

A REPRODUCTION STUDY OF NORTHERN WHITE CEDAR

By

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A THESIS

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ERRATA

The key in figures 1, 2, and 3 should read "ten year record" instead of "nine year record".

Management Specialist, were deeply appreciated.

Dr. L. E. Gysel of Michigan State College largely directed the studies and gave invaluable suggestions on the writing of this manuscript. Dr. P. A. Herbert, Dr. W. B. Drew and Mr. J. O. Veatch of Michigan State College are thanked for their participation upon the Graduate Committee.

Cusino Wildlife Experiment Station, Shingleton, furnished field help. Especial consideration is due Mr. W. J. Koski for his many weeks of field aid, his cheerful attitude and his personal interest in the project. Mr. D. F. Switzenberg took the photographs with the exception of those in which mention of the photographer is made in the caption.

Excellent cooperation was received from other interested agencies and organizations including Mr. W. M. Zillgitt, in charge of the Upper Peninsula Experimental Forest, Lake States Forest Experiment Station, Marquette, Mr. Gene A. Hesterberg, Department of Forestry, Michigan College of Mining and Technology, and the staff of the Forestry Division,

1/

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Finally, and not in an attempt to be facetious, sincere thanks are due to the Carbide and Carbon Chemicals Corporation, the makers of "612", without which most of the field work would have been unbearable. With the mosquitoes and blackflies partially under control, the days spent wading knee-deep in swamp-water, the days with dew on the waist-high brush until noon, the warm days when the "swamp-gas" created a considerable odor, and the July and August days in an alder thicket are now the subject of nostalgic memories rather than bitter cussing.

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THE PROBLEM

Northern white cedar (Thuja occidentalis L.) stands occupy approximately 639,000 acres in Michigan. About 293,000 acres of this total is found in the eastern half of the Upper Peninsula of Michigan (35).

Cedar is the staple winter food of the white-tailed deer (Odocoileus virginianus borealis Miller). It is the chief source of poles and posts in the Lake States as well as being an important source of other timber products. Northern white cedar has negative value in the extensive stands managed for pulp production.

Fewer ecological and silvicultural studies have been made on this species than on any other commercial tree species in the region. None have been made that would serve to indicate possible management practices.

It is with these facts in mind that a study was initiated concerning the factors affecting its reproduction in swamp stands in the Upper Peninsula.

REVIEW OF LITERATURE

Literature directly related to northern white cedar reproduction is limited. Papers directly concerned with any phase of the management of the species are not numerous. However, bog studies, reproduction studies of other species, and studies involving ecological factors dealt with in this dissertation are multitudinous. Studies on northern white cedar reproduction are limited to the states of Maine and Minnesota. Curtis (16) made a general study of the species including reproduction -- primarily in swamp stands characterized by high water tables throughout the year. He also conducted a similar study on the species in upland stands (15). Montgomery (42) carried on further studies of reproduction in Maine. Maki (41) studied growth and reproduction in Minnesota stands.

Stewart (50), in effect, classifies northern white cedar in a single cover type in the Lake States. Cedar is limited in the type of site that it occupies in the southern portions of Michigan, predominantly those sites with a Rifle peat soil type (55). The site preference becomes less marked as one progresses northward and westward.

The succession of cedar and its associates has been the subject of considerable study. Gates (24) classifies the Thuja association as a climax type in the hydrarch series in bog lakes in the Douglas Lake region of Michigan. In wet soils, he places Thuja as a temporary type, preceded by a bog association or a lowland forest. It is associated with and replaced by a Picea-Abies association.

Cooper (14), in describing an area evolving from Keweenaw lava flows (Isle Royale), differentiates between a bog succession

and a delta swamp succession. Thuja does not enter into the bog succession except as a subdominant to Larix, a subclimax stage of one line of development. On the other hand, he places Thuja as the dominant in a similar stage in the delta swamp succession.

For the most part, cedar seed and seedling studies have been aimed at determining the effect of environmental factors on germination rather than being carried out specifically as species studies. Heit and Eliason (30) have limited their studies to coniferous tree seed including a specific study of Thuja occidentalis regarding methods of seed testing and factors affecting germination and seed quality.

There is no apparent marked difference in the subterranean organs of a given species growing in a bog and in comparable conditions in mineral soils (19). However, Rigg and Harrar (47) contend that excessive root fusion often occurs in sphagnum and eccentricity of root growth and enlargement is characteristic of tree roots growing in sphagnum peat. Moore (43) maintains that northern white cedar is the only northeastern conifer that does not have mycorrhizal fungi in or on its roots.

The effect of light and pH on cedar reproduction are mentioned in the literature. Wiesner (60) and Burns (9), using photographic paper, calculated the average minimum light intensity requirement for cedar. Lutz and Chandler (40) point out that northern white cedar has been observed commonly on calcareous soils and is scarce or absent on adjacent acid soils. Wherry (59) discusses the reaction preference of eastern conifers including cedar.

It was found necessary to turn to the literature for methods of classifying and determining the effects of the various types of germinating media found on the swamp floor (7, 22, 26, 45). McCullough (44) has developed a system of classification for the various stages of decay in logs on the western spruce-fir forests for use in relation to their acceptability as types of germinating media. His classification was used in this study.

Zon and Averell (62), studying growth in relation to swamp drainage, conclude that growth rate decreases in proportion to the distance from the source of drainage. LeBarron and Neetzel (38) tallied sample quadrats over a long period of time at designated distances from artificial drainageways in a cedar stand and found that effective draining would change a bog conifer type to a hardwood conifer type.

Northern white cedar is an important component of many deer-yards throughout the Lake States and is subject to heavy browsing by several mammals. Bartlett (6), Swift (51), and Aldous and Smith (4) discuss the winter deer food problem in Michigan, Wisconsin, and Minnesota respectively. Davenport (17) points out that northern white cedar proved to be the only species of browse fed exclusively upon which deer were able to maintain their strength. Swift (52) reports that in northern Wisconsin, only three out of every ten young cedar remain undamaged from deer or snowshoe hare browsing. The harmful influence of snowshoe hare browsing on plantations in the Lake States has been discussed (1). Cedar is commonly damaged by snowshoe hare browsing, especially when other food is scarce (36). Krauch (33, 34) reports that rodents are highly inimical to natural coniferous regeneration in several regions.

Cedar is one of the few conifers that reproduces vegetatively. Potzger (46) acknowledges the fact that vegetative propagation occurs in conifers. Harlow (27) found occasional rejuvenation of T. occidentalis by natural cuttings in the Adirondacks. Cooper (13) is responsible for recognition of natural layering among conifers. Aldous (3) reports that cedar food and cover plantings for deer were unsuccessful in Minnesota.

DESCRIPTION OF AREA

Physiography

This study was made in the Great Lakes plains region, a glaciated part of the Great Central Lowland of the United States, and was confined to a portion of this province in the eastern part of the Upper Peninsula of Michigan. The area as a whole is underlain by paleozoic sedimentary rock. The large swamps, the specific areas that the cedar studies were made in, have developed from level till plains or old lake beds. Upland ridges in the vicinity probably are the result of glacial activity. The beds dip gently to the south as the result of a greater amount of recent uplift on the Lake Superior shore (55). Drainage is poor and haphazard. In the Cusino swamp, the location of this study, Stoner Creek provides the main drainageway, emptying into Lake Michigan at Manistique through the Manistique River.

Climate

The Cusino swamp lies approximately at 46°30' North latitude. The climate is of a marine type, governed by the force and direction of the wind.

Climatic conditions within the study area are more similar to those of the weather station near Seney, Michigan than to any of the other nearby stations at which records have been kept (54). A ten-year record shows an average January temperature of 14.9° F. and a July average of 64.8° F. Maximum temperature recorded at this station is 103° F. and the minimum is -47.0° F. The average date for the last killing frost in the spring is June 15th and for the first frost in fall is August 27. The average growing season is 73 days. A 17-year record indicates that average rainfall is 26.75 inches with a growing season range of 2.89 inches during May to 3.33 inches in September. Light frosts have been known to occur during June, July, and August (55). During the 1949 growing season, frosts were known to occur in the swamp on June 8 and July 18.

Climographs have been constructed for 1947, 1948, and through the 1949 growing season for the Seney station (figures 1, 2, 3). A climograph for the ten year period from 1930-39 inclusive has been transposed on each yearly climograph for comparison. The 1947 growing season started out cool with the latter portion of the season warmer than average. The season was dry throughout. The 1948 season was dry but the 1949 season turned out to be warm and very wet.

THE SPECIES AND ITS ENVIRONMENT

The Seed

The seeds of northern white cedar are very small in size and light in weight ^{1/}. They are approximately 1/8 inch in length with

^{1/} There are about 300,000 seeds per pound (56).

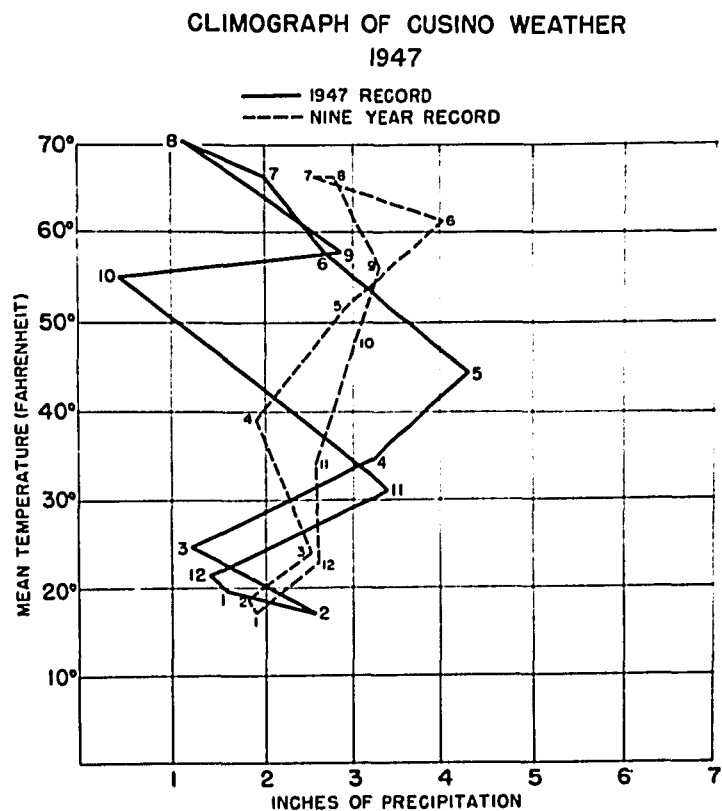


Figure 1. Climograph of Cusino weather for 1947 superimposed upon ten-year composite climograph. Graphs were constructed with Seney Migratory Waterfowl Refuge readings, the nearest inland weather station.

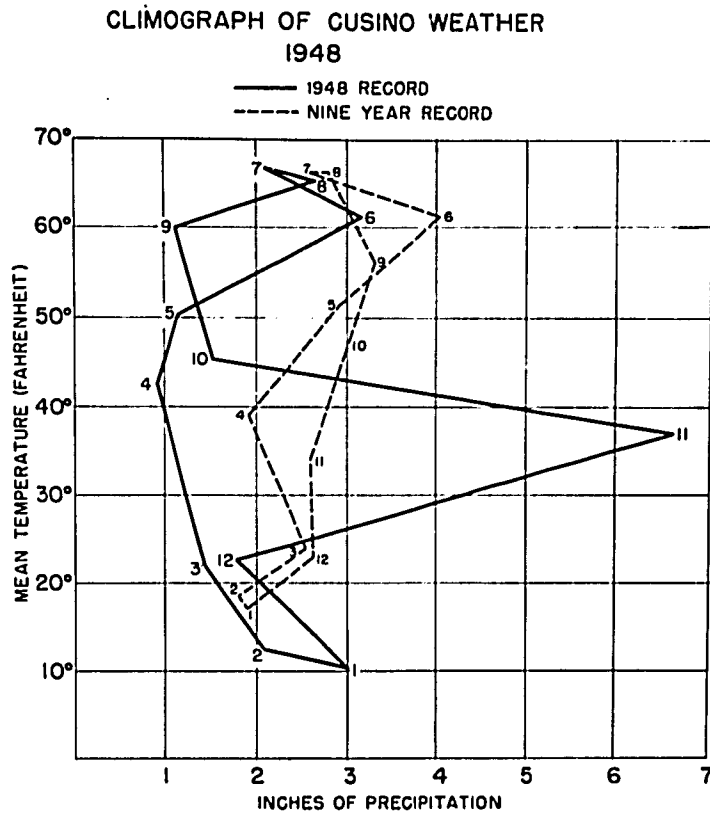


Figure 2. Climograph of Cusino weather for 1948 superimposed upon ten-year composite climograph. Graphs were constructed with Seney Migratory Waterfowl Refuge readings, the nearest inland weather station.

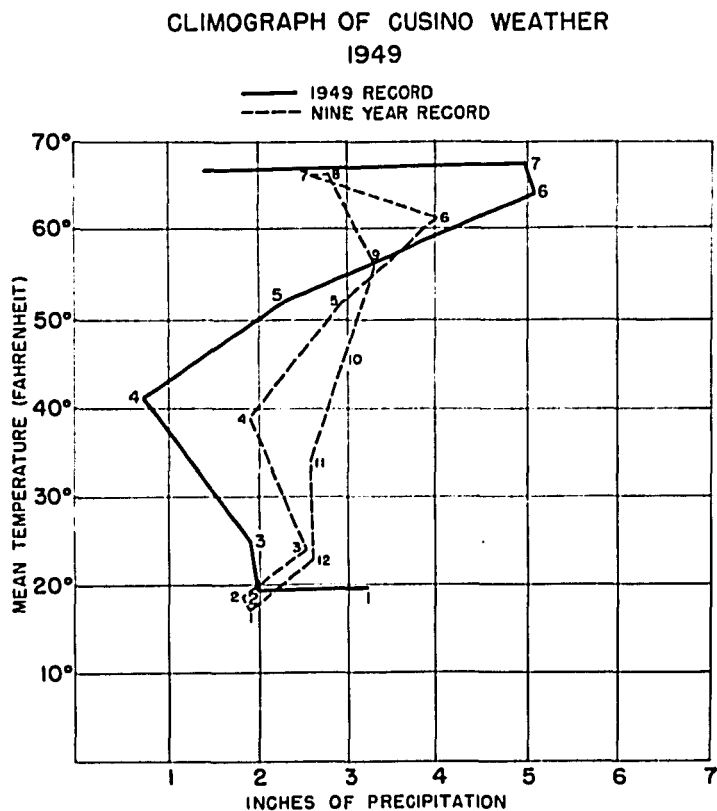


Figure 3. Climograph of Cusino weather for the first eight months of 1949 superimposed upon a ten-year composite climograph. Graphs were constructed with Seney Migratory Waterfowl Refuge readings, the nearest inland weather station.

a pair of wide wings and brown in color. High quality seed should contain roughly 75 percent filled seed and average purity should also be about 75 percent (30). Seed has been stored in sealed containers for five years at 20 to 40 C. without any apparent loss in its original viability (30).

Seed production has been noted on stems as young as 12 years in age in the Cusino area and cones were found on individuals as young as 6 years of age in Maine (16). Commencing at 20 years of age, seed is produced quite abundantly with sufficient production for commercial seed gathering occurring from 30 years of age to maturity. Seed occurs almost every year but heavy seed crops are borne at approximately 5 year intervals. It is not uncommon for an average-sized tree with a fairly full crown to produce $\frac{1}{4}$ bushel of cones. A bushel of cones averages one pound of clean seed (41). Isolated trees, and especially those on upland sites, produce seed more prolifically than the trees on swamp sites in the study area. Seed is shed throughout the fall months and is aided considerably in distribution by clipping of the branches by squirrels.

The Tree

Northern white cedar is the only member of its genus Thuja (Thuja Sarg.) that is found in the Lake States. It commonly grows from 40 to 60 feet in height and several feet in diameter.

Growth form is poor in swamp-grown cedar^{1/} ; "pistol-butts"

^{1/} For a 40 foot tree -- a common height in swamp stands -- that has a diameter at breast height outside bark of 8.0 inches, Gevorkiantz and Duerr (25) calculate the diameter inside bark at 1 foot above the ground as 9.2 inches and 3.0 inches at 30 feet above the ground.

and "bowed-butts" are common. Curtis (16) puts forth several hypotheses to explain these phenomena. Vegetative reproduction of the layering type will account for curved butts. Poor stem anchorage causes stems of all ages to be forced from the vertical because of snow, ice, or wind action. Seedlings establish themselves on rotten logs, stumps, and moss hummocks that gradually lean as the substrate disintegrates and their weight increases. Upland cedar seems to attain better form than swamp cedar. Forked-heads and stag-heads are also common in Upper Peninsula swamp stands.

Height and diameter growth of cedar are slow; Gevorkiantz and Duerr (25) use 160 years as a base in determining site index. Although old stems usually show butt rot, reliable ring counts have been obtained that indicate trees 300 years old are present in stands in the Upper Peninsula.

Lateral root systems seem to develop on swamp-grown trees, replacing the tap root of the young seedlings. The root systems are shallow, and the branch roots attain a red coloration.

Northern white cedar was one of the species included in the "pine cut" in the Lake States. Its use then was principally for shingles and poles. Today the wood is used chiefly for posts, poles, ties, lumber in boat manufacturing, cabin logs, rustic fences and furniture, novelty items, and mine lagging.

Northern white cedar foliage is the most important winter browse for white-tailed deer in the Lake States region both from a palatability and a nutritional rating (2). Although the amount of foliage produced by the total tree is correlated with diameter at breast height, the browse available for deer declines sharply beyond a d.b.h. of 3.0 inches.(2).

Cover Types and Associations

Stewart (50) classifies northern swamps into a single major type containing Thuja occidentalis, Larix laricina, and Picea mariana -- the site conditions governing the stand composition. The best stands of cedar occur on the edges of highland and swamp where the peat layer is just a few inches thick. Stewart further observed that in deep peat soils, growth of cedar is slow and recommends a rotation on an average site of 70 to 90 years for posts and 200 years for poles.

Northern white cedar is included in eight of the cover types designated by the Society of American Foresters (49), namely; 18. red spruce type 20. paper birch-red spruce-balsam fir type 21. white spruce-balsam fir-paper birch type 22. balsam fir type 23. black spruce type 24. northern white cedar type 25. tamarack type 26. black ash-American elm-red maple type. Of the types listed, only five occur in the Lake States, the white spruce-balsam fir-paper birch type, black spruce type, northern white cedar type, tamarack type, and the black ash-American elm-red maple type.

The white spruce-balsam fir-paper birch type does not commonly contain northern white cedar and occurs more extensively in northern Minnesota than in northern Michigan and northern Wisconsin.

The black spruce type is the typical bog cover type that is located on acid peat with little or no drainage. Cedar is a minor component of the stand. The type is utilized mainly for pulpwood.

The northern white cedar type ^{1/}, as established by the Society of American Foresters, is predominantly composed of cedar and is associated with tamarack, balsam fir, yellow birch, paper birch, black ash, red maple, black spruce, white pine, hemlock, and alder. The type occurs in the northern half of the Lake States region as well as in New England. It is located on sites with slow drainage and a high water table that are not strongly acid. It is also present on limestone uplands. According to its type description, it will maintain itself as long as the swamp remains wet if it is not disturbed.

The tamarack type includes considerable northern white cedar and is found in Michigan, Wisconsin, and Minnesota. It is truly a bog type, the southern stands of this type occurring as pure tamarack. It is succeeded by black spruce or cedar, depending primarily on the drainage and acidity.

The black ash-American elm-red maple type contains cedar only in the Lake States and then in small numbers. It occupies lowland sites and is considered a climax type.

Curtis (15) proposes a separate cover type for the upland northern white cedar that differs from the Society of American Forester's cedar type, a classification which includes both swamp and upland stands.

The Lake States Forest Experiment Station (35) estimated that cedar stands occupy 639,000 acres in Michigan or 3% of the

^{1/} Synonyms mentioned by the Society of American Foresters include the following types; cedar-tamarack-spruce, cedar-tamarack-spruce-balsam, cedar-spruce-balsam-white pine, balsam-cedar-tamarack-spruce, cedar-paper birch-balsam-red maple, and mixed swamp.

total forest land in the state. It is further estimated that the acreage by sections of the state is as follows;

<u>Section</u>	<u>Acres</u>
Eastern half of the Upper Peninsula	293,000
Western half of the Upper Peninsula	153,000
Northern half of the Lower Peninsula	180,000
Southern half of the Lower Peninsula	13,000

Associates of cedar that were observed and collected are listed in the Appendix. Their occurrence does not necessarily indicate common occurrence on cedar sites, however. For example, Potentilla fructosa was found rarely on cedar swamp sites whereas Cyprinedium acaule, Rubus triflorum, and Galium asprellum were commonly found. Sarracenia purpurea and Ledum groenlandicum were most abundant on the types with cedar that approach the true bog conditions. Iris versicolor and Typha latifolia were found in the moister pockets within the swamp.

Soils

Although Thuja occidentalis is considered to be a calcicole (20), its occurrence in the Lake States is by no means limited to soils of calcareous origin. It is found extensively throughout the acid swamps of the region. Cheney (12) summarized the occurrence of cedar in swamps by stating that cedar comes in only on the older bogs where the peat is fairly well decomposed.

The area studied lies within the Podzol soil region of North America. Soils are formed from material deposited by the late Wisconsin glacier and deposits are mainly of local origin.

The mineral soils of the area fall into two major groups (55), soils which have developed under free drainage and aeration and contain a normal amount of moisture for the region, and soils which are permanently or intermittently saturated with water. It is with the latter group that our interest lies although cedar does appear on soils of the first group.

A generalized soil profile with poor drainage or excessive moisture includes:

1. a dark-gray or black surface layer of organic matter.
2. a gray or drab layer of sand or sandy loam, slightly or not at all colored by organic matter.
3. a layer containing maximum concentration of clay and maximum coherence or plasticity, or one containing maximum yellow or brown coloration and maximum cementation from iron oxides.
4. the substratum or parent material.

Newton sand is a soil of the wetter swamps, the water table being only slightly lower than that of peat swamps. The profile is characterized by a 2 to 8 inch layer of peat over a sand with smoke-colored or rust-yellow splotching. It is strongly acid and covered with a vegetation common to peats and mucks.

Saugatuck sand is a wet sandy type, with a gray, sandy surface above a rust-colored or brownish-black sandy hardpan. Its surface relief is more or less a pit-and-mound condition. It is acid and supports a somewhat more mesophytic type of vegetation than does Newton sand.

Ogemaw fine sandy loam is a wet land soil characterized by a fine sand or sandy loam over an impervious clay. The height of water table is less than with the Newton and Saugatuck soils. In the Cusino

area, red maple, balsam fir, hemlock, and white spruce are among the most abundant tree species found on this soil type although cedar does occur.

The organic soils of interest to this problem exhibit a considerable range in chemical and physical properties. Spalding peat is a transition type from the open heath-bog type to the forested type of organic soils. It is strongly acid and composed of brown woody or spongy fibrous, slightly-decomposed material.

Rifle peat is an acid brown, coarsely granular or woody peat. The surface 4 to 8 inches are more decomposed, darker colored, and contain more woody material than the underlying layers. The less decomposed woody peat and raw fibrous peat are under the surface layer. It is covered with a forest type vegetation and is intermediate in development between a Spalding peat and Carbondale muck.

Carbondale peat or muck is the most productive type of organic soil in the region. It is a dark-brown, loamy or granular muck, less acid than Rifle peat. The dark-colored soil grades into a more peaty, less decomposed material at a depth of 1 to 2 feet.

Kerston muck is confined to the areas immediately adjacent to stream courses and is characterized by an admixture of alternate layers of organic material and alluvial mineral deposits.

Longrie loam overlies limestone bed rock and occupies upland ridges in the swamps in small acreages. Cedar occurs as an old field type on Longrie loam. Figure 4 illustrates a pasture in western Alger county on Longrie loam that is reverting to a northern white cedar type.



Figure 4. Cedar seedling reproduction, a portion of which is indicated by the arrow, on a Longrie loam soil type in western Alger county. This pasture is reverting to a pure stand of cedar.

The presence of peat soils in the eastern half of the Upper Peninsula is common. There is a total of 666,112 acres of peat and muck soils in the counties of that section of the state that have been surveyed (table 1).

INITIAL REPRODUCTION

Seedling Characteristics and Development

Methods

Morphological characteristics and seedling development were observed throughout the course of the experiments and incorporated into field notes. At the beginning of the study, it immediately became apparent that criteria for separation of northern white cedar seedlings from the other coniferous seedlings and herbaceous material of the swamp floor would need to be found. Identifying characteristics were arrived at through standard taxonomic procedures.

Data on the change from juvenile to adult foliage, root growth and development, rate of top growth, root-top ratios, and the indications of mycorrhizae were also obtained through general field observations.

Results

Northern white cedar seedlings, in their early years, are distinguishable from vegetative reproduction by the presence of juvenile leaves along the main stem. Juvenile leaves are oppositely arranged and generally tend to form four vertical rows on the young

Table 1. -- Abundance and frequency of muck lands in the eastern half
of the Upper Peninsula^{1/}

County	Percentage muck	Sections containing muck	Average muck acreage per section ^{2/}	Acreage muck in county
	<u>Percent</u>	<u>Percent</u>	<u>Acres</u>	<u>Acres</u>
Alger	19.1	85.7	134.9	111,936
Chippewa	18.7	63.4	184.0	188,608
Luce	33.4	85.7	243.3	195,392
Schoolcraft	22.0	78.6	176.5	<u>170,176</u>
Total				666,112

^{1/} Adapted from Harmer's calculations (28) and based on Soil Surveys in counties that have been surveyed.

^{2/} Based only on sections containing muck.

stem as compared with an alternate or whorled arrangement of adult foliage. Some seedlings establish adult foliage during the first year of growth; others that are 2-years-old have been found without adult foliage formed as yet. A 10-year-old seedling, twenty six inches high, was found with juvenile foliage still present on two small branches near the base of the stem. However, in general, the juvenile foliage is no longer present at this age. Reversion of foliage to the juvenile form in saplings and poles has been noted but is rare.

