment II. The dominant trees of the upper canopy are red maple and yellow birch, and there is a dense understory of hemlock. The groundcover consists mainly of sphagnum and other mosses. The lot is prolonged to the north on the other side of the road. Spruce is mixed in this part into an almost pure stand of tamarack which is also very dense. There are hardly any hardwoods in this part of the area.

59. Near the road from Peterham to Phillipston. This area probably should be separated into two because the growing conditions of its two parts seem to be different. The part closer to the highway looks like a red maple - yellow birch stand. The water stands at the surface and in pits of uprooted trees, as well as in small channels

between the more elevated parts of the swamp. The groundcover consists of sphagnum, tall grasses, and highbush blueberry. Many stumps indicate several cutting operations in the past. The spruce itself in this part is scattered. Its height ranges from 1 to 45 feet, its diameter up to 6 inches d.b. The fact that only small trees can be found may be an indication that the larger ones were removed in one or another cutting operation. Spruce seems to be able to establish itself well in this location, and there is a large number of small trees. They are not infected by aphids. This may be the result of the partial shade under which the young trees are growing. The highbush blueberry apparently does not offer such vigorous competition to the spruce as oak or red maple, and the spruce is able to work its way through the low canopy. The other part of this lot, which occupies the eastern portion of the area, extends over a rocky bouldery surface. This site seems to be moist, with mosses and ferns in the groundcover. Spruce apparently grows well here. It is found in all sizes up to heights of 50 feet. Species growing with spruce are hemlock, white pine, red maple, and tamarack. Reproduction is abundant, and is established exclusively on rocks, logs or other surfaces above the general level. As a whole this part of the area could be described as a rather moist rocky upland. It may have been cleared at one time, for there are stone walls nearby and also a farm which is still operated. No aphids were noticed here.

60. In the group of spruces along Baker's Lane the trees are of various heights. It may be that these trees seeded in from the swamp or

upland north of it, but they could also have been planted. If they were planted they certainly show how long spruce is able to persist under the shade of a high canopy. The lane is bordered by large maples on one side and by a hardwood-white pine stand on the other, so that spruce has not had much light available. The land on the west side of the lane is cleared and probably still used as pasture. Spruces are in a rocky, but essentially dry site here.

61. The occurrence of spruce in the Fox Swamp Tract of the Harvard Forest was described by Joseph A. Tuft in 1910. "This spruce is located on the northernmost edge of the Meadowwater tract (Fox Swamp). Here the pond merges into a swampy marsh which in some places is wholly submerged. The ground rises towards the north and has a small creek running through the centre of it. This spruce is mostly *rubra* but some show a decided tendency towards the characteristics of *nigra*, (*mariana*) in that the cones persist, and in the color of the young branches. The only companion of the spruce in this situation is the larch. The influence of the situation and the soil on the character and distribution of the spruce is very marked. The spruce that grows on the slightly raised hummocks in the swamp and those on the slopes on the sides are the taller and have the largest bole. While those on the lower portions are shorter and are not as thick through but are apparently the same age.

The best specimens are found along the borders of the sphagnum, showing that the spruce improves with improvement of the situation. A few other species such as white birch, white pine, and hemlock have

strayed across the edge of the sphagnum and installed themselves on hummocks. This fact which demonstrates that these species are quick to take advantage of any change in the factors of locality, may be the reason for the elimination of the spruce from drier ground. For there is a definite line of demarcation where the spruce stops. There is also the limit of the sphagnum. On the other hand this definite line may be due to fire which at one time reached to the edge of the swamp. For it was noticed under a large tree, all the seedlings were between the tree and the swamp and none on the side towards the burn.⁹

62. South of the Tom Swamp Road, and west of the Tom Swamp is a small, depression of about one acre between the road and the upland south of it. The water is standing at the surface here. Sphagnum and tall grasses form the groundcover. Spruce was found together with red maple and hemlock, but red maple is by far the dominant species. Only small spruces were found about 4-5 feet tall. They do not seem to be growing well. The gall aphids have injured practically every tip on the branches. The trees became established at the bases of maples, about 6 inches above the water level. It seems questionable whether the spruce would ever grow higher than 20-30 feet. There were no signs of old stumps or fallen spruce trees in this area. It is possible that after the roots came into permanent contact with the water these small trees will also die.

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