Previous to the formation of adult foliage, northern white cedar seedlings are somewhat difficult to distinguish from other swamp conifer seedlings. Figure 5 illustrates cedar seedlings both with and without adult foliage. Figure 6 provides a comparison between cedar, balsam fir, and spruce seedlings. The following distinguishing characteristics have been noted:

Northern white cedar: 2 cotyledons; juvenile leaves opposite, the 4-row characteristic being recognizable in the majority of seedlings; early leaves approximately $3/16$ inch in length, sharply pointed.

Balsam fir: 4 large primary leaves with a whorled to alternate arrangement; whitened undersurface of leaf with prominent midrib; early leaves approximately $6/16$ inch in length, blunt at the tip (obtusely pointed).

Spruce: early leaves whorled, needle-shaped, sharply pointed.

LeBarron (37) has developed a method of distinguishing black spruce seedlings from white spruce seedlings. However, in view of the fact that his method is not absolute but based on a population estimate, no distinction was made in this study.



Figure 5. Northern white cedar seedling reproduction. Note the seedling without adult foliage that is above and to the right of the seedling with adult foliage.

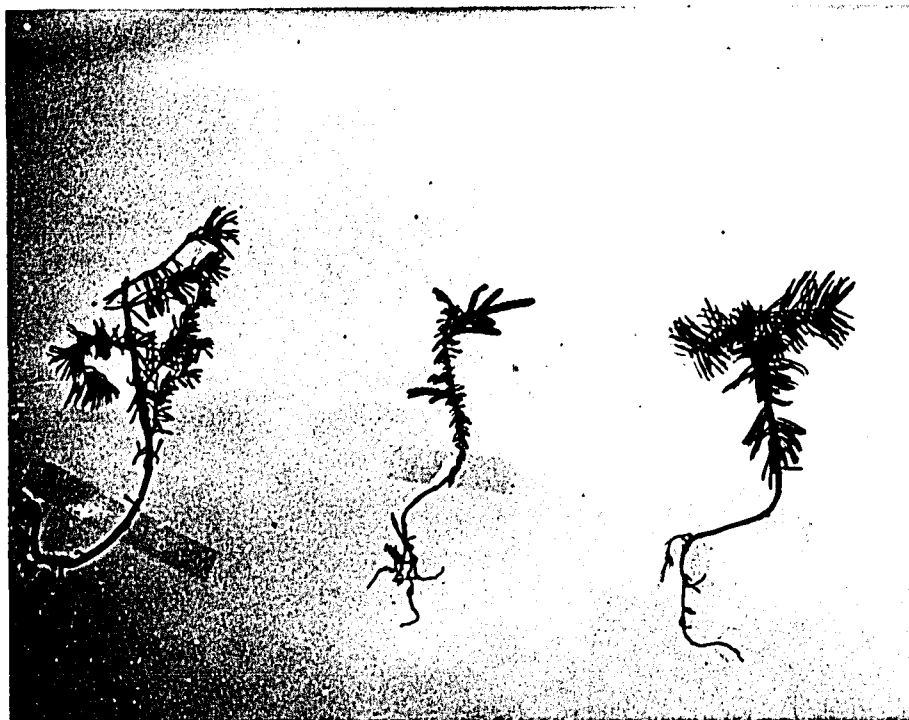


Figure 6. Left to right--spruce, northern white cedar, and balsam fir seedlings. (Photograph by Mary Jayne Hallifax, Munising, Mich.)

Exposed to adverse conditions, seedlings have the ability to reproduce by branch layering when approximately five years in age. A cedar seedling, 7.8 inches in height, was found with two side branches developing as leaders. They were partially covered with sphagnum and evidently had recently assumed an upright position, thus reducing the possibility of being smothered by the sphagnum. The leaders thus formed were 4.6 and 6.2 inches in height.

Development of a tap root during the first several years seems to be inherent in the species. This tap root system is soon replaced by a fibrous system in swamps, however. An example was found of an eight-year-old seedling that had a fibrous root system with a group of five major roots comprising the main support of the stem; adventitious brace roots had also formed on the stem and served as an aid in support. The majority of root-top ratios in 1- to 3-year-old seedlings fell between 1.25 and 3.00. The highest root-top ratios were found in a rotter wood medium.

Abnormalities in the root hairs of cedar seedlings were noted although no mycorrhizae were found and indications of the frequently branched ectotrophic type (57) were not encountered. For the most part, the abnormalities consisted of very thick root hairs with a pronounced bulbous condition at the tip.

The lack of mycorrhizae is in agreement with the literature. Moore (43) found that northern white cedar is the only northeastern conifer that does not have mycorrhizal fungi in its roots. He did note -- to a very limited extent -- that northern white cedar has a fine bristly or filamentous growth unlike the mycorrhizae that are characteristic of other conifers.

Observations of cedar seedlings in Upper Michigan indicate that there is very little difference in their development in this geographic region and in Maine as observed by Curtis (16). However, Curtis indicates that young seedlings may have 2 or 3 cotyledons. No seedlings with 3 cotyledons were found in this study.

Survival and Mortality

Methods

It was noted during the fall of 1946 that cedar had a very successful seed year in the Cusino area. In the summer of 1947, considerable cedar seedling reproduction was found along with the usual vegetative reproduction.

Four milacre plots were laid out early in the growing season of 1947 on a Rifle peat soil type to determine the amount of cedar reproduction, its subsequent survival, and the factors causing its mortality. Three of these were fenced with chicken wire and one was left open. One of the exclosures is shown in figure 7. The sites for the individual plots were originally selected on the basis of varying degrees of light intensity and density of ground cover.

The total reproduction within the plots was tallied^{1/}. The cedar seedling and vegetative reproduction was marked with wire pegs. Mortality counts were made at periodic intervals. The amount of mortality as well as its probable cause were ascertained. Plot descriptions follow.

^{1/}The reproduction present at the time of plot establishment has been designated "1947 reproduction". The amount present previous to the summer of 1947 is unknown.



Figure 7. Illustration of the type exclosure established to study amount of cedar reproduction, its survival, and causes of mortality.

Plot 1. An exclosure located in mature cedar with some balsam in the canopy. Browse line at 10 feet. Ground cover composed of a moss-grass-sedge-violet-bedstraw complex.

<u>Type of Reproduction</u>	<u>Number of stems</u>
Cedar (seedling)	191
Cedar (vegetative)	0
Spruce	4
Balsam fir	13
Red maple	4

Plot 2. An unfenced plot located in mature cedar. Canopy was composed of cedar-spruce-balsam. Ground cover essentially moss.

<u>Type of Reproduction</u>	<u>Number of stems</u>
Cedar (seedling)	74
Cedar (vegetative)	0
Spruce	3
Balsam fir	21
Red maple	6
Black ash	1

Plot 3. An exclosure located in an area of mature cedar. Immediate canopy was all cedar. Ground cover of sedge-grass-moss tended to predominate.

<u>Type of Reproduction</u>	<u>Number of stems</u>
Cedar (seedling)	68
Cedar (vegetative)	1
Spruce	2
Balsam fir	11
Red maple	3

Plot 4. An exclosure in a small natural opening in a mature cedar stand. Heavy ground cover composed of grass-sedge-moss. The light intensity in this plot was 2 to 3 times greater than that in Plots 1, 2, and 3.

<u>Type of Reproduction</u>	<u>Number of stems</u>
Cedar (seedling)	29
Cedar (vegetative)	5
Red maple	5
Black ash	1

In addition to the plots just described, three other unfenced, milacre plots were established, two in commercial cuttings and one on a small limestone ridge in a swamp. Plot descriptions follow.

Plot 5. Located in a commercial cutting made during the winter of 1946-47. Cover was composed of cedar-balsam-spruce-lowland hardwoods. Ground cover light and essentially moss with Labrador tea, Joe-Pye weed, and Rubus species.

<u>Type of Reproduction</u>	<u>Number of stems</u>
Cedar (seedling)	51
Cedar (vegetative)	9
Spruce	7
Balsam fir	46
Red maple	27

Plot 6. Located in a limestone outcropping (Longrie loam) in which the surface soil was removed for road fill (1922-23). Canopy none -- entirely open and unshaded. Ground cover sparse and consists of grass, sedge, horsetail, yarrow, strawberry, and willow.

<u>Type of Reproduction</u>	<u>Number of stems</u>
Cedar (seedling)	20
Cedar (vegetative)	0
Spruce	8
Balsam	8
White birch	8

Plot 7. Located in an area selectively cut during the winter of 1946-47. Canopy composed of cedar-spruce-balsam-lowland hardwoods. Ground cover bedstraw-moss-grass-sedge.

<u>Type of Reproduction</u>	<u>Number of stems</u>
Cedar (seedling)	28
Cedar (vegetative)	0
Spruce	4
Balsam fir	37
Red maple	7
Black ash	2

Results

The loss of seedlings during and between three growing seasons follows a constant trend (figure 8) if the plots are considered in toto. Differential mortality -- both as to time of occurrence and the amount of mortality -- occurred between the various plots (table 2).

Although expressed in smaller numbers, counts of the 1948

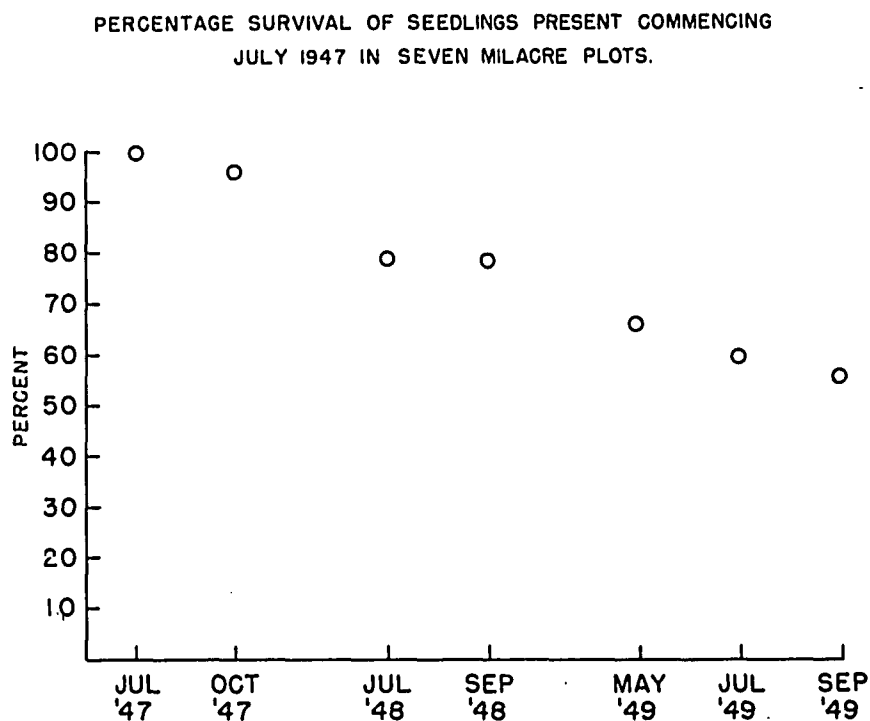


Figure 8.^{1/}

^{1/} The September 1948 calculation of the percentage survival is based on only five milacre plots.

Table 2. -- Seedling reproduction tallies for three growing seasons
in established plots

(In individual stems)

Plot	Date						
	July :	Oct. :	July :	Sept. :	May :	July :	Sept.
	1947 :	1947 :	1948 :	1948 :	1949 :	1949 :	1949
1	191	190	159	156	148	142	138
2	74	72	64	63	59	53	52
3	68	65	47	46	41	33	30
4	29	25	20	20	20	18	17
5	51	45	37	--	13	10	7
6	20	20	15	15	15	14	13
7	28	27	21	--	7	3	3
Total	461	444	363	--	303	273	260

seedlings showed essentially the same trends in loss as did the counts on the 1947 seedlings (table 3). The heaviest mortality was in Plots 5 and 7, the plots located in commercially cut areas that were cut by a selective-cutting method (tables 2 and 3).

Difficulty was encountered in determining accurately the causes of individual cases of mortality of northern white cedar seedlings. Observations, coupled with a knowledge of the climatic conditions, were the only tools available. One of the chief problems encountered stemmed from the fact that the foliage of northern white cedar did not show signs of injury or death until quite some time after the causal agent had acted^{1/}. The effect of snowshoe hare and rodent browsing are discussed elsewhere in this dissertation and are not included here in view of the fact that only a portion of the plots were exclosures. In view of the difficulties involved, the causal agent of only 38 percent out of the 212 mortalities recorded was determined.

By far the greatest amount of seedling mortality was caused by desiccation. In many instances, seeds germinated during the wet spring season on the top of stumps or logs with very little decay, in the thin layer of litter covering brace roots, in clumps of moss that later dried up, or on the swamp floor in areas that later became desiccated.

Late frosts were found to kill seedlings. A frost occurred on June 8, 1949, during which the air temperature immediately above the surface of the swamp floor was recorded at 24.0° F. This followed

^{1/} A seedling removed from the swamp floor in its natural media and placed inside without watering was still green after a 3-week period. It was definitely desiccated, however. Leaves were brittle, drooping, and curled but there was no appreciable loss in color.

Table 3. -- Seedling reproduction tallies for two growing seasons
in established plots

(In individual stems)

Plot	Date								
	Aug. 1948	: :	Sept. 1948	: :	May 1949	: :	July 1949	: :	Sept. 1949
1	16		16		16		16		14
2	3		3		3		2		2
3	2		2		2		1		1
4	1		1		1		1		1
5	4		4		2		1		0
6	2		2		2		2		2
7	7		7		3		3		1
Total	35		35		29		26		21
Percent Survival	100.0		100.0		82.8		74.3		60.0

approximately a month of frost-free weather. A plot tally in July indicated mortality caused by frost. Examination of the plots on November 14, 1949, showed no indications of fall frost as a factor in mortality.

Root rot was observed to be a lethal factor in seedling northern white cedar. Although no isolations of pathogenic organisms were made, appearances of some seedlings in the swamp, especially those on the swamp floor proper, indicated that the rot was a post-emergence damping off or a very early root rot. A dark lesion completely surrounding the seedling stem that appeared from varying distance above the ground surface to the ends of the root system was noted. This factor undoubtedly caused a considerable number of the deaths classified in the "unknown" category but the cause of mortality was not definite enough to classify.

The cause of mortality designated as "litter and duff" is in need of explanation. Cedar seedling growth is extremely slow. Coupled with this is the fact that large cedar does not shed its individual leaves but the abscission layer forms between branch stems and small branchlets (cladogenesis). Thus, if a single branchlet or several branchlets happen to fall upon a small seedling, the seedling covered with litter is forced into a position parallel to the swamp floor and eventually killed. The difficulty arises in finding the remains of the seedling following mortality.

It is suspected that this cause of mortality ("litter and duff") is largely limited to swamp stands containing cedar although it may express itself on other coniferous seedlings also. Cladogenesis is peculiar to cedar alone of the Lake States swamp conifers with which

we must contend. The hardwood litter was not observed to be as significant a factor as the cedar branches in mortality of this type.

Seedlings were found with poorly developed root systems which had failed to branch out. In some cases, the development of the root systems was physically difficult due to the type of medium upon which the seed germinated. This was especially true when the germinating medium chanced to be a log or stump with little decay.

Competition is also a cause of seedling mortality. In the plots under observation during the 3 growing seasons, competition from grass was predominant. Grass growth would completely surround the seedling, thus causing its death towards the latter portion of the growing season.

Another type of competition that was not encountered in these particular plots due to the lack of its presence within the study plots is competition from sphagnum. As previously stated, cedar seedlings are especially slow growing, slower growing than the accumulation of sphagnum which may smother the seedlings. Obviously, this factor does not express itself on the whole of the seedling population but only in areas of heavy sphagnum growth. Sphagnum grows much more rapidly in the open than in the shade and the competition becomes more noticeable under the open condition.

The relative amounts of mortality that the various causes were responsible for in Plots 1, 2, 3, and 4 -- exclusive of snowshoe hare and rodent browsing -- are as follows:

<u>Cause</u>	<u>Percentage mortality</u>
Desiccation	38.5
Spring frosts	19.2
Root rot	15.4
Litter and duff	11.5
Poorly developed root system	11.5
Competition from grasses	<u>3.9</u>
Total	100.0

Including rodent and snowshoe hare browsing as a mortality factor, the percentage mortality caused by all factors, known and unknown, for Plots 1, 2, 3, and 4, is as follows:

<u>Cause</u>	<u>Percentage mortality</u>
Rodent and snowshoe hare browsing	8.5
Desiccation	7.2
Spring frost	3.6
Root rot	2.9
Litter and duff	2.2
Poorly developed root system	2.2
Competition from grasses	1.1
Unknown	<u>72.3</u>
Total	100.0

It should be realized that rodent and snowshoe hare browsing as a cause of mortality is much easier to definitely ascertain than the other factors enumerated. It is undoubtedly a more reliable estimate of mortality than are the other values obtained.

In the plots that are located in the commercially cut areas (Plots 5 and 7), the mortality caused by desiccation was approximately 63.8 percent of the total mortality. The areas upon which these plots were located were found to be dry during the late summer and fall of 1948, the period during which most of the mortality occurred. It is possible that some of the mortality classified as caused by desiccation might have been caused by sunscald. However, there seemed

to be enough canopy left in the general vicinity of the plots to preclude this possibility.

Tallies made for shorter periods, i.e. one and two growing seasons, on 14 other plots indicated that the same causes of mortality occur as were previously mentioned and in about the same proportions.

The factors affecting mortality of cedar seedlings have received little attention in the Lake States. It is realized that the results of this study are indicative only of the study area and that the importance of each factor will vary with location.

Montgomery (42) has tallied seedling reproduction by single years in 1- to 8-year-classes in a Maine study. He has thus provided an indirect measure of mortality. His observations indicate that mortality of seedlings approaches 100 percent in five years.

Desiccation as a factor in cedar seedling mortality has been recognized by Curtis (16) although he does not attempt to estimate its relative importance. He also concedes that "there is strong evidence that 1- and 2-year-old cedar seedlings may suffer fatally from late spring frosts".

Types of Reproduction

Methods

It has long been known that northern white cedar is able to reproduce vegetatively as well as by seed. The nurseryman has found cuttings to be a satisfactory method of propagating cedar commercially. However, little is known about the specific natural means of

vegetative reproduction and their relative abundance in cedar stands. Hawley (29) lists three types of vegetative reproduction that may be effective in establishing or renewing a forest: sprouts from the stump or from the roots (root suckers), cuttings, and layering. Preliminary observations were limited to classification into these categories. Later, it was possible to further subdivide the classes according to the apparent cause or method involved.

A cruise of twenty 1/100th acre plots was made to determine the number of stems falling into each category that was established. This necessitated a critical examination of the root system of each stem. The plots were located in such a manner that cutting had occurred in ten of them.

Some difficulty was experienced in determining the origin of the larger stems. A limit of 8 feet in height was used in an effort to obtain important data within the realm of desired accuracy. A lower limit of 2 feet was established. A classification designated "unknown vegetative type" was also established to include stems which did not definitely belong in any of the specific classes.

Results

Small seedlings can be distinguished from vegetative types, in most cases, by the presence of juvenile leaves. Cases are found of vegetative shoots reverting from adult to juvenile foliage but are usually associated with rodent browsing.

Several methods of layering were noted. There is a natural tendency for the lower cedar branches to droop towards the forest floor. The weight of the foliage together with the weight of snow and

ice forces some branches into contact with the swamp floor. It is apparent that rapidly growing sphagnum beds build upward in some cases and thus engulf the branches. Duff and litter cover many of the branches in contact with the swamp floor. These processes all tend to provide a moist medium around the branch that is favorable for the development of adventitious roots from the tracheal rays of the stem and thus the formation of new individuals. This method of layering has been designated "branch layering". Figure 9 illustrates this type of vegetative reproduction.

A single branch may be covered at several points by moist media and start formation of adventitious roots at all of these points. Because of the utilization of low branches in this type of reproduction, it follows that this means of reproduction is most prevalent in the vicinity of stems of the lower age classes.

Layering also occurs in conjunction with broken or severed branches that are in contact with the swamp floor. This contact may be made as a result of wind-breakage or logging. In these cases, the stems are not dependent upon the root system of the parent tree but must form a root system of their own by branch layering. Two categories were established for these means of vegetative reproduction, "layering from windthrow" and "layering from logging".

Windthrows also produce vertical stems in a manner somewhat different than that previously described. In many cases, the branches of windthrows either continue to grow upward or assume a vertical position, obtaining water and nutrients from the portion of the root system of the parent stem that is still in the ground. An example of



Figure 9. Branch layering. The stem held in the right hand has become imbedded in sphagnum, thus providing a moist medium for the branch held in the left hand. Adventitious roots have formed on the branch and a new individual established.

this type of reproduction^{1/} was found in which the parent cedar stem (3 inches d.b.h.) had fallen and six of its branches had formed upright stems (figure 10). The old root system supported all these stems. Three of the stems are now 1 inch d.b.h., one stem is 2 inches d.b.h., and two stems are 3 inches d.b.h. The designation "windthrow" has been given this type of growth.

Natural cuttings are difficult to trace positively to their origin. However, definite examples of this type of reproduction were found. The first example of this type was found in the Upper Peninsula Experimental Forest, Dukess, Michigan. A stem of vegetative reproduction was formed by rabbit cutting, the cutting falling, being partially covered with duff, and rooting. In this instance, eight branch roots were formed. Several similar examples have been found since.

No cases were found of stool sprouting or of root suckering. Isolated cases of formation of coppice shoots on stumps were found but they showed no indication of development to a degree that might be classes as a stem of reproduction. Cases were found involving "topped"^{1/} stems in which the laterals took over as a leader. However, this probably should be classified as a transformation rather than a means of reproduction in that no increase in the number of stems resulted.

^{1/}More of a transformation than true reproduction; but for purposes of this study classed as a type of vegetative reproduction.

^{2/}The term "topped" refers to a tree that has had its main stem cut or broken at a point that is above the usual height of cutting.



Figure 10. Illustration of vegetative reproduction formed from a windthrow. The sapling stems have developed vertically from branches on a windthrown tree.

Seedlings, branch layers, and stems originating from windthrow accounted for over 90 percent of the reproduction (table 4). Approximately 80.9 percent of the vegetative reproduction was caused by layering of one type or another.

There was no significant difference between the abundance of the various types of vegetative reproduction in the plots with cutting and the plots without cutting (table 5). The obvious exception is in the category "layering from logging".

It should be re-emphasized that the plots sampled in determining the types of reproduction were located on organic soils. Observations have indicated that the relationships expressed here between the various types of reproduction do not hold on the so-called "old-field" types in Upper Michigan. The reproduction is predominantly of seedling origin in these stands.

Curtis (16) mentions three types of vegetative reproduction by:

1. layering.
2. tops and branches of thrown trees that develop root systems.
3. thrown or partially thrown stems when the uppermost branches from them begin to grow vertically in their new position even though the stem of the tree may not be in contact with the forest floor.

Most of the types established in this study could be classified under the same categories; layering from windthrow and layering from logging and would thus fall into the classification "tops and branches of thrown trees develop root systems". He does not mention natural cuttings as a means of vegetative reproduction. Montgomery (42) has evidence of root sprouting and stump sprouting. These types of reproduction were not of consequence in this study.

Table 4. -- Types of cedar reproduction on a swamp site^{1/}

Type	: : Number of stems :	: : Percentage :
Seedling	108	20.0
Branch layering	326	60.4
Layering from windthrow	14	2.6
Layering from logging	9	1.7
Windthrow	58	10.7
Natural cuttings	1	0.2
Unknown vegetative types	24	4.4
Total	540	100.0

^{1/} Based on tallies of cedar 2 to 8 feet in height in twenty
1/100 acre plots.

Table 5. -- Relative amounts of vegetative reproduction in 10
plots without cutting and 10 plots with cutting

Type	Treatment	
	Without Cutting	With Cutting
	Percent	Percent
Branch layering	74.2	77.4
Layering from windthrow	3.0	3.6
Layering from logging	0.0	5.3
Windthrow	16.7	8.3
Natural cuttings	0.4	0.0
Unknown vegetative types	5.7	5.4
Total	100.0	100.0

Maki (41), working in Minnesota, feels that the proportions of seedling and vegetative reproduction is governed primarily by the type of seed bed. He concludes that under dense, mature cedar stands, seedling reproduction is dominant due to the slow growth of sphagnum and sparseness of herbaceous cover, thus providing little interference with seedlings. With a fairly dense sphagnum mat, layers are dominant due to smothering of seedlings by the sphagnum mats. In cut-over areas, sphagnum usually resumes growth with renewed vigor but both seedlings and layers are common.

Observations in the Upper Peninsula of Michigan do not concur with these results of Maki in their entirety and the heavy emphasis on type of seedbed as the determining factor is thought to be misplaced. It is agreed that dense, mature stands produce predominantly seedling reproduction but it is for the reason that branch layering is the principal type of vegetative reproduction and that the lower branches in a dense, mature stand have been self-pruned long since; this does not allow for the formation of branch layers. It is agreed that sphagnum aids branch layering but it is felt that the age of the stand and the severity of cutting if it has occurred are the dominant influences in determining the type of reproduction that will be present.

In other studies concerned with the proportion of seedling reproduction to vegetative reproduction, Curtis (16) reports that rejuvenation of swamp cedar in Maine is mainly through vegetative propagation and the number of stems originating through vegetative means is probably large in comparison with the number originating from seed. This, in effect, is similar to the results in Upper Michigan.

Environmental Factors Affecting Initial Reproduction

Laboratory Studies

Seed Viability

Cones were collected during the fall of 1948 from two swamp stands in the Upper Peninsula of Michigan and air-dried. The seed was extracted by sieving and placed in cold storage. Standard germination tests were run using Petri plates and filter paper.

Further seed was obtained from a commercial seed source; it had been collected in Door County, Wisconsin. Germination percentage was again calculated for the field run seed. Selections of well-filled, healthy appearing seeds were made and germination tests conducted. The results of all germination tests were then computed on percentage bases to determine viability.

Germination was determined from Baldwin's standard (5). He defines germination as having occurred at the time that the tip of the radicle has elongated far enough beyond the seed coat to show a normal growing tip and gives indications of developing into a healthy seedling.

Germination from 1948 seed collected in swamp stands in the Upper Peninsula indicated approximately 3.0 percent germination of field run seed. Germination approximated 9.0 percent on seed obtained from Door County, Wisconsin. By selecting only well-filled, healthy appearing seeds from this lot, germination was increased to 80.0 percent under optimum conditions.

Several methods of approach including Korstian's procedure on southern white cedar (32) were utilized in an attempt to determine

the amount of viable seed per unit of forest floor, but none of the methods proved satisfactory. Germination counts on milacre plots gave the only indication that could be obtained of the number of viable seeds. Throughout the course of the study, the highest germination on an acre basis^{1/} was 427,000 seedlings with counts above 150,000 seedlings per acre quite common. Tallies and observations showed that a satisfactory amount of viable seed was present in the areas studied.

Light

A study of the effect of light on seed germination was initiated. Preliminary tests under conditions of full sunlight and full darkness were followed by a series of full sunlight, full darkness, and partial sunlight. Four replicates of 100 seeds each were used in the latter tests.

Three layers of moist filter paper were placed in Petri dishes, the filter paper serving as germinating media. The plates were sealed with Scotch tape to prevent moisture loss. Water was added as necessary.

A similar series was wrapped with a heavy sheet of black paper, sealed, and then covered with a wrapping of white paper. These wrappings were removed only long enough to obtain germination counts and to add water. The partial sunlight series was constructed in the same manner as the full sunlight series. However, it was placed in

^{1/} Most of the counts were on a milacre basis and expanded to an acre basis for comparison with the results of other workers.

partial light conditions. The mean foot candle power for the partial light replicates, obtained from a series of six random readings during daylight hours, was 76.3. Germination was checked semi-weekly.

Germination under partial light conditions appears to be better than germination in the dark, from the standpoint of vigor of germination and rapidity of germination (table 6). There was no significant difference in total germination between partial light and darkness. Full sunlight inhibited germination.

Acidity

Five replicates, each consisting of 100 selected seeds, were adjusted to pH intervals of one unit from 3.0 to 8.0 with initial deviations not greater than one-tenth pH unit to determine the effect of pH upon seed germination. Difco standard agar at a concentration of 20 grams per liter of water was adjusted with nitric acid and sodium hydroxide to obtain the desired degrees of hydrogen-ion concentration. A Beckman electric pH meter was used to make the pH determinations. Germination was at room temperature. The pH was measured again at the conclusion of the experiment.

A trend of increase in germination with a decrease in hydrogen-ion concentration is apparent (table 7). It becomes less pronounced as the length of the germination period increases. A statistical analysis of the data indicates a significant decrease in germination below pH 4.0 under the conditions of the experiment.

Types of Germinating Media

A test to determine the effect of different types of

Table 6. -- Accumulative seed germination in different light
conditions in laboratory tests

(In number of seeds germinated)

Light Condition					
	7	10	14	17	21
Full sunlight ^{1/} ^{2/}	0	0	0	0	0
Partial light	109	203	229	236	236
Darkness	14	63	117	179	187

^{1/} Four one-hundred seed replicates were initiated in each light condition.

^{2/} Established on July 1, 1949.

Table 7. -- Accumulative seed germination at various pH levels
under laboratory conditions

(In number of seeds germinated)

pH	Test Period in Days			
	7	10	14	17
^{1/} 3.0	0	20	72	92
4.0	1	48	259	347
5.0	4	79	281	362
6.0	2	20	186	293
7.0	16	142	346	378
8.0	33	186	371	400

^{1/} Five one-hundred seed replicates were initiated at each pH level.

germinating media under controlled temperature and moisture was initiated. Four replicates, each consisting of 100 selected seeds, were germinated in four types of natural germinating media; the organic swamp floor, logs in various stages of decay, hardwood litter, and mineral soil as a check. The swamp floor sample was obtained from the top inch of an organic swamp soil classified as a Rifle peat. The decaying log sample was obtained from the same location and would fall into the decay class 5 according to McCullough's classification¹/(44). The hardwood litter sample was predominantly composed of alder leaves and was obtained in a large alder clump on the edge of the swamp. A small percentage of red maple litter was included in the sample. A very limited amount of decay had occurred, but the leaves of the component species were recognizable. The mineral soil sample that served as a check was obtained from the A₁ horizon of a Trenary fine sandy loam.

The samples that were kept in Petri plates at room temperatures with an adequate supply of moisture. Germination was checked semi-weekly.

An analysis of variance showed no significant difference in seed germination between any of the media. Results are shown in table 8.

¹/ McCullough defines decay class 5 (D5) as fallen trees definite in outline but with decay well advanced as indicated by the presence of loose fragments of wood.

Table 8. -- Accumulative seed germination in various types of
natural media under laboratory conditions

(In number of seeds germinated)

Types of Natural Media	Test Period in Days				
	7	14	21	28	35
Swamp floor	15	187	226	229	229
Decaying logs	4	137	208	236	254
Hardwood litter	14	237	250	258	258
Mineral soil	1	137	184	189	189

1/ Four one-hundred seed replicates were initiated in each type of natural media.

Temperature

Preliminary tests to determine the effect of constant temperatures upon the seed germination were established in the laboratory at 4° Centigrade intervals from 10° C. to 34° C.^{1/} using moist filter paper in Petri plates as germinating media. Refrigerator controls at 10°, 14°, and 18° and incubators at higher temperatures provided the temperature chambers. Average daily variation in temperature approximated ±0.5 C. In a thirty day period following the establishment of the tests, germination occurred from 18° to 34° with maximum germination to 24° to 26°.

With these results in mind, a series of tests were instigated at 10°, 14°, and 18° and a check at room temperature to better establish the minimum temperature at which germination would occur. The tests at room temperature averaged 24.2° C. with an average daily variation of 2.65° C. as obtained from thermograph readings.

Five replicates of each treatment, each containing 100 selected seeds^{2/}, were established. Germination was checked semi-weekly.

It can be seen that low temperatures have an adverse effect upon seed germination (table 9). No germination occurred below 18° C. It was also noticed that initial seedling growth was less vigorous at the low temperatures.

^{1/}Mechanical difficulties necessitated a 24° C. test instead of 22° C.

^{2/}Source of seed was Door County, Wisconsin.

Table 9. -- Accumulative seed germination at various temperatures
under laboratory conditions

(In number of seeds germinated)

Temperature	Test Period in Days				
	: 7	: 10	: 13	: 17	: 20
$\frac{1}{10}^{\circ}$ C.	0	0	0	0	0
14 $^{\circ}$	0	0	0	0	0
18 $^{\circ}$	0	3	14	23	30
Check (24.2 $^{\circ}$)	102	243	286	296	305

1/ Five one-hundred seed replicates were initiated at each temperature level.

Field Studies

Season of Seed Germination

A series of ten milacre plots were picked clean of cedar seedlings reproduction prior to the 1949 growing season. Throughout the growing season, semi-weekly checks were made of the plots in an attempt to find new seedlings. Seedlings found were marked with numbered pegs to prevent duplication in counting. The date and type of medium upon which the seedlings were growing was also recorded.

It is acknowledged that the date at which the seedlings were found was later in the growing season than the date of emergence. In order to limit this factor, as well as the possibility of discovering seedlings that might have been missed in previous inspections, the presence of the two primary cotyledons in a healthy state was deemed necessary for inclusion in the data.

Emergence was first noted on the 3rd of June and continued until the 28th of July. The preponderance of emergence occurred between the 5th of June and the 5th of July (figure 11).

The first emergence noted was that occurring on exposed stumps. No germination occurred on the swamp floor until June 27th, by that time, 77 percent of the germination that was noted on logs and stumps in various stages of decay had been tallied. Germination on the swamp floor was definitely later than on logs and stumps.

Effective Seeding Distance

Methods

Observations were made throughout the course of the study to determine the effective seeding distance of cedar. A concerted effort was made to locate seedlings that were situated in relation

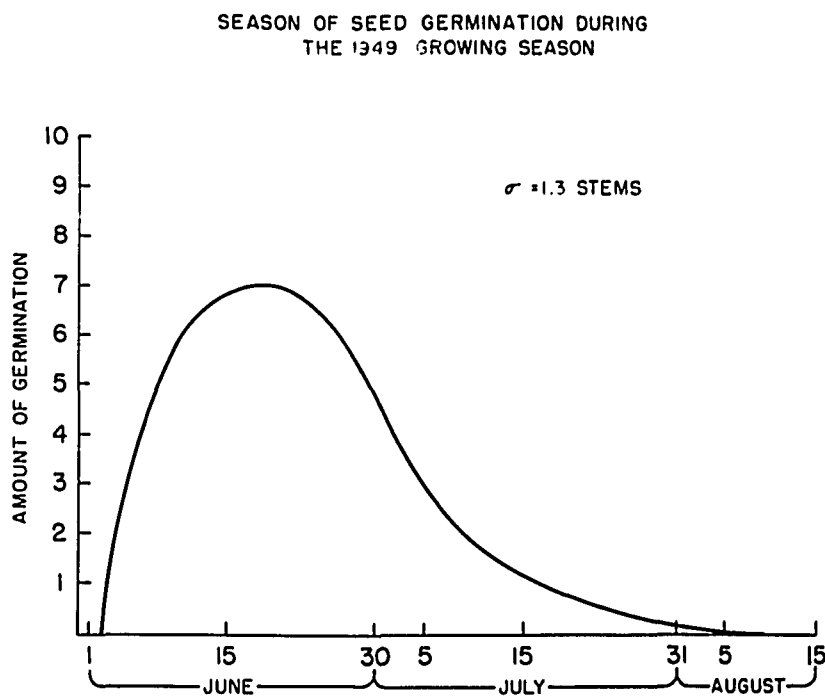


Figure 11. Germination period as determined by the number of new stems found at each inspection.

to a single seed-bearing tree such that the parent could be definitely determined. Observations were limited to swamps or swamp borders to reduce the possible effect of slope. Distance and direction of the seedling from the parent were noted. Prevalent winds in the area are from the northwest.

Results

Numerous instances were found in which seedlings were located from 40 to 53 feet from the nearest seed trees. It is concluded, from the observations made, that adequate stocking will occur 40 to 50 feet from seed trees, this being especially true in the direction of the prevailing wind.

The maximum distance of adequate seedling reproduction from seed trees was found in an area clear cut according to the classical definition (29) between 1937 and 1940. The area with seedling production illustrated in figure 12 contained 223 seedlings on a milacre basis. Ring counts showed all seedlings had developed after the clear cutting operation. The distances to the nearest cedar trees of seed-bearing age were in the cardinal directions and as follows^{1/}:

<u>Direction</u>	<u>Distance</u>
North	93.0 feet
West	158.0 feet
South	80.0 feet
East	143.0 feet

^{1/} It is highly improbable that animals or birds could have been the dispersing agent in this case. All indications suggest wind as the means of dispersal.

A HEAVILY SEEDED AREA IN A COMPLETE, CLEAR CUTTING
SHOWING THE NEAREST SEED TREES

Scale: 1"=80'

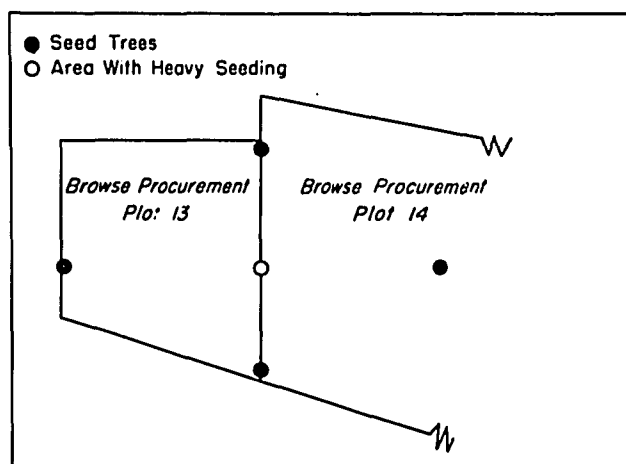


Figure 12.

A word of explanation is due concerning the light conditions in this clear cut area. The immediate area in which these seedlings were found was located under cover of partial windthrow and high butts of leaning trees. The light intensity within the area of seedling establishment was only 10 percent of that throughout the remainder of the area.

Because cedar seldom grows isolated, and in view of the fact that few technically clear cut areas containing satisfactory light conditions for seed germination are available, satisfactory work areas were difficult to find. Results on this phase of the study are thus observational of necessity.

Rate of fall is an important factor in dispersal by wind. Cedar seed is light in weight (approximately 325,000 seeds per pound) and possesses a relatively large wing to aid in seed dispersal. On the other hand, the total height of the species is small and acts toward limiting the dispersal distance.

Seed dispersal of northern white cedar stands is not dependent upon the wind alone. Mention should be made of the extensive work that is undertaken by the red squirrel in this respect. Throughout the course of the study, this chattering little mammal was often observed scurrying about the cedar trees. In the fall, he cuts cone clusters and branches containing the clusters. The percentage of seed dispersed or eaten by this animal is not known but it is felt that it has a profound effect on seed distribution.

Light

Methods

Throughout the course of the study, light readings were taken

on all milacre plots established to determine the effect of light upon the initial establishment of cedar seedlings and vegetative types of reproduction. Readings were taken with a DeJur Amsco Model 5B incident light meter and were taken as near to 10 AM and 3 PM as possible. These times were arbitrarily chosen because of the similar foot candle power in full sunlight during the two periods. It was also felt that the two periods were most representative of daily conditions in that readings at these two hours would tend to balance the readings in plots that were shaded during the morning and open in the afternoon and vice versa.

Readings were taken only during periods of a clear sky. Except in a single group of plots, readings were taken from one-half hour before the designated time to one-half hour following the designated time. In the series of plots located in Section 13 T44N R26W, travel distances were of such a magnitude that readings had to extend to a maximum of one hour past the designated times.

An extended effort towards uniformity in method was made in taking all readings. That is, the light meter was held at waist level with the operator's back to the sun and at a distance such that the operator's shadow did not fall across any part of the milacre plot. A single operator made all the readings.

The entire plot was covered with the meter. The reading selected was the apparent modal reading with the operator still bearing in mind the minimum and maximum readings. This integration was thought to be most representative of the light conditions within the plot. It was also upon the recommendation of the DeJur Amsco Corporation engineers (39) that light flux falling upon the object

was used as a criterion for measurement rather than the amount of light reflected from the object.

Calibrations from light meter readings to total light flux foot candles were furnished by the DeJur Amsco Corporation and are shown in figure 13. The individual plot light meter readings were converted into foot candle power and a mean obtained for the plot. Classes were then established in foot candle power corresponding to light meter units insofar as the accuracy of the instrument is in block units. The standard deviation of the seedling tallies was obtained for each class and plot rejections were made at a level of greater than two standard deviations from the arithmetic mean.

Several problems presented themselves in the designation of height classes to be included within the tallies. It is acknowledged that some of the vegetative reproduction is over 2 feet in height at the time of origin, especially those forming vertically from windthrows. However, it is felt that the majority of the stems formed from branch layering are under 2 feet in height at the time adventitious roots form. It is also acknowledged that seedling reproduction and vegetative reproduction of the same height would be quite widely separated in age. With these facts in mind, the height class from 0 to 2 feet in height was designated as initial reproduction.

Results

Figures 14 and 15 illustrate graphically the abundance and

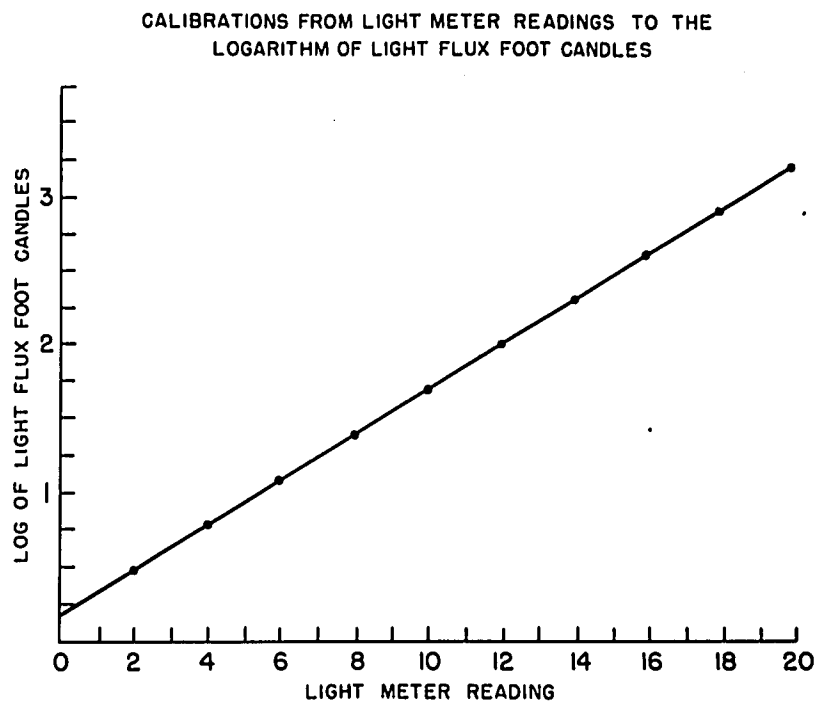


Figure 13.

frequency^{1/} of seedling reproduction under 2 feet in height. The seedling reproduction abundance and frequency data are included in table 35 (Appendix).

The results indicate that light intensity is not a critical factor in seedling germination and initial establishment throughout the normal range of light conditions found in our swamp stands and swamp cuttings. There is a decrease in both abundance and frequency at both extremes. The conditions at the lower end of the table, i.e. conditions with an average foot candle power of 5 to 7, were found in very dense stands and were usually located in an area with a sufficient amount of reproduction in the somewhat larger size classes. The average minimum light intensity requirement^{2/} approximates 0.067. The conditions at the upper end of the table with a foot candle power of 331 and upwards were found in 10-year-old cuttings that were harvested under a system of absolute clear cutting.

The results also indicate that light intensity was not a critical factor in vegetative reproduction. Initial establishment was found throughout the range of light conditions that are present in our swamp stands and swamp cuttings (table 10). There was a decrease in both abundance and frequency at the lower extreme. The plots at that end of the table, i.e. conditions with foot candle power of 5 to 10, were found in very dense stands with a sufficient

^{1/} The term "abundance" is used in this dissertation to designate a count of a given species present on a unit area basis. It is acknowledged that this is a rather broad use of the term but was used in view of the fact that density seemed difficult to visualize in relation to a stand of seedlings. Frequency is defined as a measure of the degree of dispersion measured on a percentile basis.

^{2/} The ratio between intensity falling on the forest floor and intensity in the open.

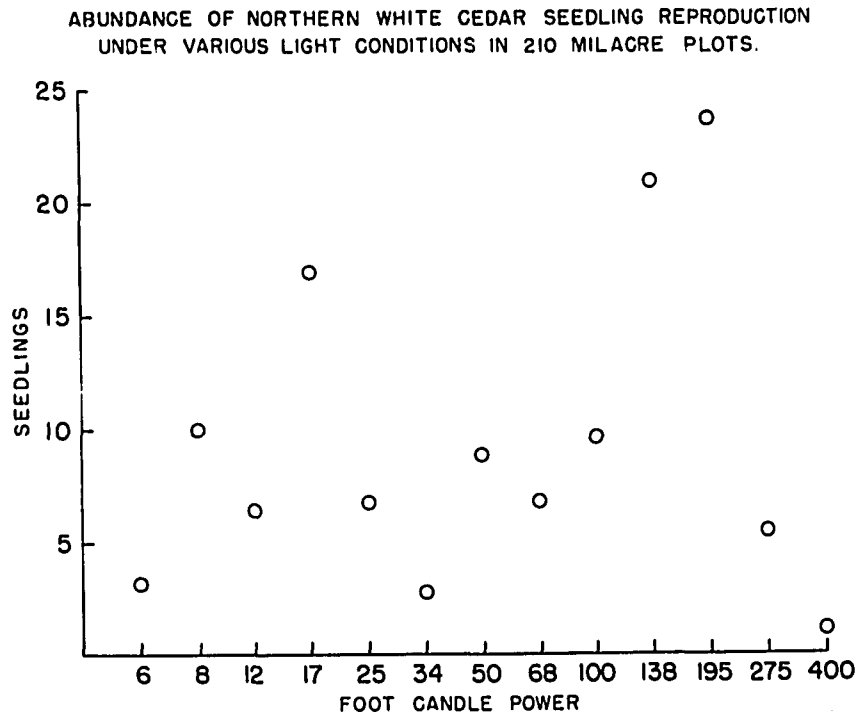


Figure 14. Abundance of northern white cedar seedling reproduction under various light conditions. Each dot represents the mean number of seedlings in the plots examined that were tallied in that specific light class. The number of milacre plots in each light class represented in this figure is indicated in Table 35.

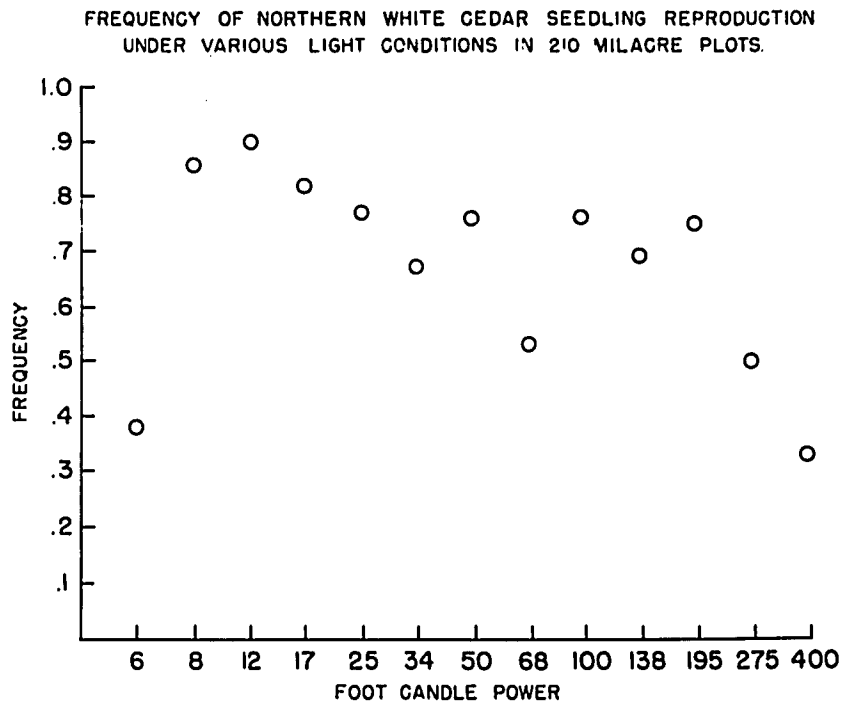


Figure 15. Frequency of northern white cedar seedling reproduction under various light conditions. Each dot represents the percentage of milacre plots in which cedar seedling reproduction was found.

Table 10. --Abundance and frequency of vegetative reproduction under
2 feet in height in various light conditions

Foot-candle power	Abundance	Frequency	Number of mil- acre plots in class
	<u>Number of stems</u>	<u>Percent</u>	
5-7	0.7	22.	9
7-10	0.6	43.	14
10-14	1.9	59.	17
14-20	2.3	68.	22
20-28	1.7	52.	27
28-40	2.8	69.	13
40-58	4.9	87.	16
58-81	0.8	55.	11
81-114	1.4	44.	9
114-162	0.5	50.	4
162 plus	3.9	64.	11

amount of reproduction in the larger height classes and extremely heavy self-pruning. Nine of the readings in the most intense class^{1/} had foot candle power above 331 and were located in an area that was clear cut ten years previous to the plot examination.

The conclusions correspond very closely with those of Maki (41). From limited observations, he concludes that there is no correlation between radiation intensity and the number of seedlings without regard to age. Probably Baldwin (5) best summarizes the effect of light on seeds of forest trees by stating that light is rarely necessary but in nearly all cases germination is improved and hastened by it.

This discussion is not in anyway meant to invalidate the effect of light upon seedling growth and development following seed germination and initial establishment. Observations indicated that light is beneficial, increases the growth of reproduction, and that possibly the species becomes more light tolerant with age.

Acidity

Methods

A study was initiated to determine the effect of pH upon seedling and vegetative reproduction under field conditions. In 156 of the milacre plots established throughout the course of the project, pH readings were obtained. During the 1948 growing season, determinations were made with a "soiltex" kit. However, in view of

^{1/} This relatively low figure was chosen as an upper class designation because of the difficulty in obtaining an adequate number of plots in the more open areas.

the difficulties encountered due to the organic matter in muck and peat soils clouding the single colorometric reading, a LaMotte-Morgan soil testing kit with a series of indicators was used during the 1949 season to alleviate this difficulty. Samples were collected from within the top 2 to 3 inches of soil and seedling and vegetative reproduction was tallied. Plot rejections were made as previously.

Results

Seedling reproduction increases with a decrease in hydrogen-ion concentration above 6.0 to a neutral and slightly alkaline condition (circum-neutral). There seems to be no appreciable difference in reproduction in the range between pH 4.0 and 6.0. Indications point to a possible reduction below this level. Figure 16 illustrates the seedling abundance and figure 17 shows the seedling frequency data in a graphic presentation^{1/}.

The results in table 11 indicate a decrease in abundance and frequency of vegetative reproduction at the higher pH levels (above pH 7.0). However, this is above the organic soil range in most of the study area. All the observations in the class 7.0 to 7.9 fall at pH 7.5 or below.

General observations also bear out these findings concerning vegetative reproduction. In the Longrie loam type^{2/} that is present in or near swamps, seedling reproduction seems to take over old fields that have been utilized as pastures. This is in contrast

^{1/} The seedling abundance and frequency data are presented in table 35 (Appendix).

^{2/} Longrie loam is characterized by a limestone bed rock and is neutral to alkaline in reaction.

ABUNDANCE OF NORTHERN WHITE CEDAR SEEDLING REPRODUCTION
AT VARIOUS Ph LEVELS IN LOWLAND STANDS IN 156 MILACRE PLOTS.

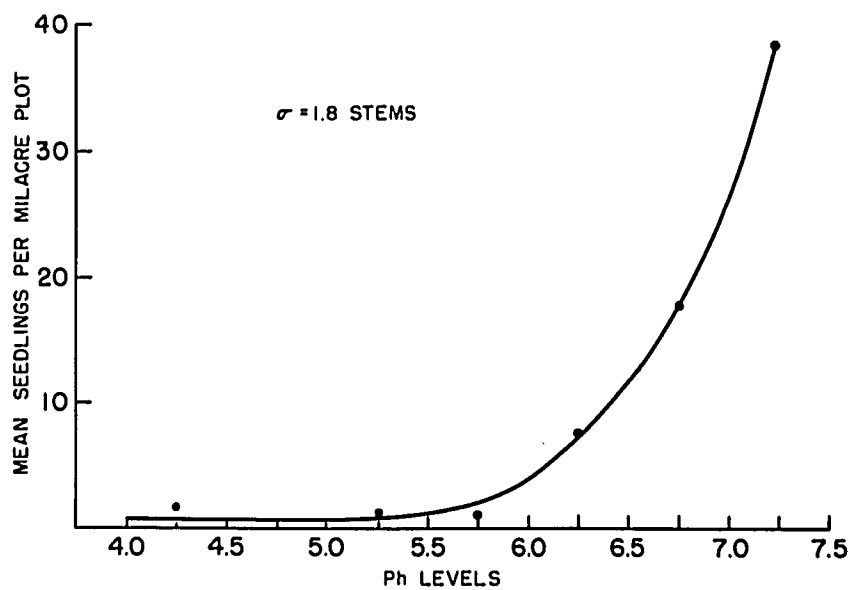


Figure 16.

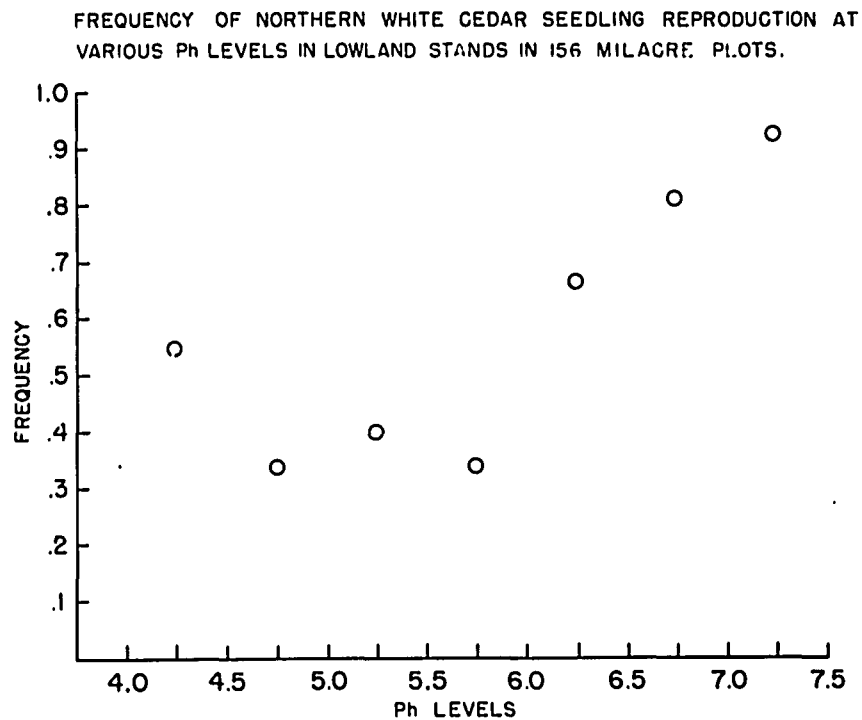


Figure 17. Frequency of cedar seedling reproduction at various pH levels in lowland stands. Each dot represents the percentage of milacre plots in which cedar seedling reproduction was found.

Table 11. -- Abundance and frequency of vegetative reproduction in
swamp stands at various pH levels^{1/}

pH	Abundance	Frequency	Number of mil- acre plots in class
	<u>Number of stems</u>	<u>Percent</u>	
4.0-4.9	1.4	33.	21
5.0-5.9	1.5	33.	17
6.0-6.9	2.2	37.	108
7.0-7.9	0.7	15.	13

^{1/} Tallies are based on stems from 0 to 2 feet in height.

to many stems of vegetative reproduction that we often find in swamp cuttings.

It should be realized that the pH values are very closely correlated with soil type in swamp soils. A grouping of the pH values by soil type would show that the lower pH values are representative of the plots established in Saugatuck, Ogemaw, and Newton types. The intermediate values represent Rifle peat sites. The higher values were found on Carbondale peat. The neutral and slightly alkaline readings were found in Carbondale peat with shallow deposits of marl and on Longrie loam that was located within swamps.

The correlation between an increase in seedling reproduction above pH 6.0 to the neutral point and slightly alkaline conditions is not absolute, however. It would appear that the rise in germination and initial establishment, although correlated with pH, is not due to the hydrogen-ion concentration but rather due to other physical, chemical, or biological factors involved in the integration designated as pH. Wilde (61) described the circum-neutral soils (pH 6.6 to 7.3), essentially the groups with better seedling establishment in this study, as being characterized by high activity of micro-organisms, rapid humification and nitrification, high availability of nutrients, and usually in good physical condition.

Adequate germination occurred throughout the normal range of pH values found in the cedar stands. The lower values at which germination and initial establishment might be prohibited are of little consequence to the forester. Baldwin (5) concludes

that most forest seeds exhibit a rather wide range of tolerance to reaction and germinate well within the limits of acidity usually found in nature.

The results would indicate some agreement with Fernald (20) in his classification of cedar as a calcicole. However, it should be strongly emphasized that the occurrence of the species and its reproduction are definitely not limited to basic sites and have the capacity to adapt themselves remarkably to the acid conditions of the Upper Peninsula swamps.

Types of Germinating Media

Methods

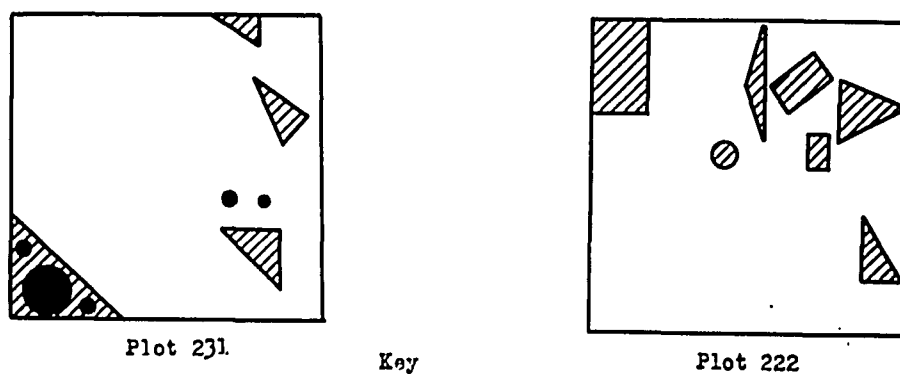
It was observed early in the course of the field work that in swamp stands cedar seedlings germinated and grew best on logs and stumps in varying stages of decay, bare or moss-covered, as germinating media. An effort was made to find the extent to which this observation held true.

Twenty seven semi-permanent milacre plots were established, nine in each of three different types of sites, at 50 foot intervals. One group was located in a deep swamp site on Rifle peat and designated as such, another group was located near the edge of the swamp on Carbondale peat, and a third group located on a Newton sand. The cover was such that alder clumps were not prevalent on any of the sites.

Seedlings were counted on comparable areas of logs, stumps, and down stems¹ and organic soil of the swamp floor in each type of site. Decayed logs were measured in milacre plots covered by this type of germinating medium was ascertained. Figure 18 illustrates the method devised by the author to determine the portion of the ground area within the swamp occupied by logs and stumps in various stages of decay.

Type of medium studies on vegetative reproduction were conducted on an observational basis.

¹/Hereafter collectively designated as "decayed logs" or a similar abbreviated terminology.



An illustration of the method used to determine the portion of the ground area within the swamp occupied by logs in various stages of decay (including stumps and windthrows).

Figure 18.

Results

This study indicated that logs in various stages of decomposition are the favored type of medium for germination of seedlings (table 12). Eighty seven percent of the seedlings tallied germinated on this type of medium. It was impossible to identify the species of the logs in most cases; however, it was possible to identify some northern white cedar and yellow birch logs. The log in figure 19 is typical of this type of medium. Figure 23 indicates a stump that vegetation is utilizing as a germinating medium.

The proportion of ground cover that is the favored type of germinating medium varies from 0 percent to 39 percent with a mean of 16.3 percent for 27 milacre plots (table 13). The amount of log medium varies on different sites, possibly due to different productive capacities, conditions for decay, and logging history. However, the same type of medium was favored on the three different sites included in this study.

Analyses of correlation and regression were calculated where applicable. No significant correlation or regression was present between the number of seedlings and the square feet of medium that consisted of logs in varying stages of decay.

Within the plots with the best reproduction of cedar, several generalizations were noted:

1. the canopy was composed of a pure coniferous stand with cedar the predominant species.
2. the seedling populations were located considerably above the general level of the swamp floor.

Table 12. --Types of germinating media relative to
seedling reproduction

Site	Log Medium		Organic Soil	
	Square feet	Number of	Square feet	Number of
	examined	seedlings	examined	seedlings
Carbondale peat	46.5	15	46.5	0
Rifle peat	45.5	57	45.4	13
Newton sand	46.2	13	46.2	0
Total	138.2	85	138.1	13



Figure 19. An example of the type of medium classified as "logs in varying stages of decay". Woody medium varies from slightly decayed to advanced decay classes.

Table 13. -- Percentage of swamp floor covered by logs in varying stages of decay on three different sites

Plot	Site		
	Carbondale	Rifle	Newton
	peat	peat	sand
	<u>Percent</u>	<u>Percent</u>	<u>Percent</u>
1	39	14	22
2	11	23	15
3	20	9	24
4	11	8	30
5	1	7	10
6	35	15	11
7	32	17	1
8	16	18	0
9	15	31	5
Mean	20.0	15.8	13.1

3. the seedlings growing on decayed logs had better developed root systems than those growing on the swamp floor.
4. the presence of suitable media in a swamp stand is not adequate insurance in itself that cedar seedling reproduction will occur.

An absence of seedlings was noted in deer runways and other areas with an abundance of deer and rabbit scats (figure 20). This might be partially explained by the trampling effect of deer which causes death of young seedlings and changes the physical condition of the organic soil. Several of these areas suggest a hypothesis that the concentrations of scats may exert a chemical effect that is inimical to seed germination and seedling establishment.

There seems to be a question in the minds of the foresters and game managers throughout the region as to whether the seedlings growing on partially decayed logs will be able to survive. The frequent occurrence of concrete examples leads to the hypothesis that there is possibly a far greater number of stems that originated in this type of medium present in mature stands than heretofore suspected. Figures 21 and 22 illustrate common examples of seedling produced stems. A numerical comparison of adult stems that had originated on logs and on the swamp floor was not attempted.

Observations indicated that the formation of vegetative reproduction is more dependent upon the moisture condition of the medium than upon its composition. It was found that a moist coniferous litter or sphagnum moss was the best medium for vegetative formation, probably due to the importance of branch layering as a means of vegetative reproduction. In a series of twenty



Figure 20. Illustration of heavily used deer runway. Note the concentration of scats in the run.



Figure 21. An example of a cedar pole that developed from the seedling type of reproduction. Although its origin is difficult to prove, deduction indicated that seedling type origin would be the only possibility.



Figure 22. An example of an adult cedar that has developed from a seed which presumably germinated in the duff and moss on the fallen log. Again, deduction precludes the possibility of a vegetative type origin.

1/100th acre plots, an average of 8.4 stems of vegetative reproduction were found in five plots where sphagnum moss was sparse as compared with a mean of 18.9 stems in 15 plots where sphagnum moss was medium or heavy.

Although logs in various stages of decay occupy a relatively small proportion of the total available germinating media (20.0%, 15.8%, and 13.1% respectively on 3 soil types), they are the favored medium for seed germination in the field. The fact that there was no significant difference in seed germination between types of germinating media, including hardwood litter, in the laboratory under similar conditions of temperature and moisture indicates that under satisfactory field conditions of these two factors among others, there should be no difference between the types of media as regards germination and initial development.

However, observations substantiated by moisture studies indicated that the hardwood litter in the swamps, predominantly a medium of alder leaves, had a lower moisture content than either the organic swamp floor or logs in varying stages of decay. It is felt that moisture is definitely the limiting value in the establishment of seedling cedar reproduction in alder clumps.

The most exposed wood media are also subject to considerable desiccation. Seedlings that might establish themselves on the upper portion of a stump as indicated in figure 23 would be subject to desiccation during the latter portions of the growing season.

The results of McCullough (44) indicate that the establish-



Figure 23. An exposed stump, a type of germinating medium found in swamps that was classified as "logs in varying stages of decay". Seedlings that became established near the cut end of stumps were often found to be subject to desiccation.

ment of Engelmann spruce and alpine fir seedlings is not dependent upon the herbaceous and shrub succession or the degree of decay of logs but that it can occur on logs showing only slight signs of decay. With this in mind and the fact that the species in the northern swamps that contribute fallen logs and stumps have very divergent wood characteristics, no such classification was designed. Logs with slight decay, in the moss stages of succession with a scattering of herbaceous vegetation, were the best germinating media.

Although the early decay classes provide the most satisfactory germinating media, it does not follow that logs in the early stages of decay are the best types of media for the ultimate establishment and survival of the reproduction. Observations indicate that the later stages of decay are superior in this respect. Several significant facts are offered in its support. There is less physical impediment to root penetration in the later classes. They also appear to have a higher capacity for moisture absorption than the slightly decayed logs.

It is probable that until the present century or the last few years of the past century -- with the exception of swamps with heavy and complete burns -- a goodly number of the swamp stands in the Upper Peninsula of Michigan were virgin. With the very slow decay that occurs under these conditions, the percentage of the swamp stands occupied by a medium of the type most suitable for seedling development was probably at an optimum. With ever-increasing utilization of forest products and reduction of woods

waste, the percentage of area occupied by this type of medium will no doubt decrease. Such a condition cannot help but have an influence upon the future amount of medium most satisfactory for germination. From a long time aspect, there is the possibility of a correlation of the amount of satisfactory germinating media with the means of slash disposal.

Not only was this type of medium (logs in various stages of decay) found very suitable for cedar seedling reproduction but observations indicated that it is equally as advantageous for the seedling reproduction of spruce and balsam fir.

It is regretted that the opportunity to observe and study the effect of fire upon germinating media and cedar reproduction in general did not present itself. It is a factor that should receive attention.

Temperature

Methods

The effect of temperature upon seedling reproduction was undertaken in an attempt to obtain specific information concerning swamp temperatures and to determine the effect of several aspects of temperature upon reproduction:

1. late spring and early fall frosts upon seedling mortality.
2. the low temperature of the forest floor in relation to the delay or prohibition of seed germination.
3. the role of soil temperature as a factor determining the preference for the type of germinating medium in swamps.

Two partial weather stations were constructed within the swamp.

Minimum and maximum temperatures were obtained in three positions at each site, one set at 2 to 3 inches below the surface of the swamp soil, another set from the inside of decayed logs (the most satisfactory germinating media for cedar seedlings in the swamp), and a third set from 2 to 3 inches above the surface of the swamp floor. Figures 24 and 25 illustrate the types of installations. The set at the Cusino station was used as an upland check of air temperatures. Readings were obtained semi-weekly.

Results

Figures 26, 27, and 28 indicate the mean, minimum, and maximum temperatures throughout the growing season at 2 to 3 inches above the surface of the swamp floor (Air), 2 to 3 inches below the surface of the swamp floor (Soil), in decaying logs, and at an upland check station (Air). It can be seen that during the period of seed germination (June and July), the temperatures within logs in various stages of decay were higher than the temperature of the forest floor. The maximum temperatures attained in the decaying logs was also higher; minimum temperatures overlapped in range. This latter phenomenon appeared to occur at times when the water table would drop beneath the gauges in the swamp floor.

The average semi-weekly variation between minimum and maximum temperatures was also greater within the logs. It averaged 6.8° F. for the swamp soil stations as compared with 10.6° F. for the decaying log stations. The average variation of the air just

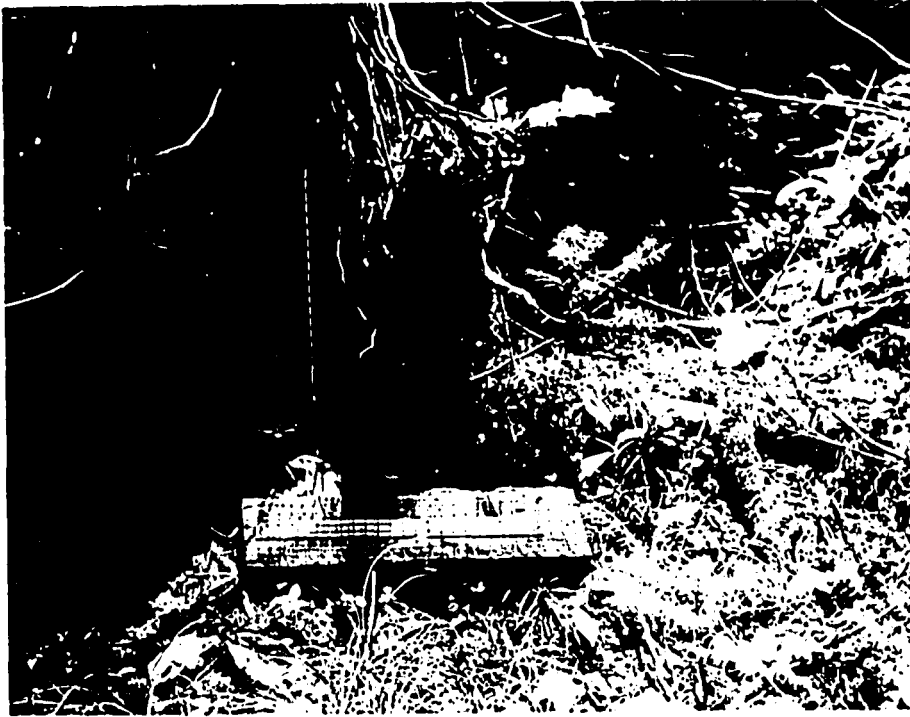


Figure 24. An illustration of the location of thermometers designed to obtain minimum and maximum temperatures above the surface of the swamp floor.



Figure 25. An illustration of the location of thermometers designed to obtain minimum and maximum temperatures in decaying logs.

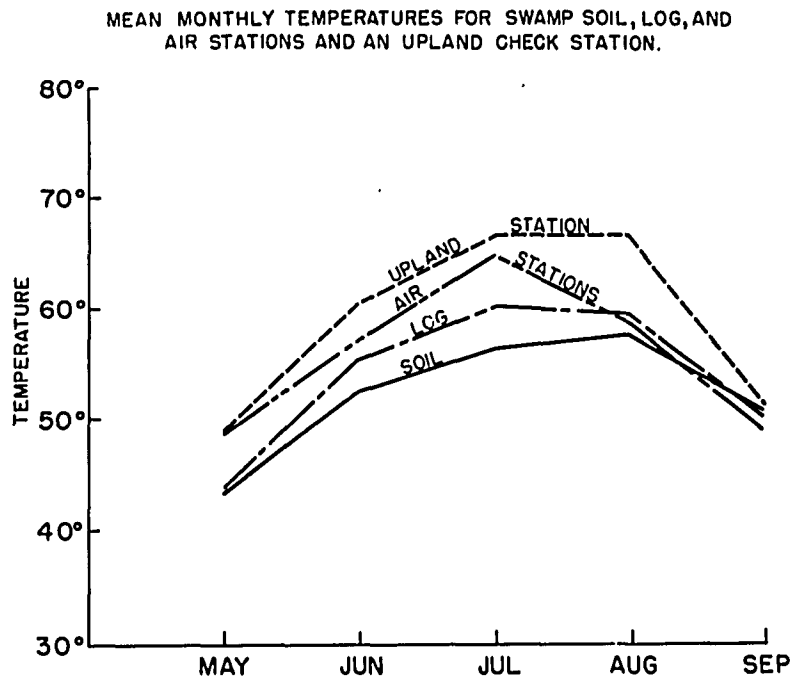


Figure 26.1/ 2/ 3/

- 1/ Temperature readings were in degrees Fahrenheit.
- 2/ Readings obtained during 1949 season.
- 3/ The upland check station measured air temperatures.

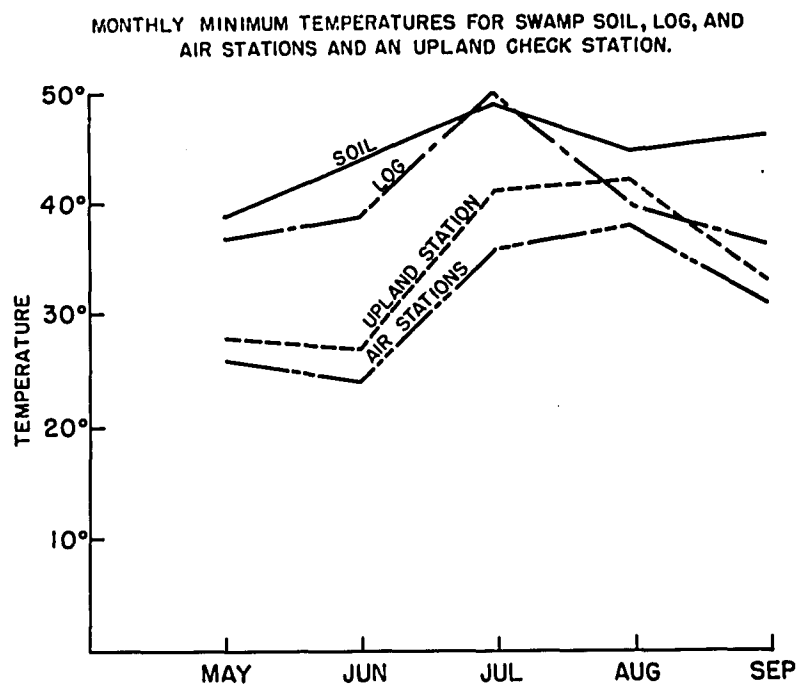


Figure 27.1/ 2/ 3/

- 1/ Temperature readings were in degrees Fahrenheit.
- 2/ Readings were obtained during 1949 season.
- 3/ The upland check station measured air temperatures.

MONTHLY MAXIMUM TEMPERATURES FOR SWAMP SOIL, LOG, AND
AIR STATIONS AND AN UPLAND CHECK STATION.

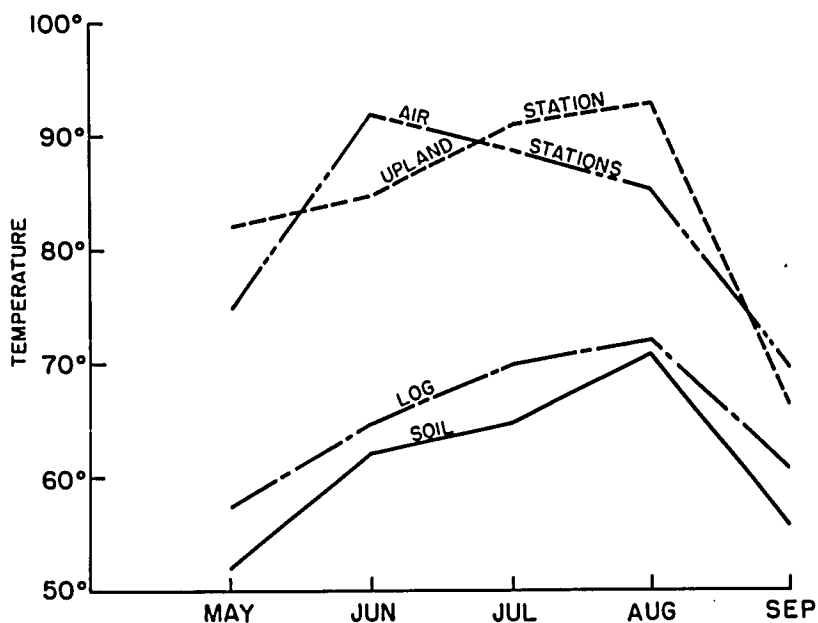


Figure 28.1/ 2/ 3/

- 1/ Temperature readings were in degrees Fahrenheit.
- 2/ Readings obtained during 1949 growing season.
- 3/ The upland check station measured air temperatures.

above the swamp floor was 30.0° F.

Results at the two stations were in very close accord with each other. Table 14 indicates the variation between the two soil and log stations for the month of August, 1949.

It is also noteworthy that the average air temperatures within the swamp are considerably lower than those of a check station located on an adjacent upland ridge. This is especially true of the minimum temperatures and the average monthly temperatures (figures 26 and 27).

The effect of late spring and early fall frosts on reproduction are discussed in detail elsewhere in this dissertation. In summation, late spring frosts were found to kill seedlings. No indication was found of damage by early fall frosts.

Germination of seeds on the swamp floor was late. It was definitely behind seed germination on other types of media. It is felt that the low temperature of the swamp floor caused this delay.

The fact that the mean temperature of the swamp floor was found to be lower than that of logs and stumps in varying stages of decay correlated with the amount of seedling reproduction. The factor causing the difference in germination between these two media, in the cases that were not exposed to such a degree that moisture supply is the limiting factor, is temperature.

The limited work of LeBarron and Neetzel (38) at Dukes, Michigan on swamp soil temperatures provides a further check on the results obtained in this study. On June 11, 1941, twelve

Table 14. -- Temperature relationships during August 1949

(In degrees Fahrenheit)

Station	Location	Mean	Minimum	Maximum	Variation ^{1/}
		temperature	temperature	temperature	
1	Soil	59.0	45.0	68.0	10.0
2	Soil	56.5	46.0	71.0	8.8
1	Log	59.5	40.0	72.0	13.6
2	Log	59.3	45.5	72.0	11.0

^{1/} Based on the average semi-weekly variation between minimum and maximum temperatures.

inches below the surface of the swamp floor, the temperature was 52° F. with a range of between 46° and 49° in similar positions elsewhere in the swamp. Readings for that period during 1949 at 2 to 3 inches below the swamp surface at Cusino averaged 49° F. for Station 1 and 48.5° for Station 2.

The laboratory results indicated that the lower threshold for germination of cedar occurred somewhere between 14° and 18° C. (57.2° and 64.4° F.). If exposure to cold temperatures during the winter plus alternation of temperature has not markedly lowered the threshold of germination, the temperature studies would indicate that the seed is able to attain the surface temperature of the media involved and commence germination without a warm layer of soil.

The hypothesis that the exposure to cold and alternating temperatures have slightly lowered the threshold seems more tenable. This conclusion is based on the fact that swamp soils are characterized by a very high water table during the period of germination, thus possibly reducing the temperature differential between the surface and underlying layers.

Soil Moisture

Methods

Soil moisture studies with regards to initial seedling reproduction were instigated with the following objectives in mind:

1. to obtain specific information on swamp moistures.
2. to determine the effect of low mid-summer moisture on seedling mortality.
3. to determine if soil moisture is a factor influencing preference for type of germinating media in the swamp.

Paired samples of approximately 50 grams each were obtained semi-weekly at each of two stations in each of two types of germinating media -- logs in various stages of decay and within the top 3" of the organic soil. These samples were taken from May 12 to September 26 during the 1949 growing season. Samples were oven dried at approximately 100° C. and reweighed when oven dry. The actual percentage of moisture was then determined. Samples were obtained from media that was supporting cedar seedling reproduction. Weighings were made to a 2 mg. accuracy and moisture percentages calculated.

Two water level gauges were installed during the summer of 1947. One was located in Section 19 T47N R16W, close to the upland but within a cedar-spruce type. It was subject to considerable drainage from the uplands and thus showed marked fluctuations. The other gauge was located in Section 30 T47N R16W -- within the swamp proper and not subject to the fluctuations described for the previous gauge. Readings were taken irregularly during 1947, weekly during the summer of 1948, and weekly during the entire growing season for 1949.

Figures 29 and 30 show the water level during the 1948 and 1949 growing seasons.

Results

It was noted that the moisture content of the swamp floor was greater than the moisture content of logs in various stages of decay upon which cedar was found germinating (table 15). The moisture percentages of both types of media throughout the growing season is well above the wilting percentages arrived at by Feustel and Byers (21) for peats. The mean soil moisture percentage throughout the growing season was determined to be 560.1 percent for both stations. The mean log moisture percentage for that period was found to be 473.9 percent. The standard deviation of the individual semi-weekly determinations from the seasonal mean was found to be 120 percent for the soil medium and 135 percent for the log medium.

Water was standing in the swamp on July 23, 1949. This condition was not the result of recent rains but rather is indicative of the water table at that time. The data indicative of the role of desiccation in the section of the dissertation on seedling mortality were largely gathered following a several month period of dryness in the 1948 growing season.

Although determinations were not carried out on hardwood litter throughout the growing season, observations indicated that the principle reason that viable seeds of cedar did not tend to germinate upon the litter was the lack of moisture in the medium. Samples of hardwood litter gathered on July 28, 1949 following two days of rainy weather with a precipitation of approximately 1.24

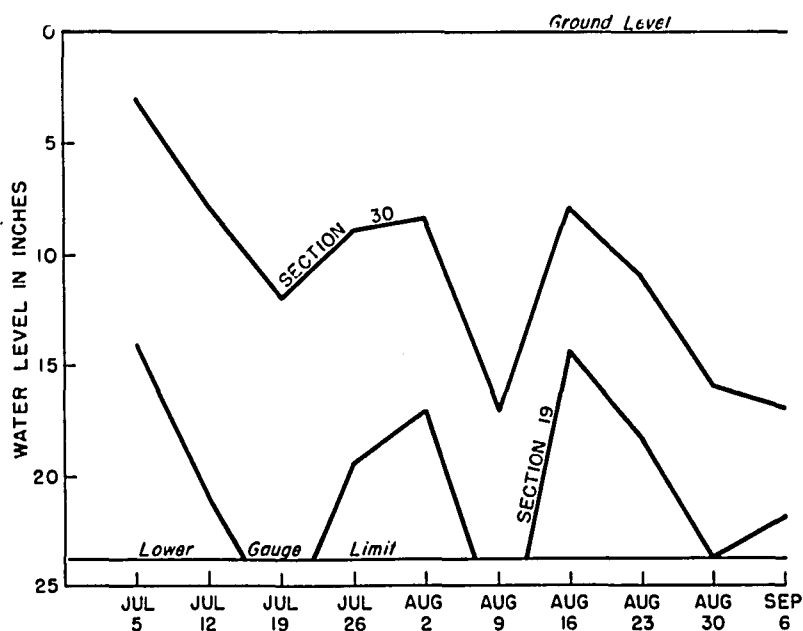


Figure 29. Water level readings during the 1948 growing season indicating weekly fluctuations in the water table. The Section 19 gauge was located close enough to the upland so that it was subject to rapid drainage. This phenomenon probably accounts for the greater variation in its readings as compared with the Section 30 observations.

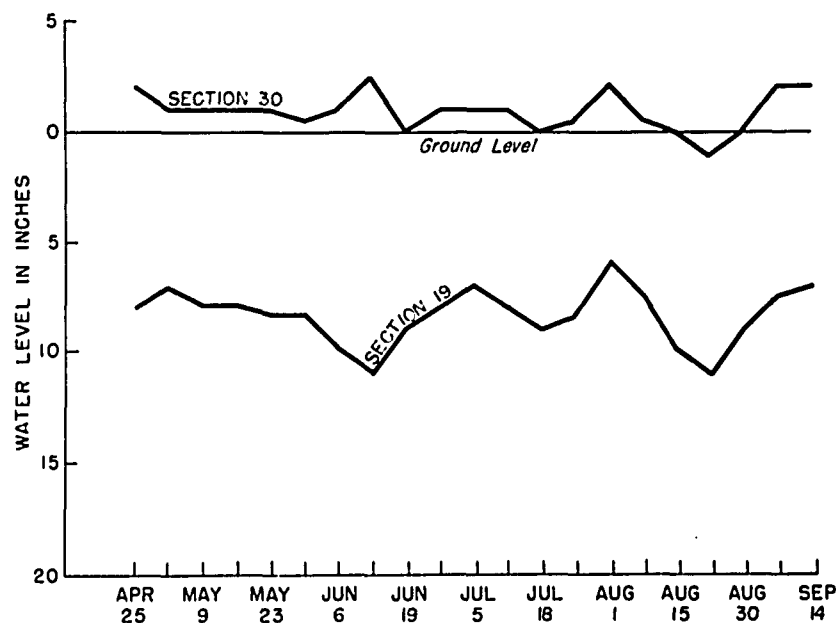


Figure 30. Water level readings during the 1949 growing season indicating weekly fluctuations in the water table. The gauge in Section 30 was inundated during most of the observation period. A comparison with the 1948 season illustrates the extreme variation between growing seasons (figure 29).

Table 15. -- Average moisture percentage of the two major types of
germinating media for cedar^{1/}

(In percentage)

Month	Soil		Log	
	Station 1	Station 2	Station 1	Station 2
May	591	604	507	489
June	579	540	404	421
July	566	600	495	480
August	544	514	457	504
September	480	547	574	536
Mean ^{2/}	560.6	559.7	470.7	477.2

^{1/} Data collected during 1949.

^{2/} Based on an average of the semi-weekly readings.

inches had an average moisture percentage of 148.4 as compared with 666.2 percent in the organic swamp soil and 447.7 percent for logs in varying stages of decay. During the drier periods of the growing season, this type of medium was found so dry that crumpling with the hands would break the leaf components of the litter into numerous pieces.

It should be emphasized that hardwood litter covers an important portion of the ground area of swamps. The areas which are inimical to cedar seedling reproduction are mainly alder clumps or alder stands constituting a significant acreage.

The observations attributed to the "swamp floor" are composed of mosses, coniferous litter, and the remains of shrubby and herbaceous associates among other things. The needle--type character of the coniferous leaves is of such a nature that it does not form a mat similar to that formed by hardwood litter. The exceptions occur in northern white cedar and white pine. Observations indicated that cedar branchlets on the swamp floor have a high moisture retaining capacity and seem to be moist enough to allow adequate reproduction. White pine needles, however, are inclined to form a mat that has a tendency to dry out on the surface layer.

Drainage

Methods

A study was instigated to determine the effect of natural drainage^{1/} upon northern white cedar seedling reproduction. Experimental design followed that of LeBarron and Neetzel (38) insofar as possible. With their results in mind, four lines were established perpendicular to the Creighton creek (Section 19 T47N, R16W) on meanders in such a manner that the closest distance from the plots to a drainageway would be along the established line. The lines were 125 feet in length with plots located from the bank of the stream to the end of the line at 25 foot intervals. A milacre was examined at each plot location for cedar seedling reproduction under 2 feet in height.

Plot rejections were at 2 standard deviations. In this discussion none of the plots has been included that fall outside the limits of 2 standard deviations. Thus approximately 5 percent of the more erratic plots are eliminated. Two standard deviations was chosen as the point of rejection in accordance with the suggestion of Bruce and Schumacher (8). Inclusion of plots with greater than two standard deviations from the arithmetic mean would permit single plots to exert undue influence upon calculations of means.

^{1/}

Artificially induced drainageways are of little consequence in swamp stands but the presence of streams and natural drainageways effect considerable areas. Therefore, the latter situations were chosen for studies on the effect of drainage.

Results from the four lines were tallied. These results prompted the establishment of four more fifty foot lines with plots at 25 foot intervals. Initial reproduction (0 to 2 feet in height) was tallied from milacre plots in the same manner as previously described. The area is located in a Rifle peat soil type. The cover was predominantly cedar with an admixture of spruce and balsam. Stream drainage is into the Creighton River, the Manistique River, and thence into Lake Michigan.

Results

The tallies of the four lines established indicated a definite decrease in seedling reproduction from a 50 foot distance to the stream's edge. Four more lines established perpendicular to the drainageway and with plots at the stream's edge, 25 feet, and 50 feet supported the initial results. The data for the eight lines were grouped (table 16).

It was found that the plots directly adjacent to the stream were in water during a portion of the study period. It was also observed that the percentage of herbaceous ground cover decreased as one traveled away from the stream's edge. The vegetation adjacent to the stream was mainly composed of sedges.

Light readings indicated that the swamp surface adjacent to the stream's edge received more light than the plots farther removed due to the opening made by the stream itself. However, light measurements carried on throughout the course of the study indicated that the values obtained were not too high for seedling establishment.

Table 16. -- Average seedling reproduction at various distances from
a natural drainageway.

Distance from drainage	:	Average number of seedlings	:	Number of observations
Stream's edge	:	3.75	:	8
25 feet	:	5.38	:	8
50 "	:	8.12	:	8
75 "	:	11.75	:	4
100 "	:	13.50	:	4
125 "	:	10.75	:	4

It is felt that the relationships obtained in this phase of study were correlated with inundation but no experimental evidence can be produced in behalf of this hypothesis.

Rodent and Snowshoe Hare Browsing

Methods

Rodent and snowshoe hare browsing was noted very frequently in cedar reproduction in the study area. With these observations in mind, a series of plots were instigated to check the combined effect of their browsing upon initial seedling reproduction (0 to 2 feet in height).

Two rodent and snowshoe hare proof plots and two check plots were constructed and located in such a manner that rodent and snowshoe browsing within the plots could be the only significant differentiating factor. Costs of material and labor limited further replication. There was necessarily some difference between light conditions in the check and the animal proof plots but this was reduced insofar as possible by placing a partial wire along the check plot sides. The plots each covered one square meter of the swamp surface.

One-half inch pipe was cut and assembled into a square meter frame with a bar down the center for support. A union was included in each half of the frame to enable it to be tightened to the exact size. This frame was attached to 6-foot lengths of three-fourths inch pipe and driven three feet into the ground. The tops of

the plots were covered with 4 x 4 mesh hardware cloth. The sides of the animal proof plots were dug in to a depth of 6 inches below the swamp floor level. The wire sides of the check plots were placed at 14 inches from the ground line to allow ample room for rodents and snowshoes to enter the plot. Figures 31 (a) and (b) illustrate the rodent and snowshoe proof plots and the check plots.

An index of the rodent population in the study area was obtained during the summer of 1948 (table 17), following in general the procedure outlined by Calhoun(11). A total of 605 trap nights in three days trapping on four lines were used to obtain the index. The trap lines were placed at a distance from the plot locations that should preclude the possibility of an influence on the rodent population but were still close enough to be within the same cover type.

The winter rodent population was not obtained. No index of snowshoe hare population was determined although observations indicated that the snowshoe hare were abundant in the study area.

Results

Table 18 indicates the seedling mortality in the plots between the time of establishment (July, 1948) and the time the snow was off the ground in the following spring (April, 1949). Examinations showed that the mortality of 8.5 percent of the seedling population in the check plots was definitely due to rodent and snowshoe hare browsing. Snowshoe hare scats were found on the floors of these plots. In Plot 299, a check, three other seedlings had lost their tips due

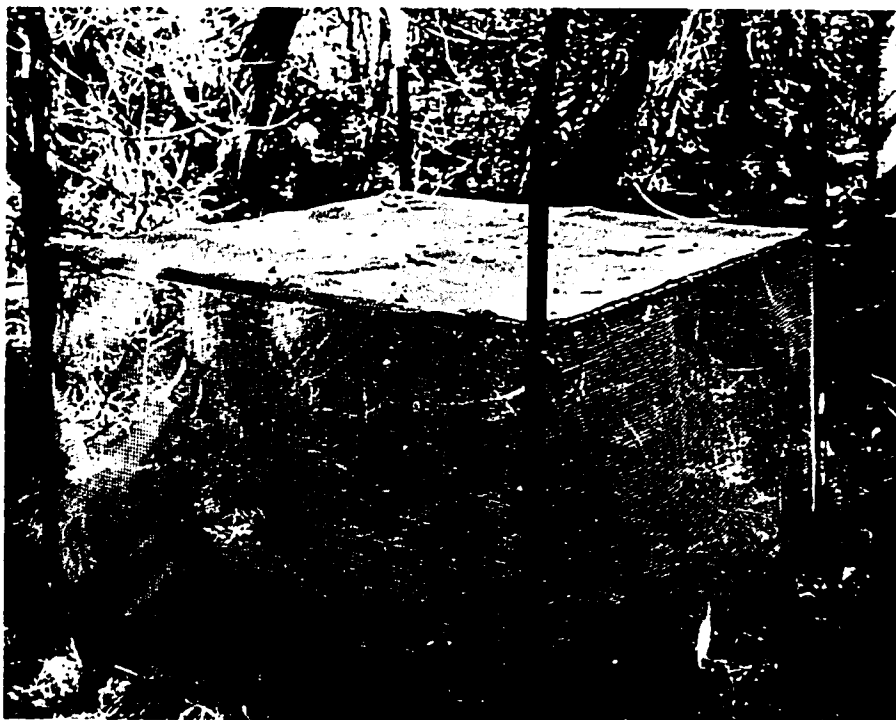


Figure 31. (a) Rodent and snowshoe hare proof plot. (b) Check plot.

Table 17. -- Results of 605 trap nights on four rodent trapping lines^{1/}

(In individuals trapped)

Species	:	Male	:	Female
	:		:	
<u>Sorex cinereus</u> (Masked shrew)		6		6
<u>Clethrionomys gapperi</u> (Red-backed vole)		1		2
<u>Microtus pennsylvanicus</u> (Meadow vole)		2		0
<u>Eutamias minimus</u> (Least chipmunk)		1		0

^{1/} The trapping period was during August 1948.

Table 18. -- Seedling counts in rodent and snowshoe hare proof
plots and checks

(In number of stems)

Plot	Type of Plot	:	:	:	:	Loss
						Caused by
			July	April		Browsing
			1948	1949		
300	Rodent and snowshoe proof		33	33		0
296	Rodent and snowshoe proof		35	34		0
299	Check		38	33		$\frac{1}{2}$
294	Check		33	29		4

1/ The loss of the other 3 seedlings was caused by factors other than rodent and snowshoe hare browsing.

to browsing. Five seedlings in Plot 294, also a check, showed similar damage. Thus at least 20 percent of the seedlings in the check plots showed browsing mortality or injury during a single winter.

Browsing of small seedlings was not confined to the specific area included in this phase of study. Counts made in the Escanaba River area -- specifically, Section 13 T44N R26W -- indicated widespread damage by rodent and snowshoe hare browsing also. On a mile-acre plot of 103 seedlings, 20 of them (19.4%) were severely browsed. Another plot containing 401 seedlings had approximately 40 percent of its seedlings browsed.

Although the studies include both rodent browsing and snowshoe hare browsing, the resulting damage was grouped. Both mice and snowshoe damage were found. A microscopic check indicated equal damage by the two groups insofar as identification could be made.

It was not possible to determine the type of damage to seedlings in their first few years of growth. The cedar stem was more of a succulent than woody nature and methods of identification (48) did not adapt themselves. The seedlings were too small to indicate more than a single tooth-cut.

The effect of rodents on seedling reproduction is not unique to northern white cedar. Krauch (33, 34) has demonstrated that silvicultural methods designed for controlling of the rodent population is necessary in Douglas-fir silviculture in order to obtain adequate stocking.

It was thought that the check plots might attract rodents and snowshoes due to the fact that the hardware cloth used as a covering

did collect a layer of snow and thus exposed this area before the surrounding swamp floor in the spring. However, the results of checks in other areas tend to discredit the possibility of this being a major source of error.

Soil and Cover Types

Methods

Soil Types

Some of the component factors constituting the differences between and among soil types were studied in detail rather than as a study of the sum expression of the edaphic factors as soil and are presented in other sections of the dissertation. However, insofar as many of the observations were made by a soil type grouping, results of these observations are included in the following discussion.

Cover Types

Stand compositions and basal areas were obtained by 1/10th acre cruises on 15 plots which were established in conjunction with the soil type observations.

Results

Soil Types

Although northern white cedar occurs on Kerston muck, inundated conditions caused by beaver dams on the Kerston muck tracts within the general study area precluded the possibility of studying this type.

Spalding peat stands including cedar were found to be

lightly stocked. Cedar was scattered, old, and small; cedar reproduction was limited.

Reproduction on Ogemaw fine sandy loam was extremely limited. Cedar is not one of the dominant species in the original stands. Although this soil class would fall into a drainage catena with Saugatuck and Newton sands more closely than with the upland soil types, it showed little promise of becoming a cedar-producing type.

Newton and Saugatuck sands are more or less intermediate in number of seedling stems between the poorly drained upland soils with cedar occurring in the canopy and the organic swamp soils. The highest numbers of stems of reproduction were found in the more highly decomposed organic soils of the swamps, Rifle peat and Carbondale muck.

Although Longrie loam does not cover extensive areas, it was found in swamp border and ridge situations. Excellent cedar reproduction occurs in a forest type that can justifiably be included in the "old field" cedar type (15) on Longrie loam.

The depth of organic soil was measured to provide a clearer picture of the conditions existing throughout the swamp and adjacent ridges. The depths varied markedly -- from 2 to 3 inches on upland sites and Newton and Saugatuck sands to as deep as 76.5 inches in the deep Rifle peat. Watson (56) indicates that the site is progressively better as the organic soil layer decreases in depth.

Site indices by soil types were obtained following the suggestions of Gevorkiantz and Duerr (25). The values obtained placed the sites within a narrow range of differences. With the exception of a Newton sand area and the Carbondale muck type, the site index for cedar in the soil types studied fell in the 45 class.

The Newton sand area was a somewhat poorer site, the site index of one of the plots falling into the 35 class. On one of the Carbondale muck plots, a site index of 55 was obtained. No stands of Longrie loam of sufficient height to safely fit the tables were found. Site index as usually defined^{1/} did not seem to adequately differentiate cedar sites.

Cover Types

Northern white cedar was found to occur most commonly in the Cusino area in three major forest types; the black spruce type, the northern white cedar type, and the black ash-American elm-red maple type. Its occurrence in other types was limited. In closed stands, it was found that an increasing amount of cedar reproduction seemed to be roughly correlated with an increasing basal area of cedar. Total reproduction under 2 feet in height in 6 milacre plots located in stands with less than 40 square feet basal area of cedar per acre showed an average of less than one seedling per plot as compared with 6.4 seedlings per milacre in 9 plots on which the basal area of cedar ranged from 40 to 100 square feet. Vegetative reproduction averaged 1.8 stems per milacre for the lower basal areas and 9.9 stems per milacre for the higher ones.

There is a definite relationship between soil and cover types. The black spruce or tamarack types are correlated with Spalding peat. The black spruce type is also found to be prevalent

^{1/} Site index is usually defined as the height in feet of the asymptote of the height-d.b.h. curve.

on Newton sand. Ogemaw fine sandy loam areas supported an association that would probably be classified as a white spruce-balsam fir-paper birch type. The Longrie loam soil type is associated with the northern white cedar cover type and Saugatuck sand with the black ash-American elm-red maple type.

Rifle peat, Kerston muck, and Carbondale muck support a cedar-spruce-balsam fir tamarack association, all of which would be classed as the northern white cedar type. On the Carbondale muck, there is an influx of lowland hardwoods and the most highly decomposed areas of this type might be found supporting the black ash-American elm-red maple type.

Age of Stand

Methods

Observations throughout the study indicated that the age of main stems at the time of cutting when considered on a stand basis might influence the layering ability of the lower branches. It is also known that self-pruning reduces the number of lower branches that would be capable of layering at the time of cutting.

Two swamp cedar stands were chosen for the study. Their selection was primarily based on the relative amounts of vegetative reproduction over 2 feet in height. A completely clear cut area at Cusino had excellent vegetative reproduction. The Bob's Lake release cuttings (Plot 36) had little or no reproduction of a vegetative nature. The stand adjacent to the cutting at Cusino was primarily in the 0 to 6 inch d.b.h. classes. The remaining uncut stand at Bob's Lake appeared mature with overmature stems in evidence.

Five lines (1 chain x 10 links each) established in each of the two locations were searched for cedar stumps of the previous cut, i.e. approximately 10 years ago. The stumps were measured with a diameter tape, cut back to obtain a fresh cut, and smoothed down to a surface such that the annual rings could be ascertained with the aid of a hand lens. Only 3 of the stumps in the 10 plots were decayed to the point that a partial estimate of age was necessary. Tallies of vegetative reproduction of cedar and the number of stems of other species were made in each of the plots. Height class was designated as from 2 to 8 feet. The average age of the cedar stumps in each location was calculated and the mean diameter of the stems at each location was ascertained. The number of former

stems by age classes was obtained and summarized in an accumulative table.

Results

More cedar stems of smaller diameter and younger age classes were cut in the Cusino cuttings than in the Bob's Lake cuttings (table 19). The difference in the amount of cedar vegetative reproduction in favor of the Cusino cutting is very apparent (table 20). In the light of observations of the remaining plots at Bob's Lake, it is clearly evident that the type of cutting^{1/} did not differ enough from the Cusino cuttings to cause the difference in results. Reliable estimates indicate that the Cusino stand was cut at a much earlier age than the Bob's Lake cutting and smaller stems were cut although we were not able to establish the exact age of the stands at the time of cutting. Table 21 presents data showing that this condition exists -- the fact that 64 percent of the stems cut at Cusino were in the 80-year age class or under whereas only 36 percent of the cedar stems at Bob's Lake fell within this category. In actual numbers, there were 3.8 times as many stems in the 80-year class or under at Cusino as at Bob's Lake.

Further observations disclosed that the only vegetative reproduction found in the Bob's Lake cutting was located in Plot 40 -- a plot cut to a 4 inches d.b.h. minimum diameter limit but with young cedar stems from 2 feet in height to 3 inches d.b.h.

^{1/} The Cusino cutting was an absolute clear cut. The Bob's Lake cutting (Plot 36) was to a 4 inches d.b.h. minimum diameter limit.

Table 19. -- Number of cedar stumps, their mean ages and diameters

Item	:	Plots					Weighted mean
	:						
	:	1	2	3	4	5	
	:	:	:	:	:	:	

Bob's Lake Cuttings (Plot 36)

Number of stumps	11	2	6	5	1	
Mean age in years	130.1	158.5	152.3	106.2	43.0	129.4
Mean diameter in inches	7.2	10.6	5.9	4.6	2.0 ₁ /	6.4

Cusino cuttings (Browse Procurement Plot)

Number of stumps	7	6	15	11	15	
Mean age in years	111.0	48.6	77.0	107.0	74.6	83.7
Mean diameter in inches	4.6	2.1	3.8	4.3	3.3	3.7

1/ Indications showed that the stumps smaller than 4 inches d.b.h. were in or along skid roads.

Table 20. -- Reproduction from 2 to 8 feet in height

(In number of stems)

Stems	:	Plot				
	:					
	:	1	2	3	4	5
	:	Per acre				

Bob's Lake Cuttings (Plot 36)

Cedar (vegetative)	0	0	0	0	0	0
Other stems per acre ^{1/}	43	53	66	50	64	5520

Cusino Cuttings (Browse Procurement Plot)

Cedar (vegetative)	52	48	74	68	56	5960
Other stems per acre ^{1/}	35	26	20	22	38	2820

^{1/} All alder and willow stems above 2 feet in height were tallied in view of their rapid rate of growth. Other species tallied include spruce, balsam fir, tamarack, white birch, red maple, red-osier dogwood, balm of giliad, black cherry, serviceberry, and aspen.

Table 21. -- Accumulative tally of stumps by age classes

(In number of stumps)

Plot	Age									
	:20 :	40 :	60 :	80 :	100 :	120 :	140 :	160 :	180 :	Over 180
<u>Bob's Lake cuttings (Plot 36)</u>										
1	0	0	2	4	7	7	7	7	9	11
2	0	0	0	1	1	1	1	1	1	2
3	0	0	1	2	3	3	3	4	4	6
4	0	1	1	1	2	2	5	5	5	5
5	0	1	1	1	1	1	1	1	1	1
Total	0	2	5	9	14	14	17	18	20	25
<u>Cusino cutting (Browse Procurement Plot)</u>										
1	0	0	1	2	3	4	7	7	7	7
2	0	2	4	6	6	6	6	6	6	6
3	1	4	5	11	13	13	13	15	15	15
4	0	1	3	4	6	7	9	10	10	11
5	1	2	7	11	12	14	15	15	15	15
Total	2	9	20	34	40	44	50	53	53	54

in evidence.

A combination of two factors appears to manifest itself in this expression of the age of the stand upon vegetative cedar reproduction. The stands containing predominantly mature and overmature stems with a high basal area per acre^{1/} are self-pruned to a height that would preclude the possibility of extensive branch layering, the principle type of cedar vegetative reproduction. The younger stems that do have lower branches also seem to express more vigor in the branch layers that form than do older trees.

^{1/} Gevorkiantz and Duerr (25) correlated increasing age with increasing density of cedar when expressed as basal area.

ADVANCED REPRODUCTION

Survival and Mortality

Methods

Twenty four 1/100th acre plots were established in a heavy winter deer yard on a Rifle peat soil type to determine the amount of mortality in the 2 to 8 foot height class and the causal agents. This necessitated a critical examination of each stem, including the root system, to determine the cause or causes of mortality insofar as possible. In the event that the effect of two or more possible causes was noted, e.g. both deer and snowshoe hare browsing, the factor that was most apparent was chosen. If the cause of mortality was not clear-cut, the stem was classed in an "unknown" category.

Advanced reproduction was established as that reproduction that was from 2 to 8 feet in height. The height classification was made for a combination of reasons. Observations indicated that a different set of environmental factors are able to express themselves on these stems than on lower stems. The height at establishment to the 2 foot level would be the most equitable size class for both initial seedling and vegetative reproduction. The designation of 2 to 8 feet as advanced reproduction would also allow a more complete analysis of the original plot tallies insofar as they were taken in 0 to 2, 2 to 5, and 5 to 8 foot height classes.

Comparable tallies were made in an unbrowsed portion of the

swamp but mortality numbers were insufficient to make a numerical comparison between the causes of mortality.

Results

A total of 724 cedar stems were tallied in twenty-four 1/100th acre plots. Of this total, 49.3 percent (357) stems were living and 50.7 percent (367) were dead. It is not known how long a period this mortality represents. Decay of woody material is known to be very slow in swamps and it is probable that the mortality is the accumulated mortality over a considerable period of years.

Deer browsing can readily be distinguished by its ragged cuts and the "pulling off" of browse. Mortality of advanced reproduction caused by deer browsing is shown in figure 32. A comparison of reproduction that is free from browsing is shown in figure 34. Figure 35 illustrates stems that have developed to a height such that their top foliage is unavailable to deer.

Snowshoe hare browsing is characterized by sharp, smooth cuts of the limbs. Although a combination of deer browsing and snowshoe hare browsing was found to occur, little trouble was experienced in determining which cause was predominant.

Cases were observed in which rot had occurred on the branch from which the root system evolved in stems of vegetative reproduction formed by branch layering. The rot then seemed to progressively invade that portion of the branch under the surface of the swamp floor.

Mortality was laid to competition in heavy clumps of reproduction that were under a heavy overstory. These cases were



Figure 32. Cedar mortality caused by deer browsing. Note the presence of other woody species that are unbrowsed.



Figure 33. Dead and dying young cedar as a result of deer browsing. Potegannissing Deer Yard, Drummond Island, 1941.
(Photograph by S.C. Whitlock.)



Figure 34. Unbrowsed cedar reproduction. This may be compared with a heavily browsed condition (figure 32).

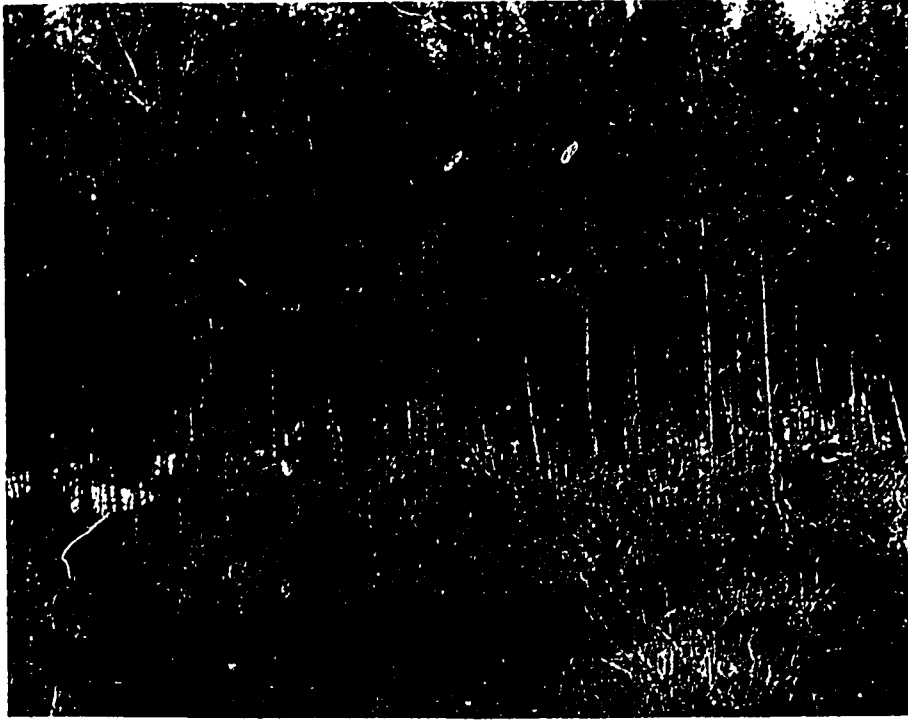


Figure 35. Browse line on cedar. Long Point Bass Lake Deer Yard, Drummond Island, 1936. (Photograph by F.E. Gillette.)

thoroughly perused for deer and snowshoe hare browsing before the stems were classified under the cause of competition.

In some stems, formed by branch layering, the adventitious roots failed to develop. Roots were found to be short and few in number. It was realized that many of the smaller roots might have decayed and would not be in evidence if mortality had occurred several years previous to the time of examination.

The leader (main stem) of some of the reproduction was found broken. The probable causes were snow and ice accumulations with possible wind action.

Windthrow of stems of the large diameter classes was found to destroy reproduction during the process of windthrowing. The windthrow was not that of the reproduction itself.

The two most frequent causes of mortality in twenty 1/100th acre plots located in a portion of the swamp with no deer activity were snowshoe hare browsing and root rot.

Deer browsing has long been known to be an important factor in mortality of cedar reproduction in the height classes between the snow level and the upper limits of availability to the deer. This particular mortality study on advanced reproduction attributed 45 percent of the mortality to deer browsing (table 22). Snowshoe hare browsing accounted for approximately 20 percent of the mortality encountered. Aldous and Aldous (1) concur in the importance of snowshoe hare browsing in relation to forest reproduction by regarding it as one of the limiting factors in plantation establishment in the Lake States.

The results of this study concerning snowshoes are in

Table 22. -- Advanced cedar reproduction mortality in a winter
deer yard on a Rifle peat soil type

Cause	Number of stems	Percentage loss
Deer browsing	164	44.7
Snowshoe hare browsing	72	19.6
Root rot	22	6.0
Competition	19	5.2
Failure of root system to develop	16	4.4
Broken leader	7	1.9
Windthrow	2	0.5
Cause unknown	65	17.7
Total	367	100.0

agreement with Trippensee^{1/} although observations indicate that snowshoe damage to northern white cedar is a definite problem. Not only have these studies indicated that rabbit browsing is an important causal agent of mortality in advanced cedar reproduction, but it has also indicated that the snowshoe markedly reduces the already limited supply of deer browse.

A practice suggested by Trippensee (53) for reducing coniferous plantation damage by the varying hare might well aid in reducing its damage to cedar, i.e., retaining the enemies of the varying hare, including timber wolves, coyotes, bobcats, lynx, and the great horned and barred owls.

Effect of Deer and Snowshoe Hare Browsing Upon Advanced Reproduction and Stand Composition

Methods

A series of exclosures were established by Civilian Conservation Corps crews during the summer of 1937 under the direction of Shaler E. Aldous at the Upper Peninsula Experimental Forest, Dukes, Michigan. Each exclosure covers an area of 600 square feet, 400 square feet of which has been made deer proof and 200 square feet of which has been made deer and snowshoe hare proof. The effect of twelve years exclosure of deer and the combined exclosure of deer and snowshoes on reproduction is thus available.

^{1/}Trippensee (53), in discussing food preference of the snowshoe hare, states that "the idea I cover type for the snowshoe is a mixture of hardwoods and conifers, hardwoods for food and conifers for protection".

The four exclosures were located in different sites. Exclosure 1 was located in Section 25, T 46 N R 23 W and had not been cut in recent years. Exclosure 4 was in an acre block that was clear cut^{1/} in 1937. Exclosure 5 was adjacent to it in an uncut stand in Section 27 T 46 N R 23 W. Species composition of the stand composing the general type in which Exclosures 4 and 5 were located was^{2/}:

<u>Species</u>	<u>Stems per acre</u>	<u>Range in d.b.h. in inches</u>
Cedar	298	2 - 21
Balsam fir	172	2 - 13
Black spruce	44	2 - 13
Red maple	36	2 - 13
Black ash	31	2 - 12
Yellow birch	17	3 - 16
Other spp.	17	2 - 6

Exclosure 7 (Section 23 T 46 N R 23 W) was located in an overmature reserve stand. Cedar stems 18 inches d.b.h. and over are common. All exclosures fall within the Hulbert land type, predominantly Carbondale muck.

The snowshoe hare population in the general area is very high. In the vicinity of Exclosure 1, snowshoes have been the chief cause of plantation failures. The deer population is not an acute problem in the area. No browse line was present. The only figures available on deer population indicate that the "deer kill per square mile" in the county is below the average for the Upper Peninsula of Michigan. In 1948, the "deer kill per square mile" in Marquette county was 1.95 as compared with an Upper

^{1/} Specifications indicated a minimum d.b.h. of 4.0 inches. However, ^{2/} 2 and 3 inch defective stems were also cut.

^{2/} This tally was made prior to clearcutting a portion of the area.

Peninsula mean of 2.53 (23).

A check (400 square feet) was established adjacent to each exclosure. Although stems in all the plots were tallied according to Michigan Conservation Department Game Division Browse Study Form No. 1 (Appendix D), and replicates were established within each exclosure, size classes and replicates were lumped for statistical treatment. It is realized that snowshoe hare and deer browsing could have little effect on the number of stems over 3 inches d.b.h. However, their numbers per acre were not significantly large enough to influence an analysis of snowshoe and deer browsing on the number of stems per acre.

Results

The general composition of stems over 2 feet in height in each exclosure area reveals that cedar is an important component of the stand (table 23). Exclosure of deer and snowshoes had no effect upon the number of stems of cedar (table 24). Although no reduction in number of stems due to browsing is indicated, damage from snowshoe browsing is very apparent. For example, in the vicinity of Exclosure 1 and within the deer exclosure portion of that plot, 20 to 25 percent of the cedar stems from 2 to 8 feet in height were severely damaged due to snowshoe browsing.

The associates of cedar showed varying effects of browsing. Black spruce was not present in large enough numbers to provide an estimate. No significant difference was noted between the various treatments as regards the number of balsam fir stems per acre. Alder and red maple showed a highly significant loss in

Table 23. -- Stand table in enclosure areas^{1/}

(In number of stems per acre)

Species	Enclosure area			
	1	4	5	7
Cedar	3594	2795	980	1016
Black spruce	73	109	109	73
Balsam fir	1089	1416	109	290
Alder	726	5046	944	182
Red Maple	2977	2251	4610	2105
Black ash	109	3412	3884	36
Other sp.	145	1597	36	254
Total	8713	16626	10672	3956

^{1/} Stems two feet in height and over.

Table 24. -- Stems per acre two feet in height and over

Treatment	Exclosure				
	1	4	5	7	Mean
<u>Cedar</u>					
Check	2178	4792	980	653	2151
Deer exclosure	4900	1198	436	1525	2015
Snowshoe hare and deer exclosure	3703	2396	1525	871	2124
<u>Alder</u>					
Check	762	2178	544	0	871
Deer exclosure	109	3158	544	109	980
Snowshoe hare and deer exclosure	1307	9801	1742	436	3322
<u>Red maple</u>					
Check	544	3158	1198	2722	1906
Deer exclosure	2287	1416	3920	2287	2478
Snowshoe hare and deer exclosure	6098	2178	8712	1307	4574

number of stems per acre due to snowshoe browsing (table 24).

There is no significant loss in numbers of stems of these species due to deer browsing. Black ash showed no significant difference in numbers of stems per acre due to browsing.

It is interesting to note that in the clear cut area (Enclosure 4), snowshoes preferred alder, red maple, black ash, and red-osier dogwood to northern white cedar and the other conifers present for food.

Effect of Deer Browsing upon Advanced Reproduction and Stand Composition

Methods

It has been the opinion of numerous foresters and game managers that extremely heavy browsing of northern white cedar by deer would change the competition within a stand to such an extent that there would be partial exclusion of northern white cedar.

A group of large enclosures were available for study at the Cusino Wildlife Experiment Station. These eight enclosures, one acre each in size, are located in various types of swamp and hardwood stands and have been subjected to different amounts of deer browsing over the past ten years. Construction is of large poles with two heights of standard snow fence. Figure 36 illustrates a general view of the enclosures.

The correlation of cedar reproduction and young stand development with deer browsing is largely dependent upon an accurate estimate of the browse conditions present. A method



Figure 36. A browse plot viewed from the outside showing the type enclosure construction used. The Andropogon furcatus in the foreground was noted only along the swamp roads. It was not used by deer to any extent inasmuch as the deer were ranging in the uplands at the time that the grass would be of value as forage.

of quantitative comparison of browse conditions based on the information acquired by use of the Michigan Department of Conservation Game Division Browse Study Form No. 1 was devised to obtain this estimate. A discussion of the browse appraisal method is included in Appendix D.

Davenport et al (18) provide a rather detailed description of the browse plots at Cusino that were used in this study. However, their description was primarily aimed at a discussion of the plots with carrying capacity in mind and a further description was felt necessary.

Browse plots 1, 5, 6, 7, and 8 were found to be satisfactory for the purpose of this study^{1/}. These plots were originally cruised as cedar-spruce-balsam fir-swamp hardwoods with heavy stocking, 0 to 6 inch d.b.h. The stand densities and dates of establishment are as follows:

<u>Plot</u>	<u>Total Stems per Acre</u>	<u>Date Established</u>
1	8680	1936-37
5	17360	1938-39
6	11680	1938-39
7	13980	1938-39
8	13720	1938-39

The cruise data obtained during the summer of 1949 was then analyzed for "percentage of available browse". Results

^{1/} Browse plots 2 and 3 were excluded from the study because they were not pure stands of conifers. Plot 2 was a cutover stand of hardwood reproduction and Plot 3 a mixed swamp type of both conifers and hardwoods. Plot 4 was discarded because cruise records indicated a low stocking in comparison with the other plots at the time of establishment (3140 stems per acre).

are:

<u>Plot</u>	<u>Percentage of available browse</u>
1	23.3
5	3.0
6	0.6
7	45.2
8	6.9

Thus a classification according to the present browse condition would include Plots 5 and 6 as completely browsed out, Plot 8 was very heavily browsed, Plot 1 as medium to heavy browsing, and Plot 7 with a high percentage of available browse. It was decided that one plot in each group should be given intensive study. Plot 5 was selected to represent the completely browsed out plot because Plot 6 had a stream running through or adjacent to several of the lines that might have provided a substantial error. Plot 6 also had an extremely heavy concentration of deer placed in it for a single yarding season (10 deer in 1938-39).

According to Davenport et al (18), at the time of plot establishment, 38 percent of the total stems within Plot 1 were northern white cedar and 41.5 percent speckled alder and high-bush cranberry. On the basis of the commercial species^{1/} plus alder, cedar accounted for 39.5 percent of the stems above 2 feet in height. Deer were browsed in this plot throughout its existence. The total known deer days^{2/} of browsing from the time of establishment to the summer of 1949 is 2366.

^{1/} Cedar, spruce (black and white), balsam fir, black ash, and red maple.

^{2/} During World War II, all plots except Plot 7, the control, were cleaned of snow fence such that differential browsing was by chance during this period. Plot 7 remained intact.

Plot 5 had the highest total number of stems per acre at the time of establishment. Cedar accounted for 17.8 percent of the stems of commercial species and alder above 2 feet in height. Alder was very heavy in the plot (58.0%) and a generous sprinkling of black ash and red maple was present. Plot 5 has been browsed since establishment with 1106 days of individual deer browsing.

Plot 7 had 25.8 percent cedar stems of the commercial species and alder. This plot has been a complete control since 1938-39 with the exception of a 132 pound adult female deer that escaped from Plot 8 into Plot 7 for a period not exceeding 32 days during the 1949 yarding season. Therefore, in this plot virtually all the reduction in available browse during the past ten years has been due to snowshoe hare browsing and natural pruning.

Plot 8 originally was composed of 30.2 percent cedar stems as calculated by the same criterion used for the other plots. A total of only 657 deer days of browsing are on record. Practically the only foods within the plot at the time of establishment were cedar and a small amount of balsam.

The "percentage of available browse" on the cedar at the time of plot establishment for Plots 1, 5, 7, and 8 is as follows:

<u>Plot</u>	<u>Percentage of available browse</u>
1	56.3
5	49.9
7	56.0
8	41.9

Results

All the plots showed a decrease in available browse during the eleven or more yarding seasons. A comparison of the tabulations of "percentage of available browse" at the time of plot establishment and in 1949 substantiates this fact. The decrease of 10.8 percent in Plot 7 is attributed to snowshoe browsing and natural pruning. Figure 37 illustrates the extent to which these factors can effect the food supply.

It should be noted that there is an increase in cedar stems in all the plots during the interval from the time of establishment to the summer of 1949 (figure 38). The increase in stems is least in the very heavily browsed area and becomes increasingly larger as the "percentage of available browse" becomes larger.

Although there was no difference in cedar stems over 2 feet in height at the time of plot establishment, an analysis of the 1949 data shows a significant difference in cedar stems between the plots. There is a correlation of .978 between the number of cedar stems per plot and the "percentage of available browse" (Appendix A).

Table 25 enumerates the cedar reproduction from 2 to 8 feet in height on an acre basis as found in the summer of 1949. It can again be seen that there is an increase in cedar reproduction as the "percentage of available browse" increases. It is especially evident in the check plot.

Table 26 also brings out an important consideration in swamp ecology. In all cases, the number of alder stems decreased over the eleven year period, in spite of heavy browsing of the cedar and less desirable species in some of the plots.



Figure 37. Browse plot 7 indicating a portion of the plot in which self-pruning and snowshoe hare browsing have reduced the browse supply. It is not meant to imply that the present browse condition shown here is the result of only these two factors, however. Deer browsing, prior to the plot establishment, might have been a partial cause, especially in the case of the older stems.

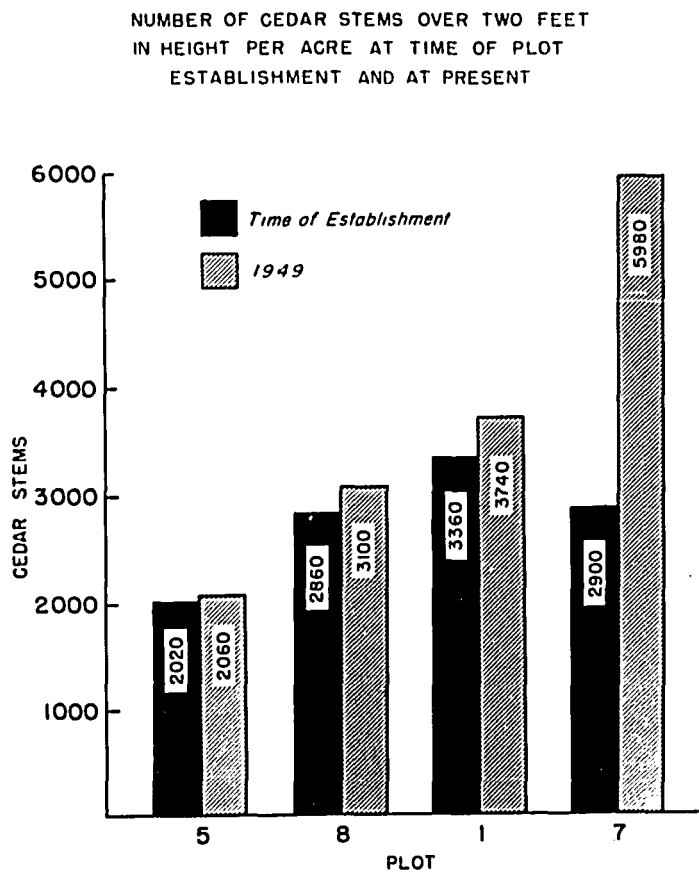


Figure 38. Plot 5 was completely browsed out in 1949, plot 8 was very heavily browsed, plot 1 has been subject to medium to heavy browsing, and plot 7 was an unbrowsed check.

Table 25. -- Cedar reproduction from 2 to 8 feet in height on an acre in 1949

(In number of stems per acre)

Plot	Browse Condition	Browse Class				Total
		No Browse	0-33%	34-66%	67-100%	
5	Very heavily browsed	0	100	560	460	1120
8	Heavily browsed	0	40	600	1720	2360
1	Medium browsed	0	180	400	1780	2360
7	No browsing	0	160	20	4800	4980

Table 26. -- Alder stems per acre 2 feet in height and over at
the time of plot establishment and summer 1949

(In number of stems per acre)

Date of tally	Plot			
	5	8	1	7
Time of establish- ment	6580	6300	3100	5400
Summer 1949	4060	5580	2580	2880

It must be remembered that the stand as a whole was comparatively young at the time of plot establishment (0 to 6 inch classes), the heavy cut probably having been 30 to 40 years previous. The number of alder stems has decreased as much as 46.7 percent in an eleven year period. Although a good share of this was probably due to the mortality of alder stems within the clumps, considerable evidence was present of conifers enroaching upon the alder clumps.

There was no correlation between the "percentage of available browse" and the increase or decrease in number of stems of the other species.

Upon completion of the study, the data from Plot 6 was checked for comparison. Essentially it followed the same trends as Plot 5 -- another heavily browsed plot -- in that there was an increase in cedar stems and a decrease in alder stems over the years.

SILVICULTURAL PRACTICES

Effect of Certain Silvicultural Practices upon the Reproduction of Cedar and its Associates

Methods

Bob's Lake Cuttings

A series of experimental swamp cuttings were initiated in the winter of 1937 by the Game Division, Michigan Department of Conservation with the cooperation of the Michigan Emergency Conservation Work program Camp Escanaba River (Civilian Conservation

Corp). L.A. Davenport was responsible for the planning phases with various foresters and game managers responsible for the field work involved. It was possible to correspond and converse with several of the technicians responsible for the project as to the conformity of field work with the specifications.

A checkerboard series of plots each five chains square were laid out with picket lines separating the individual plots. A total of forty-four plots were established in this manner. Figure 39 illustrates the plots that were established and cut prior to the time of photographing (October 4, 1939). Figure 40 illustrates the plot design and indicates the depth of the organic soil layer throughout the area studied.

The plots designated as the "Bob's Lake Release Cutting" are located in the $S\frac{1}{2}$ of the $NW\frac{1}{4}$ and the $N\frac{1}{2}$ of the $NE\frac{1}{4}$ of the $SW\frac{1}{4}$ Section 13 T44N R26W. Odd numbered plots were used as check plots with no silvicultural treatment.

There was no differentiation between species regarding the diameter limit on the portion of the cut plots for which a limit was designated. All trees on the plots below the specified limits were not cut or pruned in any manner except where necessary for roads or picket lines.

On the portion of the cut plots designating a leave stand in trees per acre, the stems left were good stems, evenly spaced, and not necessarily the large stems. Wherever possible the merchantable material was removed and the leave stems selected from the remaining stand. The leave stems were selected in the following order of priority by species; white pine, northern white cedar, hemlock, balsam fir, spruce, birch, black ash, red maple, poplar,

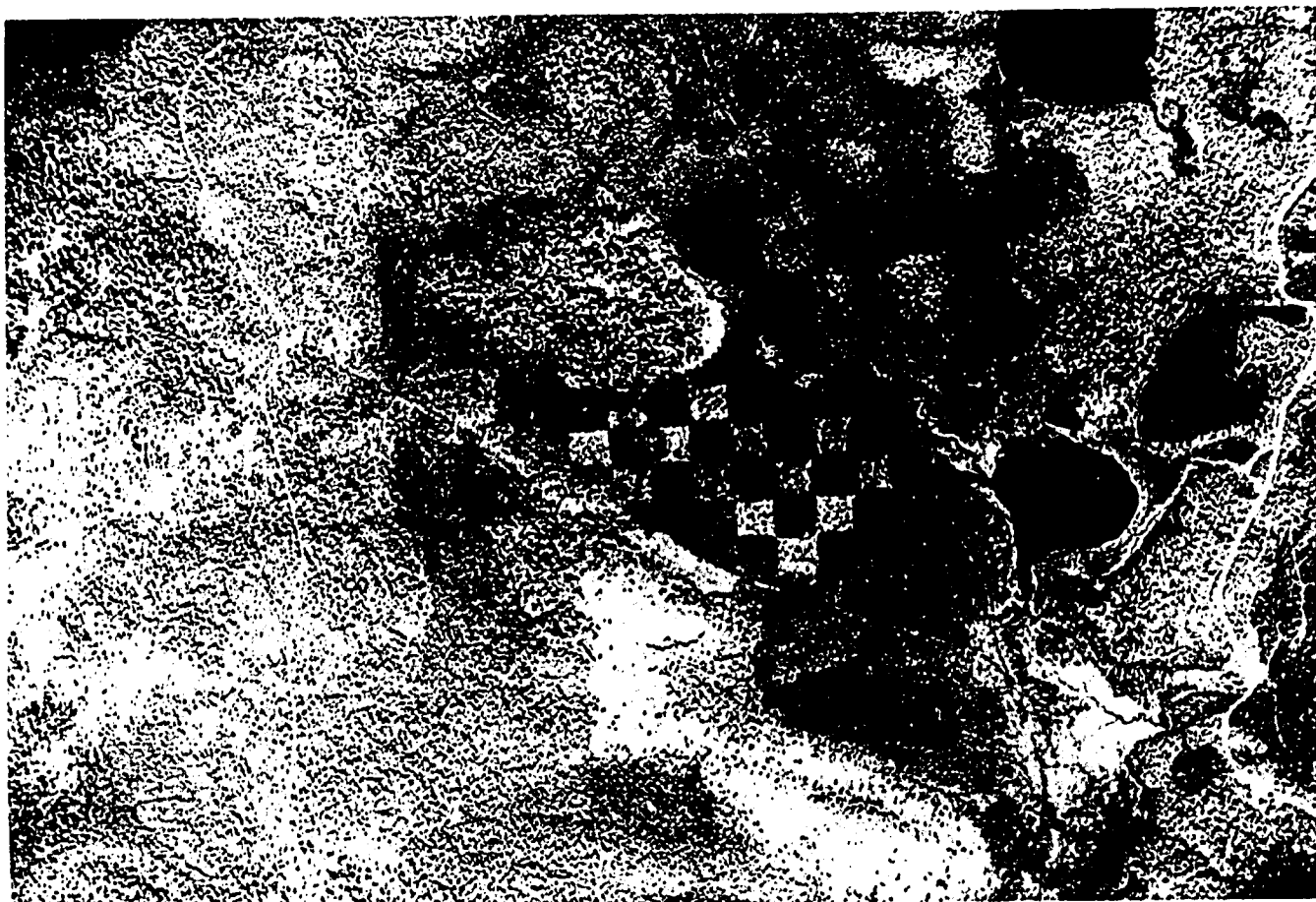


Figure 39. An aerial photograph of the checkerboard design in Section 13 T 44N R 26W. This photograph was taken before all the cuttings were made.

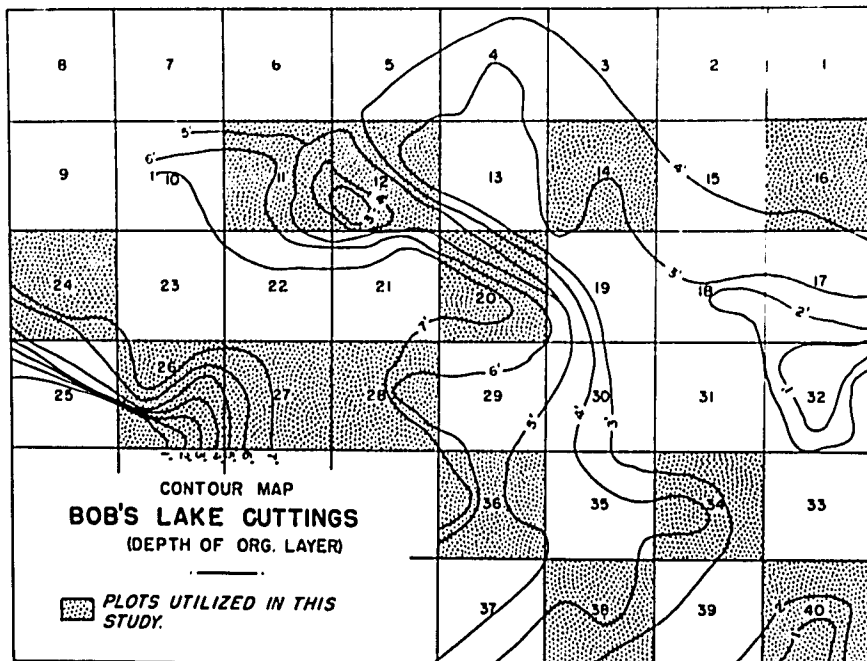


Figure 40. Contour map of the Bob's Lake cuttings showing the depth of the organic soil layers. The experimental design was a checkerboard pattern of 5-chain square plots with the various cuttings occurring in the even-numbered plots.

and balm of giliad. Stems containing available browse were given preference over stems that had no available browse, either from animal browsing or self-pruning.

For interpretation of the slash disposal specifications, the term "browse species" was defined as including northern white cedar, hemlock, and red maple.

Cruises at the time of plot establishment were made in an east-west direction through the centers of the plots, thus covering a strip five chains by ten links. Cruises were made in conformance with Browse Study Form No. 1. The availability region was considered to be from the ground up to 6.5 feet in height.

The 1949 cruise was conducted in a slightly different manner in order to conform with procedure used elsewhere in this dissertation. Five temporary lines, each 1 chain in length, were established on each plot that was selected for study. Posts were placed at either end of the line. Location of plots was according to the plan illustrated in Figure 41. Cruises were taken in 10 link widths. All stems above 2 feet in height were tallied by browse classes. A height of 8.5 feet was used as an upper limit of browse availability.

At the time of establishment, four to six plots were cut according to each of the cutting methods in use. The plots were then replicated as to slash disposal. The cutting methods used are as follows:

1. Cut all material over 2" d.b.h.
2. Cut all material over 4" d.b.h.
3. Selective cut leaving approximately 500 stems per acre.
4. Selective cut leaving approximately 750 stems per acre.
5. Uncut check plot.

ILLUSTRATION OF CRUISE LINE LAYOUT
ON BOB'S LAKE CUTTINGS

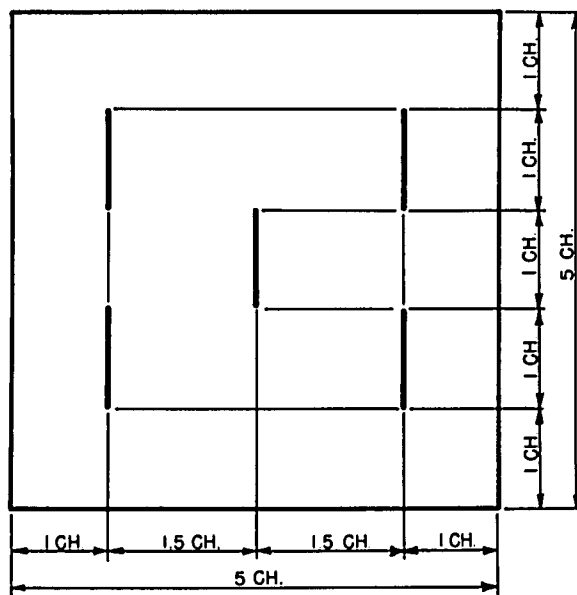


Figure 41.

Slash disposal followed two specific methods:

1. Pile and burn the slash from all non-browse species as it is cut. Scatter the slash from all browse species until the deer have had an opportunity to feed on it as much as they will, then pile and burn all the remaining slash^{1/}.
2. Pile and burn the slash from all the non-browse species as it is cut. Lop and scatter the slash from all browse species so that no part of the slash lays more than 24 inches above the ground or snow.

Plot selections were made on a basis of site and cover type. Cruises were made only on plots falling within a definite swamp cedar-balsam type. With this in mind, plots selected for consideration were those enumerated in table 27.

Incident to the cruising, soil borings were made at the south end of each line and the data obtained was incorporated into a contour map of the depth of organic soil in the experimental area. Plot 32 was found to be a Newton sand type with a very shallow organic layer and was discarded from the study.

The stand composition on an acre basis at the time of plot establishment points out the dominance of cedar (table 28).

A milacre plot was also established at the south end of each line. Cedar seedling and vegetative reproduction from 0 to 2 feet in height was tallied within these plots. Plot rejection was at 2 standard deviations from the mean or greater.

Cusino Cuttings

Twelve one-acre release cuttings (2 chains x 5 chains) were laid out during the winter of 1935-36 and were clear cut. All

^{1/} These types hereafter will be designated by the treatment of the browse species.

Table 27. -- Plots selected for comparison of cutting and slash disposal

methods

(Plot numbers)

Cutting method		
	<u>Slash disposal method</u>	
	<u>: File and burn: No slash: Lop and scatter</u>	
Cut all material over 2 inches d.b.h.	-	24, 26
Cut all material over 4 inches d.b.h.	34, 40	36, 38
Selective cut to 500 stems per acre	12, 14	20, 28
Selective cut to 750 stems per acre	--, 16	18, 32
Uncut check	11.27	

Table 28. -- Stand composition in the Bob's Lake cuttings at the
time of establishment ^{1/}

(In number of stems per acre)

Species	Size Classes		
	Stems 2 to 8 feet: in height	Stems 6 inches : d.b.h. and over:	Total stems over 2 feet in height
Cedar	189	158	1007
Spruce	2	58	109
Balsam fir	200	33	400
Alder	31	0	138
Red Maple	51	0	53
Tamarack	7	0	9
Aspen	4	0	16
Total	484	249	1732

^{1/} Obtained from 1/20th acre cruises on 9 plots.

are located in the $W\frac{1}{2}$ of Section 30 T47N R16W. The soil type throughout the area is Rifle peat; swamp types constituted the cover. The Land Economic Survey, Michigan Department of Conservation, typed the cover in 1932 as a swamp cedar-spruce-tamarack type with medium stocking, 0 to 3 to 6 inches d.b.h. No record has been found as to the amount of material taken off each plot. Figure 42 shows the location of the plots.

Browse procurement plots were cut in the same manner as the release cuttings, i.e. a complete clear cut. Five lines were established in the Browse Procurement Plots, each 1 chain by 10 links. All reproduction above 2 feet in height was cruised.

Results

Bob's Lake Cuttings

Cedar seedling reproduction under 2 feet 10 to 14 years after cutting is shown in table 29. It can be seen that seedling reproduction is increasingly heavier as the intensity of cutting decreased. In all cases, there is a greater average number of seedlings in the plots in which the browse species were lopped and scattered than in the plots in which cedar has been piled and burned after browsing was completed.

A good portion of the seedlings tallied in the Bob's Lake plots was in the 1- and 2-year-old class. Not all of the reproduction was of this size, however. Seedlings from 10 inches to 2 feet in height were frequently noted.

Cedar vegetative reproduction under 2 feet in height was

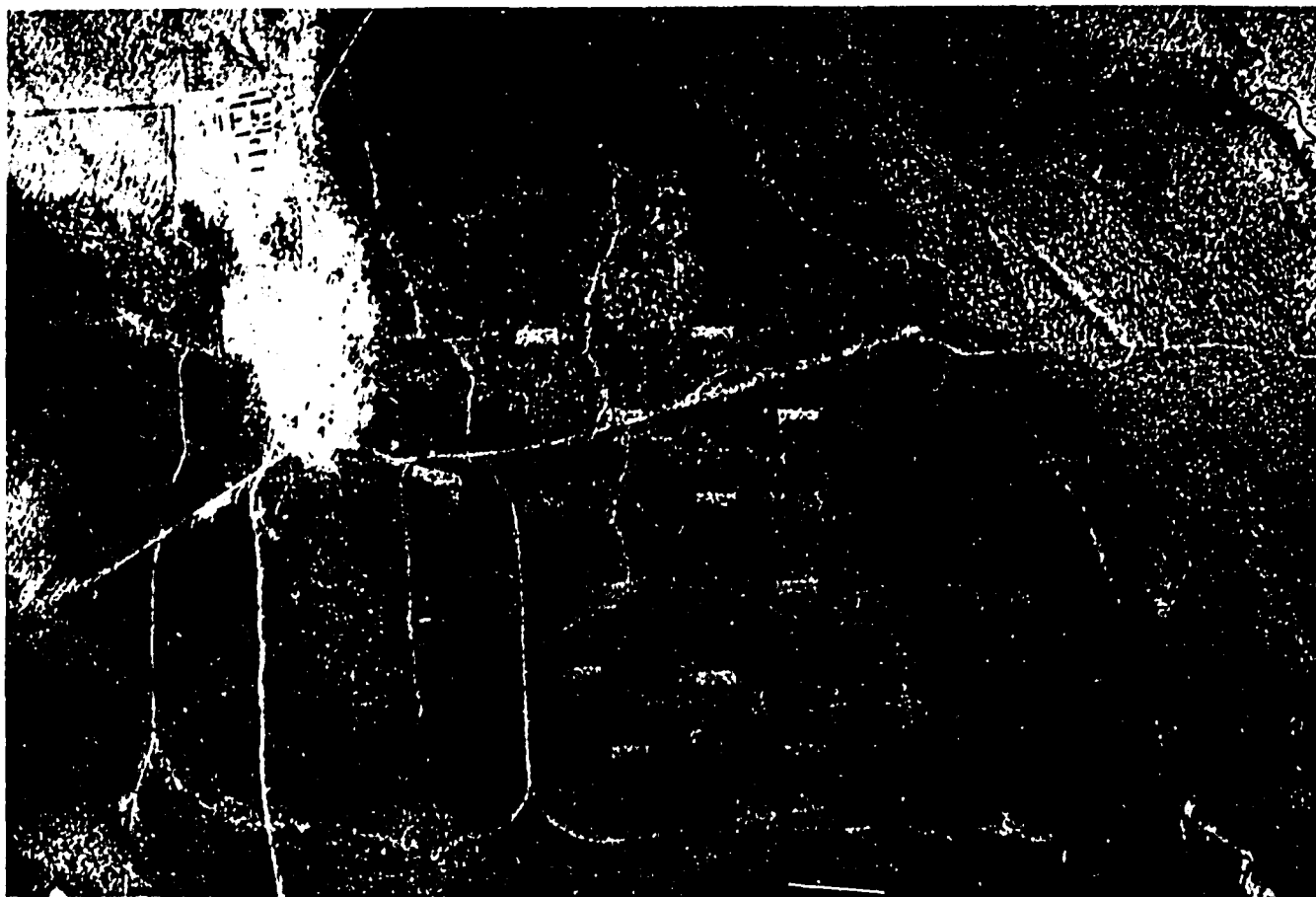


Figure 42. An aerial photograph illustrating the Cusino cuttings.

Table 29. -- Average number of cedar seedlings per milacre plot in
summer 1949

Cutting method	Slash disposal method	
	Pile and burn:	No slash: Lop and scatter
Cut all material over 2 inches d.b.h.	-	3.0
Cut all material over 4 inches d.b.h.	10.0	16.9
Selective cut to 500 stems per acre	26.9	31.6
Selective cut to 750 stems per acre	29.8	36.0
Uncut check	55.2	

negligible in all cases. Out of 71 plots critically examined, only 8 were found to have vegetative reproduction present.

The amount of cedar reproduction per acre in the 2 to 8 foot height classes at the time the plots were established is as follows:

<u>Plot</u>	<u>Number of stems</u>
11	120
12	60
24	40
26	100
27	20
28	280
36	220
38	240
Mean	135

There is inadequate cedar reproduction in the 2 to 8 foot height classes under all the cutting methods and under both slash treatments (table 30). There is too little reproduction in these size classes to correlate with any silvicultural treatment.

It appears that a heavy clear cut favors alder invasion. Lopping and scattering of slash seems to have an inhibiting effect upon alder invasion. Within the lighter cutting, i.e. lighter than a cut of all material over 2 inches d.b.h., it would appear that some factor other than degree of cutting might influence the invasion of alder. In all types of cutting, the amount of alder has increased over that of the uncut check plots (table 31).

Balsam fir reproduction is favored by the heavier cuts

Table 30. -- Cedar reproduction 2 to 8 feet in height in summer 1949

(In stems per acre)

Cutting method	Slash disposal method		
	File and burn	No slash	Log and scatter
Cut all material over 2 inches d.b.h.	-		20
Cut all material over 4 inches d.b.h.	10		10
Selective cut to 500 stems per acre	0		0
Selective cut to 750 stems per acre	0		0
Uncut check		0	

Table 31. -- Alder stems per acre 2 feet in height and over in summer 1949

Cutting method	:	
	: <u>Slash disposal method</u>	
	: <u>File and burn: No slash: Lop and scatter</u>	
Cut all material over 2 inches d.b.h.	--	7320
Cut all material over 4 inches d.b.h.	3080	1970
Selective cut to 500 stems per acre	3510	2200
Selective cut to 750 stems per acre	5620	5360
Uncut check		250

(table 32). Spruce reproduction seems to follow the same trend as balsam fir (table 33).

The order used in the classification of cuttings from heavy to light was verified by tenth-acre plots within the various cutting types. An example of the conformance to cutting specifications -- and probably the most accurate one -- is shown in Plot 28, selectively cut to 500 stems per acre. The 1949 cruise produced a tally of 530 stems per acre 3 inches d.b.h. and over.

Stems of species other than those already discussed were scattered and varied from plot to plot rather than correlating with the different treatments. On a plot with a cut of all material over 2 inches d.b.h. that was adjacent to upland aspen (Plot 24), a heavy infiltration of aspen from the residual stand was noted (540 stems per acre). Willow and red-osier dogwood also invaded several of the plots. Very little red maple and black ash were tallied.

Gusino Cuttings

Table 34 summarizes the results of this phase of study. It can be seen that cedar definitely is a heavy component of the understory. The reproduction is mainly of a vegetative origin. Counts of individual stems were not made in these plots.

Alder is not a dominant component of the stand in any of the cuttings in which it was not noted in the cover at the time of establishment.

Table 32. -- Balsam fir reproduction 2 to 8 feet in height in summer 1949

(In number of stems per acre)

Cutting method	Slash disposal method		
	File and burn	No slash	Lop and scatter
Cut all material over 2 inches d.b.h.	--		1270
Cut all material over 4 inches d.b.h.	960		960
Selective cut to 500 stems per acre	4000		1150
Selective cut to 750 stems per acre	140		460
Uncut check		290	

Table 33. -- Spruce reproduction 2 to 8 feet in height on an acre basis

in summer 1949

(In number of stems)

Cutting method	: <u>Slash disposal method</u>		
	:File and burn: No slash: Lop and scatter		
Cut all material over 2 inches d.b.h.	-		220
Cut all material over 4 inches d.b.h.	100		260
Selective cut to 500 stems per acre	240		110
Selective cut to 750 stems per acre	0		0
Uncut check		0	

KEY TO SYMBOLS IN TABLE 34.

A	Alder
B	Balsam fir
C	Northern white cedar
S	Spruce
T	Tamarack

'''	Good stocking
-----	---------------

''	Medium stocking
----	-----------------

'	Poor stocking
---	---------------

Table 34. -- Cusino cuttings summary

Release cutting plot	: Cover : 1935 :	: Cover : 1949 :	: Cover : adjacent : to plot :	: Deer : use :	: Snowshoe hare : use :
1	1/AS''	2/ <u>ABT</u> C'	SC''	Medium	Heavy
2	CSA''	<u>BTS</u> C''	CSB	Heavy	Heavy
3	ASTC	<u>ASBT</u> C''	CST	Heavy	Heavy
4	ABS	<u>BTA</u> C''	CST	Heavy	Heavy
5	-	<u>ST</u> C'''	CST	Heavy	Heavy
6	-	<u>ACB</u> C'	CS	Heavy	Heavy
7	ASCT''	<u>ABT</u> C'	SCA	Medium	Light
8	AC'	<u>CA(TS)</u> C'''	CS''	Medium	Heavy
9	ACS''	<u>ASB</u> C'	CS	Heavy	Heavy
10	C''	<u>CTB</u> C'''	CST	Light	Light
11	CAS''	<u>SBT</u> C'''	CS	Heavy	Heavy
12	-	3/	-	Heavy	-

1/ Symbol key is included on opposite page.

2/ West $\frac{1}{2}$ of Plot 12 AS; east $\frac{1}{2}$ TSB.

3/ Overstory cover is above the line; understory type below the line.

Slash piles definitely limit reproduction. There was no cedar reproduction within their boundaries. Figure 44 brings out this observation. Deer use was noted in all the areas and runways extend from plot to plot. Deer browsing has eliminated white birch and black ash reproduction in several of the areas.

The reproduction on an area that was clear cut in the same manner as the other release cuttings is as follows:

<u>Species</u>	<u>Stems per acre</u>
Cedar	5960
Spruce	520
Balsam fir	200
Alder	1540
Tamarack	160
White birch	20
Red maple	60
Black cherry	20
R. O. dogwood	200
Willow	30
Amalanchier	20
Aspen	20

It can be seen that an adequate amount of cedar reproduction is present. Alder has not invaded the area very strongly. Observations indicated that the cedar reproduction was predominantly vegetative.

Plantations

Methods

Plantations of northern white cedar were made during the fall of 1941 and the spring of 1942 in the study area. The 1941 plantings were made primarily for increasing deer food and cover. The 1942 plantings were an attempt to convert a spruce-balsam type to cedar



Figure 43. An area clear-cut in 1939-40. The stand was relatively young at the time of cutting. The cedar reproduction was vegetative in origin.



Figure 44. A slash pile in a 1935-36 cutting. Red-osier dogwood is the only woody species that has been able to reproduce within the slash pile. Photograph taken in July, 1949.

by planting recently cut-over areas.

The 1941 plantings (SE $\frac{1}{4}$ and NE $\frac{1}{4}$ of Section 19 and SE $\frac{1}{4}$ of Section 8 T47N R16W) were made with 3-2 planting stock, 9 inches in height, produced at the Hardwood State Nursery, Boyne Falls, Michigan. Forty thousand stems were planted by Civilian Conservation Corps personnel with Michigan planting bars at a 6 foot x 6 foot spacing. No soil preparation was made. The soil types planted were Saugatuck sand and Rifle peat.

The 1942 plantings were made from the same age stock using similar planting methods. However, local labor was used to make the plantings. The soil types (Sections 16 and 17 T47N R16W) were Rifle peat and Carbondale muck.

Results

The 1941 plantings proved failures. Although it is difficult to distinguish natural reproduction from planted stock in portions of the area, very little indication of planted stock was left. Natural reproduction is present in portions of the area not covered with an alder type.

The attempt to convert from a spruce-balsam type to a cedar type was also a complete failure. Adequate reproduction of balsam fir and black spruce was present. The cedar transplants that have survived show heavy deer and rabbit browsing.

The failure of cedar plantings is not confined to the Upper Peninsula of Michigan. Aldous (3) reports the failure of cedar plantations in Minnesota and concludes that it is not practical to plant white cedar as it is too severely browsed by deer. The

The only successful plantings were those protected by hare- and deer- proof exclosures. Eighty-three percent of the white cedar within the exclosures survived a growing seasons in comparison with 18 percent survival outside.

DISCUSSION

Reproduction

The diverse environmental characteristics of the northern swamps should provide an opportunity for a considerable amount of variation in the relative importance of the factors causing mortality. The varied nature of the swamp floor offers us an example of the possibilities. For illustration, black spruce, another swamp species, had 0 to 2 percent damping off on coarse sand and fine sand respectively whereas on a muck media damping off affected 80 percent of the seedlings (31). Although it is considered to be relatively resistant to damping off, cedar might also react to damping off epiphytotics in a similar manner.

The difficulties involved in differentiating between the types of reproduction have been mentioned. These were not the only difficulties involved, especially in tallying vegetative reproduction. The predominant type of vegetative reproduction, branch layering, is in effect a transformation from a branch of the parent stem to a stem of reproduction. This involved a degree of judgment that could be questioned. However, the debatable cases were few in comparison with the total number of stems tallied.

Curtis (15) gives further support to the theory that adult stems of seedling origin may possess varying degrees of sweep in his discussions of old field cedar. "Old field stands . . . established from seed . . . many individuals have sweeps of varying degrees, but that this is largely due to snow, crowding, occurrence of multiple stems, or root anchorage". Watson (56) also adds that cedar is apparently quick to form compression wood and grow rigidly into a curved stem. He also mentions phototropisms as an explanation for some of the stem curvatures. The above citations are presented in an effort to correct a widespread fallacy concerning cedar reproduction; namely, that a curved stem absolutely classifies a tree as being of vegetative origin.

The effect of light upon germination in the laboratory substantiates the observations made in the field. An absence or near absence of light reduced germination vigor. At the other extreme, i.e. full sunlight, field studies again confirmed laboratory results. Seedling germination and initial development were markedly reduced in both series. The conditions at the upper end of the table with foot candle powers above 331 were found in the 10-year-old cuttings that were removed under a system of complete clear cutting.

The effect of acidity under laboratory conditions follows somewhat the same trend as in the swamps. The decrease in germination and establishment at the lower extremes follows in both cases. The definite trend of increasing germination throughout the acidity range manifests itself above approximately pH 6.0

under field conditions. The trend in the laboratory substantiates the field results in this respect.

It was noted in the laboratory experiments that the lower pH replicates exhibited different degrees of gelation than did the upper values. A difference in hardness of the germination media (agar) could cause changes in the availability of moisture. This phenomenon might explain the laboratory results or at least indicate that pH can be of considerable complexity -- even under controlled conditions.

The experimental design in the laboratory was initiated using constant temperature as a base rather than alternating temperatures. Although it is acknowledged that an alternating temperature experiment would have more closely approximated conditions of seed germination in the swamp, it would have introduced variables that require the use of high-cost facilities. It is realized that alternations of temperature are more favorable for the germination of seed than constant temperatures and might have the effect of lowering the threshold of germination.

The marked preference of cedar seedlings in the field for a medium of logs in varying stages of decay can hardly be explained on a moisture hypothesis. It is realized that there is less fluctuation of the water supply in decayed logs. They are usually located at a slight to considerable elevation above the swamp floor and thus are relatively free from the inundations that occur during rainy periods. The moisture studies during the 1949 growing season actually showed a greater average semi-weekly variation from the mean for logs during the growing

season than did the swamp floor, however. Curtis (16) describes rotten wood as a medium in which moisture is more or less constant beneath the forest canopy.

There was a definite difference in temperature between the two types of media, the log medium showing a higher mean temperature throughout the growing season and a greater alternation of temperature. The higher mean temperature is especially noteworthy during June and July, the period of seed germination. The threshold for seed germination at a constant temperature falls between 14° and 18° C. (57.2° to 64.4° F.) with a definite decrease in germinative capacity at these temperatures. The monthly mean temperature of the swamp floor did not rise above the upper limits of this threshold until August and then only slightly.

The swamp floor is exceedingly variable in elevation if logs in various stages of decay, stumps, and pits and mounds of organic material are considered a portion of it. This variation can and does account for a remarkable degree of variation in temperature and moisture within an area as small as a milacre.

Several hypotheses may be offered regarding the limited germination of seedlings in sphagnum beds. It is felt that the sphagnum, however dense, still forms a rather open type medium in which the space occupied by air is great. There is the possibility that the apparent reduction of germination is due to this factor. It was also observed that sphagnum mats became relatively dry during periods of little rainfall. However, this is not as likely to be the cause of reduction in germination and establishment as it was found to occur later in the growing season than the time at which germination and establishment normally occur.

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Although damage by rodents and snowshoe hare is a serious problem in northern white cedar reproduction, it is not felt that poisoning is necessary as a control measure unless the effect of snowshoes upon advanced reproduction might also reach a critical stage. However, reduction of animal populations in these categories should be given due weight in cutting and slash disposal methods.

The masked shrew, according to Burt (10), is chiefly an insectivorous and carnivorous animal. The meadow vole eats grasses and sedges; the least chipmunk seeds, nuts, berries, and insects. The food of the red-backed vole is not known although Curtis (16) concludes that this species is partially responsible for seedling losses by cutting seedlings in the runways. The short-tailed weasel (Mustella cicognanii cicognanii Bonaparte) has been observed in the vicinity of the plots also but its carnivorous habits would lead to the conclusion that it would reduce the mouse population rather than the cedar seedling population.

Both frequency and abundance indicate that neither light, pH nor type of germinating media are critical factors in the establishment of vegetative reproduction throughout the range of conditions found in the swamp stands investigated. Indications show that a moist germinating medium, especially sphagnum moss, definitely aids vegetative reproduction. Insofar as few commercial species of forest trees reproduce vegetatively, no mortality studies have been found in the literature.

Management

It is concluded that seedling reproduction under 4 feet in height is unavailable to deer as winter food in the region under study. This leads to the decision that little if any browse can be produced by cedar seedling reproduction in less than 20 years under swamp conditions that cover a good portion of the deer yards in that area.

It is evident that more research should be conducted in relation to vegetative reproduction because it can produce browse in swamp stands more rapidly than that of seedling origin. Vegetative reproduction up to 5.0 feet in height probably will be weighted down by ice and snow and thus covered during the winter. Although the age class designation may indicate slow growth, this is not necessarily the case because a good number of the years represented may have been as a branch and not as a branch layer.

The increase of the number of cedar stems per acre in the Cusino browse plots that accompanies the varying degrees of browsing does not hold true in the Dukes experiments. Although this appears to be a contradiction of data, several salient points are evident. There is a difference in the ages of the stands at Dukes and at Cusino. The Cusino plots are all composed of a young stand whereas there is a gradation from very young reproduction (Exclosure 4) to an overmature stand (Exclosure 7) at Dukes. It is also evident that deer over-population has not been serious at Dukes but has been at Cusino.

The conclusions regarding the increase of cedar stems and decrease of alder, even under medium and heavy browsing conditions do not agree with the conclusions of Swift (51). He contends that in time a good deer yard, if constantly overbrowsed, will grow up to plants which deer eat only as a last resort. "Thus --- white cedar, mountain maple . . . will be replaced by tag-alder, aspen, and raspberry".

In summation, the results of the silvicultural practices studied indicate:

1. Cedar seedling reproduction is greater with lopping and scattering of slash than with piling and burning.
2. Initial seedling reproduction increases with an increasing residual stand.
3. The age of the stand will dictate the amount of vegetative reproduction to a large degree.
4. Heavier cuts favor both alder invasion and balsam reproduction.

The results of this study indicate the possibility of different approaches in silvicultural methods for various purposes of management. It is felt that conditions favoring a seedling type of reproduction should be sought for in management for commercial pole, post, and cabin log production whereas a vegetative type of reproduction would be the most favorable for game management purposes. Intermediate cuts must be considered with the same points in mind. The commercial operator's interest lies in increased stem growth. The game manager's interest centers about:

1. increased foliage growth within the height classes that are available to game animals as browse.

2. reduction of self-pruning.

3. an aid to reproduction.

If the condition expressed in table 4 holds true in the majority of swamp stands, the designation "clear out" used to describe the various types of cutting methods can not be used synonymously as expressing a method of reproduction (29). The fact that approximately 65 percent of the reproduction tallied originated from layering would change the classification to a method that is undescribed in the literature. It is proposed that two new methods of reproduction be added to forest terminology to describe the removal of the old stand and the establishment of the new crop by this type of reproduction.

The "layering method" is a method composed wholly or mainly of layers. The renewal of the forest is accomplished principally by layers. Although there is usually a mixture of seedlings and other types of vegetative reproduction. The stand is cut clear.

The "layering-with-standards method" entails the maintaining of standards above a layering forest. Reproduction is mainly from layers, but the area is never cutclear. Standards or -- in other words -- a residual stand is left standing at the end of each rotation.

It is felt that the designation of the reproduction method as a "layering method" or "layering-with-standards method" is more than merely changing the name of the method in use. A layering type of reproduction involves a new philosophy of coniferous management in the Lake States and emphasizes concepts that are quite different from the clear cutting, seed-tree, shelterwood, and selection methods.

Montgomery (42) has made strides in the direction of new management practices by suggesting that topping of cedar 4 to 10 feet in height approximately at breast height will result in a greater total number of branches, greater total length of branches, and more branch layering than an untopped check.

It was difficult to obtain an estimate of the number of seedlings per acre that constitute an adequate stocking. Hawley (29) advises the establishment of at least 2,000 to 5,000 well-distributed young plants per acre as adequate in direct seeding. Assuming these figures to constitute adequate stocking of cedar seedlings in a mixed coniferous swamp, indications are that a cut of all material over 2 inches or 4 inches d.b.h. would be unsatisfactory as a reproduction method whereas a selective cut with a residual stand of 500 or 750 stems per acre would be more satisfactory.

Evidence also points to the possibility of heavier cuts in young stands with the reproduction of cedar by vegetative means. In mature and overmature stands, a light selective cut with a thinning from below might be advisable if the management is for browse production and the young stems are devoid of browse. Windthrow, both of cedar and its associates, was encountered in heavy cuttings and adjacent to them. It must be considered in determining a cutting method.

SUMMARY AND CONCLUSIONS

Northern white cedar is assuming more importance in the Lake States each year. Although it occurs on both mineral and organic soil types in the eastern half of the Upper Peninsula of Michigan, this study is mainly concerned with swamp stands.

Laboratory studies were conducted on various factors affecting germination. Indications are that laboratory germination of seed collected in swamp stands is low under good germinating conditions. Temperatures 18° C. and below had an adverse effect upon seed germination and seedling vigor. A trend of increase in germination with a decrease in hydrogen-ion concentration above pH 6.0 was apparent, but became less pronounced as the germination period increased. No significant difference was found in the amount of germination on four natural types of media: swamp floor, logs in varying stages of decay, hardwood litter, and mineral soil as a check. Full sunlight inhibited germination and partial light was more satisfactory than darkness.

Field observations and experiments confirmed the laboratory results except as noted. Field studies indicate that sufficient seed is present in swamp stands for reproduction although viability is low. The preponderance of seedling emergence occurred between the 5th of June and the 5th of July; earlier germination occurred on partially decayed logs and stumps than on the swamp floor. Results point out that light intensity was not a critical factor in seedling germination and initial development throughout the normal range of light conditions found in our swamp stands and cuttings although there is a decrease in both

abundance and frequency at the upper and lower extremes. The abundance and frequency of seedling reproduction increases with a decrease in hydrogen-ion concentration above approximately pH 6.0. However, adequate germination occurred throughout the normal range of pH values found in cedar stands. Maximum seeding distance observed was 158.0 feet with 40 to 50 feet appearing to provide adequate insurance of a seed supply.

Under field conditions, logs in various stages of decay are the preferred types of germinating media for seedlings and were found to occupy about 16 percent of the swamp ground area. The seedlings germinating upon them developed better root systems than those germinating upon the swamp floor. A higher temperature throughout the growing season in this type of medium as compared with the swamp floor is thought to be the responsible factor. Hardwood litter and sphagnum beds were not satisfactory germinating media, the hardwood litter -- predominantly alder leaves -- being too dry. A noticeable absence of seedlings was found in deer runways.

Approximately 8.5 percent of the seedling population was found to be killed and 11.5 percent damaged by rodent and snowshoe hare browsing in a single year. Desiccation, late spring frosts, root rot, covering by litter and duff, inadequate root system development, and competition from herbaceous cover and sphagnum moss are other factors that cause mortality of young cedar seedlings. Natural drainageways had an inhibiting effect upon seedling reproduction from the stream's edge to a distance of 75 feet. No experimental evidence is offered in explanation of this phenomenon.

Growth studies indicate that approximately ten years are required for a seedling to reach 2 feet in height and twenty years to reach 4 feet in height on a Rifle peat site. Reproduction is roughly correlated with the basal area of cedar and the highest numbers of seedlings are found in areas with the greatest basal area of cedar and on the favored organic soil types, Rifle peat and Carbondale muck.

Temperature and moisture observations were carried out as a phase of the study. The temperatures within logs in various stages of decay is significantly higher and showed a greater variation than the temperature of the swamp floor. The average air temperatures within the swamp are considerably lower than those of a check station located on an adjacent upland ridge. Moisture percentages, obtained throughout the growing season from decaying logs and the swamp floor, indicated higher moisture contents than hardwood litter. The water level of the portion of the swamp that is affected by drainage from the adjacent upland slopes shows greater fluctuations than the portions that are located deeper in the swamp.

Although studies on the factors affecting vegetative reproduction were carried on in parallel with studies on initial seedling reproduction, the numbers of stems of vegetative origin were less and therefore not of a magnitude to allow statistical interpretation in many cases. Both frequency and abundance of initial vegetative reproduction indicate that neither light, pH, nor type of germinating medium are critical factors in its establishment. The presence of sphagnum moss definitely aids vegetative reproduction. The age of the stand is felt to be an

important factor in determining the amount of vegetative reproduction that will result. Rodent and snowshoe hare browsing, deer browsing, root rot, and failure of adventitious roots to develop were noted as causes of mortality in this type of regeneration. Growth, in relation to age, is difficult to determine in view of its dependence upon the root system of the parent plant in many of the forms of vegetative propagation. However, it was found to be more rapid in producing available deer browse than the seedling method. Layering, principally that of branches, and the formation of vertical stems from windthrown trees were the most common means of vegetative propagation although other types were found. In a representative stand on Rifle peat, 20 percent of the reproduction from 2 to 8 feet in height was of seedling origin and the remaining 80 percent of vegetative origin.

Forty-five percent of advanced reproduction mortality that was tallied was due to deer browsing and 20 percent caused by snowshoe hare browsing. Of the remaining 35 percent mortality, the cause of 17 percent was undetermined. Other causes that were noted include root rot, competition, failure of the root system to develop, broken leaders, and windthrow.

Although snowshoe hare browsing and a combination of snowshoe and deer browsing did not reduce the number of cedar stems per acre in a twelve year period, the snowshoe browsing severely injured as much as 25 percent of the cedar reproduction from 2 to 8 feet in height in the area studied. Among the associates of cedar, snowshoe browsing markedly reduced the number of stems per acre of alder and red maple

but had no significant effect on black ash or balsam fir.

In a period of eleven yarding seasons, the number of cedar stems over 2 feet in height showed an increase and alder in the same height classes a decrease under known amounts of deer browsing. This trend did not express itself as rapidly under heavy and medium deer browsing as it did with little or no browsing, however.

Studies on the effect of silvicultural practices upon cedar reproduction indicate that seedling reproduction is greater with logging and scattering of the slash of browse species than with piling and burning. Less alder invasion was also found with logging and scattering than with piling and burning. No reproduction was found in slash piles. Initial seedling reproduction increased with an increasing residual stand. A selective cut leaving a residual stand of 500 stems per acre or 750 stems per acre was satisfactory. The age of the stand at the time of cutting determines the amount of vegetative reproduction, the younger stands favoring it. Heavy cuts approaching and including a clear cut favor both alder invasion and balsam fir reproduction.

Management of cedar on a commercial basis should rely on a system that favors seedling reproduction in view of the importance of form. Management for mass foliage production should favor vegetative reproduction as it reaches an available height for browsing sooner. Reproduction methods are suggested insofar as the data and observations obtained in this study would allow.

It is proposed that the terms "layering method" and "layering-with-standards method" be used in forest terminology to

designate the types of reproduction methods that describe cedar reproduction.

Attempts to increase deer food and cover and to change cut-over spruce-balsam type to cedar type by cedar plantations have been unsuccessful.

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APPENDICES

Table 35. -- Abundance and frequency of seedling reproduction under 2 feet
in height in various light conditions

Foot-candle power	Abundance	Frequency	Number of mil- acre plots in class
	<u>Number of stems</u>	<u>Percent</u>	
5-7	3.2	38.	8
7-10	10.0	86.	14
10-14	6.5	90.	19
14-20	17.0	82.	28
20-28	6.6	77.	31
28-40	2.9	67.	15
40-58	9.0	76.	25
58-81	6.8	53.	19
81-114	9.6	76.	17
114-162	21.0	69.	13
162-232	23.8	75.	8
232-331	5.5	50.	4
331 plus	1.2	33.	9

Analysis of variance. Germination of cedar seed in the laboratory under different light conditions. Original data presented in table 6.

Source	D. F.	S. S.	Variance	F	5%	1%
Treatment	1	60	60	1.50	4.21	7.68
Time	4	1377	344	8.60**	2.73	4.11
Treatment x Time	4	1806	452	11.30**	2.73	4.11
Replicates	3	83	28	1.43	8.62	26.50
Error	27	1076	40			
Total	39	4402				

Analysis of variance. Germination of cedar seed under various pH conditions. Original data presented in table 7.

Source	D. F.	S. S.	Variance	F	5%	1%
pH	5	3229	645.8	35.5**	2.30	3.20
Time	3	16254	5418.0	297.6**	2.70	3.98
Replicates	4	12	3.0	6.1*	5.66	13.57
Time x pH	15	5045	336.3	18.5**	1.78	2.25
Error	92	1671	18.2			
Total	119	26211				

$$\begin{aligned}
 \text{L. S. D.} &= \sqrt{\text{Error variance} \times N \times 2} \times t_{0.5} \\
 &= \sqrt{18.2 \times 6 \times 2} \times 1.985 \\
 &= \sqrt{218.4} \times 1.985 \\
 &= 29.4
 \end{aligned}$$

Treatment	Total	Comparisons
pH 3.0	92	Less than 4.0, 5.0, 6.0, 7.0, 8.0
4.0	347	Less than 7.0, 8.0
5.0	362	Less than 8.0
6.0	293	Less than 8.0
7.0	378	
8.0	400	

Analysis of variances. Germination of cedar seed in the laboratory on various types of germinating media. Original data presented in table 8.

Source	D. F.	S. S.	Variance	F	5%	1%
Treatment	3	754	251	1.37	3.86	6.99
Replicates	3	238	79	2.32	8.81	27.34
Error	9	1646	183			
Total	15	2638				

Correlation between the number of cedar stems per acre at present (1949) and the percentage of browse available in Cusino Browse Plots.

Plot	(X) Cedar Stems	(Y) Browse Percentage	(X) ²	(Y) ²	XY
5	103	3.0	10,609	9.00	309.0
8	155	6.9	24,025	47.61	1,069.5
1	187	23.3	34,969	542.89	4,357.1
7	299	45.2	89,401	2,043.04	13,514.8

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$$r = \frac{46.68}{20,620 \times 1,105} = .978$$

Appendix B: Common Names of Trees and Shrubs and their
Scientific Equivalents.

Alder	<u>Alnus incana</u> Willd.
Amalanchier	<u>Amelanchier canadensis</u> (L.) Med.
Ash, Black	<u>Fraxinus nigra</u> Marsh.
Aspen (Poplar)	<u>Populus tremuloides</u> Michx.
Balm-of-Giliad	<u>Populus balsamifera</u> L.
Birch, White (Paper Birch)	<u>Betula papyrifera</u> Marsh.
Birch, Yellow	<u>Betula lutea</u> Michx.
Cedar, Northern White (Arborvitae)	<u>Thuja occidentalis</u> L.
Cedar, Southern White	<u>Chamaecyparis thyoides</u> L.
Cherry, Black	<u>Prunus serotina</u> Ehrh.
Cranberry, High-bush	<u>Viburnum opulus americanum</u> (Mill.) Ait.
Dogwood, Red-osier	<u>Cornus stolonifera</u> Michx.
Elm, American	<u>Ulmus americana</u> L.
Fir, Alpine	<u>Abies lasiocarpa</u> (Hook.) Nutt.
Fir, Balsam	<u>Abies balsamea</u> (L.) Mill.
Fir, Douglas	<u>Pseudotsuga taxifolia</u> (La Marck) Brit.
Hemlock	<u>Tsuga canadensis</u> (L.) Carr
Maple, Red	<u>Acer rubrum</u> L.
Pine, Eastern White	<u>Pinus strobus</u> L.
Spruce, Black	<u>Picea mariana</u> (Mill.) Brit.
Spruce, Engelmann	<u>Picea engelmannii</u> Engelm.
Spruce, Red	<u>Picea rubra</u> Link.
Spruce, White	<u>Picea glauca</u> (Moench) Voss.
Tamarack	<u>Larix laricina</u> (DuRoi) Koch.
Willow	<u>Salix</u> spp.

Appendix C: Common Names of Birds and Mammals and
their Scientific Equivalents.

Birds

Barred Owl
Great Horned Owl

Strix varia varia Barton
Bubo virginianus virginianus (Gmel.)

Mammals

Bobcat
Chipmunk, Least
Coyote
Deer, White-tailed
Hare, varying (snowshoe)
Lynx
Shrew, Masked
Squirrel, Red
Vole, Meadow
Vole, Red-backed
Weasel, Short tailed
Wolf, Timber

Lynx rufus rufus Schreber
Eutamias minimus jacksoni Howell
Canis latrans latrans Say
Odocoileus virginianus borealis Miller.
Lepus americanus phaeonotus Allen
Lynx canadensis canadensis Kerr.
Sorex cinereus cinereus Kerr
Tamiasciurus hudsonicus loquax Bangs.
Microtus pennsylvanicus pennsylvanicus Ord.
Clethrionomys gapperi gapperi Vigors
Mustela cicognanii cicognanii Bonaparte
Canis lupus lycaon Schreber

Appendix D. Method of Deer Browse Analysis

Introduction

The method described herein is a rather radical modification of the Aldous method of deer yard analysis 1/ that was used in determining browse conditions described in this dissertation. The fundamental concepts involved have been in use for sometime by the Game Division, Michigan Department of Conservation.

Field Procedure

Field procedure is based upon the Game Division Browse Study Form No. 1, a copy of which is included with the description. Collection of data was made in permanent plots one chain in length and 10 links (6.6') in width.

Stem counts were made of the dominant browse species -- northern white cedar -- in the yard under study.

All stems of the dominant browse species over two feet in height were tallied according to the breakdown of the field sheet. Previous experience indicated that the inclusion of the 0 to 2 foot class would introduce a marked error in that the stems within this height class are unavailable as winter food for the whitetail due to snow conditions.

Office Procedure

Summarize the field data. Obtain the total number of stems in each browse category. Calculate the percentage of stems in

1/ Aldous, S. E. 1944. A Deer Browse Survey Method. Journal of Mammalogy 25:130-136

each browse class.

<u>Browse Class</u>	<u>No. of Stems</u>	<u>Percentage in Class</u>
No browse	50	51.0 (50/98)
0 - 33%	28	28.6 (28/98)
34 - 66%	6	6.1 (6/98)
67 - 100%	<u>14</u>	<u>14.3</u> (14/98)
TOTAL	98	

With the percentage in each class, we are prepared to obtain a browse index. In doing so, we must establish a single value of available browse for each of the tally classes. The mean of each class was chosen as most representative of the class. The values for the various classes would then be:

<u>Class</u>	<u>Browse Factor</u>
No browse	0.0
0 - 33%	16.0
34 - 66%	50.0
67 - 100%	84.0

By multiplying the percentage in each class by the browse factor we arrive at a "browse index". Using the same examples as previously, we would obtain the following results.

<u>Class</u>	<u>Percentage In Class</u>		<u>Browse Factor</u>		<u>Browse Index</u>
No browse	51.0	x	0.0	=	0.0
0 - 33%	28.6	x	16.0	=	4.6
34 - 66%	6.1	x	50.0	=	3.0
67 - 100%	14.3	x	84.0	=	<u>12.0</u>
					19.6

The "browse index" 19.6 may be used as a final value for

comparison between yards or between successive years in the same yard. However, it was found more satisfactory to use the "percentage of available browse" as a comparative value rather than the "browse index".

It should be remembered that the "browse index" is based on a maximum value of 84, the mean percentage of browse in the upper browse class on Form 1 (67-100%). By dividing the "browse index" by this value (84.0), we arrive at the "percentage of available browse" for the indicator species. Thus we would arrive at a figure of 23.3 ($19.6/84.0$) as the "percentage of available browse" for the example cited.

Discussion

The analysis of field information in accordance with the method described made possible the highest degree of utilization of field tallies taken at the time of plot establishment. A numerical estimate of browse conditions was obtained by this method. A third advantage that this method presented was that the factors of natural pruning and loss of browse due to snowshoe hare browsing were integrated into the values obtained.

It is acknowledged that there are several serious disadvantages inherent in the method employed. No allowance is made for the varying percentage composition of the indicator or dominant browse species nor is allowance made for possible differences in browse productivity on various sites. It was felt that uniformity of the site and forest type would confound this source of error to a large degree. A further disadvantage

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of this method lies in the fact that -- at present -- satisfactory factors are not available that would allow conversion of the final value -- percentage of available browse -- into pounds per acre of available browse, a figure directly related to the ultimately desired integration, carrying capacity. However, the latter disadvantage seems to be inherent in all the browse cruising methods in use today.

MICHIGAN DEPARTMENT OF CONSERVATION
Game Division

BROWSE STUDY FORM

Name of Yard _____ Study Plot No. _____ Average Maximum Snow Depth _____
Location: T _____ N _____ R _____ Sec. _____ Sub _____ Height of Browse Line _____
Project No. _____ Investigator _____ Date _____

SPECIES	1. 0-2 ft.	2. 2-5 ft.	3. 5-8 ft.	4. 8'-3" DBH	5. 3-6" DBH	6. 6-9" DBH	7. 9" DBH
No Browse							
0 - 33 %							
34 - 66 %							
67 - 100 %							
No Browse							
0 - 33 %							
34 - 66 %							
67 - 100 %							
No Browse							
0 - 33 %							
34 - 66 %							
67 - 100 %							
No Browse							
0 - 33 %							
34 - 66 %							
67 - 100 %							

Appendix E: Associates of Cedar from Collections and Observations.

Scientific Name	Common Name
<u>Abies balsamea</u> (L.) Mill.	Balsam fir
<u>Acer rubrum</u> L.	Fed maple
<u>Acer pennsylvanicum</u> L.	Striped maple
<u>Acer saccharum</u> Marsh.	Sugar maple
<u>Alnus incana</u> (L.) Moench.	Speckled alder
<u>Amelanchier canadensis</u> (L.) Medic.	Service berry
<u>Andropogon furcatus</u> M.	Beard grass
<u>Aralia nudicaulis</u> L.	Wild sarsaparilla
<u>Betula alba</u> L.	White birch
<u>Betula lutea</u> Michx. f.	Yellow birch
<u>Botrychium virginianum</u> (L.) Sw.	Rattlesnake fern
<u>Carex flava rectirostra</u> Gaudin.	-
<u>Carex folliculata</u> L.	-
<u>Carex stricta</u> Lam.	-
<u>Carex trisperma</u> Dewey	-
<u>Chamaedaphne calyculata</u> (L.) Moench	Leather leaf
<u>Chelone glabra</u> L.	Balmomy
<u>Cornus alternifolia</u> L. f.	Alternate-leaved dogwood
<u>Cornus canadensis</u> L.	Bunch berry
<u>Cornus stolonifera</u> Michx.	Red-osier dogwood
<u>Corylus rostrata</u> Ait.	Beaked hazelnut
<u>Cypripedium acaule</u> Ait.	Stemless lady's slipper
<u>Cypripedium pubescens</u> (Willd.) Knight.	Larger yellow lady's slipper
<u>Equisetum</u> spp.	Horsetail
<u>Eumatorium perfoliatum</u> L.	Boneset
<u>Eumatorium purpureum maculatum</u> (L.) Darl.	Joe-Pye weed
<u>Fragaria vesca americana</u> Porter	-
<u>Fraxinus nigra</u> Marsh	Black ash
<u>Galium asprellum</u> Michx.	Rough bedstraw
<u>Gaultheria procumbens</u> L.	Teaberry
<u>Gentiana procera</u> Holm.	Gentian
<u>Habenaria dilatata</u> (Pursh) Gray.	Fringed orchis
<u>Heraclium lanatum</u> Michx.	Cow parsnip
<u>Imatiens biflora</u> Walt.	Spotted touch-me-not
<u>Iris versicolor</u> L.	Larger blue flag
<u>Larix laricina</u> (DuRoi) Koch.	Tamarack
<u>Ledum groenlandicum</u> Oeder.	Labrador tea
<u>Lilium philadelphicum andinum</u> (Nutt.) Ker.	Wood lily
<u>Linnaea borealis americana</u> (Forbes) Rehder.	Twin flower
<u>Lobelia Kalmii</u> L.	-
<u>Lonicera canadensis</u> Marsh.	American fly honeysuckle
<u>Lonicera hirsuta</u> Eat.	Hairy honeysuckle
<u>Lycopus americanus</u> Muhl.	-
<u>Maianthemum canadense</u> Desf.	-
<u>Microstylis monophyllos</u> (L.) Lindl.	Adder's mouth
<u>Monotropa uniflora</u> L.	Indian pipe
<u>Parnassia caroliniana</u> Michx.	Grass of Parnassus
<u>Picea canadensis</u> (Mill.) BSP.	White spruce
<u>Picea mariana</u> (Mill.) BSP.	Black spruce
<u>Pinus Strobus</u> L.	White pine

<u>Polygonatum commutatum</u> (R. & S.) Dietr.	Great Solomon's seal
<u>Populus balsamifera</u> L.	Balsam poplar
<u>Populus tremuloides</u> Michx.	American aspen
<u>Potentilla fruticosa</u> L.	Shrubby cinquefoil
<u>Prunella vulgaris</u> L.	Heal-all
<u>Prunus serotina</u> Ehrh.	Wild black cherry
<u>Ranunculus acris</u> L.	Tall buttercup
<u>Rhamnus alnifolia</u> L'Her.	Buckthorn
<u>Ribes</u> spp.	-
<u>Rosa</u> spp.	-
<u>Rubus triflorus</u> Richards.	Dwarf raspberry
<u>Salix</u> spp.	-
<u>Sarracenia purpurea</u> L.	Pitcher-plant
<u>Scirpus atrovirens</u> Muhl.	Bulrush
<u>Scutellaria galericulata</u> L.	Skullcap
<u>Senecio aureus</u> L.	Golden ragwort
<u>Sisyrinchium angustifolium</u> Mill.	Blue-eyed grass
<u>Smilacina racemosa</u> (L.) Desf.	False spikenard
<u>Solidago serotina</u> Ait.	Golden rod
<u>Solidago uliginosa</u> Nutt.	Golden rod
<u>Sphagnum</u> spp.	-
<u>Stellaria longifolia</u> Muhl.	Chickweed
<u>Thalictrum polygamum</u> Muhl.	Tall meadow rue
<u>Tsuga canadensis</u> (L.) Carr.	Hemlock
<u>Typha latifolia</u> L.	Common cat-tail
<u>Vaccinium</u> spp.	-
<u>Valeriana uliginosa</u> (T. & G.) Rydb.	Swamp valerian
<u>Viburnum cassinoides</u> L.	Wild raisin
<u>Viola</u> spp.	-