EFFECTS OF FOREST AGE AND GROWTH ON THE AVAILABILITY OF FORAGE FOR DEER IN WHITE CEDAR SWAMPS

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EFFECTS OF FOREST AGE AND GROWTH ON THE AVAILABILITY OF FORAGE FOR DEER IN WHITE CEDAR SWAMPS

By

Lawrence Atwell Ryel

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INTRODUCTION

During the winter in northern Michigan, white-tailed deer (*Odocoileus virginianus borealis* Miller) subsist largely on woody browse. These animals concentrate in dense stands of trees and shrubs usually in lowlands, when deep snow restricts their movements. Suitable deeryard winter concentration areas usually are small as compared with the size of the summer range. In the northern Lower Peninsula of Michigan these deeryards must supply woody browse and protection during the winter for a deer population which, in the warmer months, occupies an area 12 to 13 times larger (Bartlett, 1950).

A large proportion of Michigan deeryards are located in coniferous swamps, and northern white cedar (*Thuja occidentalis* L.) is perhaps the most important food and cover species found in these swamps. The importance of white cedar as a winter deer food in Michigan is emphasized by Bartlett (1948), who says that ". . . white cedar . . . (is) the most desired, most nutritous, and most abundant winter deer food present in deeryards . . .". Feeding experiments in the Upper Peninsula of Michigan (Davenport, 1937) indicated that white cedar was the only native browse species tested that, by itself, would support deer in winter. Howard (1937) found white cedar to be the principal winter deer food in Wilderness State Park, Emmet County, Michigan. Duvendeck (1952) listed white cedar as the second most preferred winter food in the northern Lower Peninsula of Michigan.

Data from other states too indicate that its importance to deer is widespread in the Lake States. Frank (1940) lists white cedar as second in importance for providing winter food in the Adirondack region of New York. Swift (1946) in Wisconsin calls white cedar one of the principal winter deer foods and puts it fourth (first among tree species) in order of palatability of winter browse species there. Aldous and Smith (1948) indicate that white cedar is much sought after by deer in northeastern Minnesota.

Unfortunately, in many parts of the Lake States the supply of white cedar browse during the last twenty to thirty years has become far short of the amount needed to carry expanding deer herds through the winter (Swift, 1946; Aldous and Smith, 1948; and Bartlett, 1950). In the northern Lower Peninsula of Michigan, for instance, Bartlett (1950) estimated that in 1949 only one-third of the yarding areas had good food conditions, and that during severe winters as many as 50,000 animals died of starvation.

The causes of deer food shortages in Michigan and Wisconsin are considered by Bartlett (1943, 1950) and Swift (1946), respectively, to be over utilization of browse by high deer populations and maturing of the trees. Where deer over utilize a white cedar yard, a definite browse line (Figure 1) usually is obvious along the perimeter. But does the lack of a browse line mean that food necessarily is plentiful in the swamp?

Some quantitative work apparently has been done on the effects of the maturing of white cedar on the browse supply but it largely has been incidental to other goals. The Lake States Forest Experiment Station (1940) during a study to learn the quantities of browse that would be available from cedar cutting operations, computed the average amounts

Figure 1. Heavily browsed edge at St. Helen Swamp

of browse available to deer (that is below a height of seven feet) per tree. This was done for different trunk diameter classes. They found that the amount of browse on a tree increased up to a trunk diameter of about three inches but thereafter declined rapidly due to dying (self-pruning) of the lower branches. (All tree diameter references are averages at 4 1/2 feet above the average ground level of the tree.) Nelson (1951) during a cedar reproduction study in the eastern Upper Peninsula of Michigan determined that in a fenced and unbrowsed area the percentage of available browse had declined 10.8 percent in 11 years as a result of snowshoe hare browsing and natural pruning despite the absence of deer. Aldous (1952) in northern Minnesota and northern Michigan found that due to self-pruning a series of unbrowsed trees seven feet to 15 feet in height had 51.1 percent less foliage below seven feet at the end of a six year period than they did at the start. Duvendeck (1952), working in the northern Lower Peninsula of Michigan in an area not damaged by deer, found that 32.3 percent of the white cedar trees had been self-pruned to a point where less than one-third of the estimated original available browse remained per tree.

The present work is an attempt to supplement these findings with more detailed data on the importance of self-pruning in white cedar in the deer yards of the Lower Peninsula of Michigan.

LOCATIONS AND DESCRIPTIONS OF SWAMPS STUDIED

Studies were conducted in seven cedar swamps in the northern Lower Peninsula of Michigan. Three were in Roscommon County, three in Kalkaska County, and one in Grand Traverse County (see Figure 2). The Houghton Lake Wildlife Experiment Station, The Heights, Michigan, served as the work station.

These swamps were located near the center of administrative Region II of the Michigan Department of Conservation (Lower Peninsula north of Highway M-20). This region contains about 12,000,000 acres of which 37 percent is in agriculture. The remaining 63 percent consists of pine lands 8.1 percent, upland hardwoods 60.3 percent, lowland hardwoods 2.5 percent, spruce-fir 3.7 percent, coniferous swamp (including white cedar) 3.8 percent, bogs and marshes 0.4 percent, and deforested land 21.2 percent (Bartlett, 1950). About 180,000 acres of Region II are in stands of white cedar (Nelson, 1951), mostly swamps.

The swamps studied were on soils with the organic portion extending to at least a depth of three feet in all areas where intensive studies were made. The pH of the upper 12 inches of soil ranged from 6.0 to 7.5 as determined by a Soiltex soil reaction test (Spurway and Lawton, 1949).

All of these swamps have been cut over to a greater or lesser extent resulting in uneven-aged stands, the trees varying in age by more than twenty years. Charred stumps indicated that all had been subjected to fire at least once. Bartlett (1931) indicates that this is the general rule in the cedar swamps of Region II.

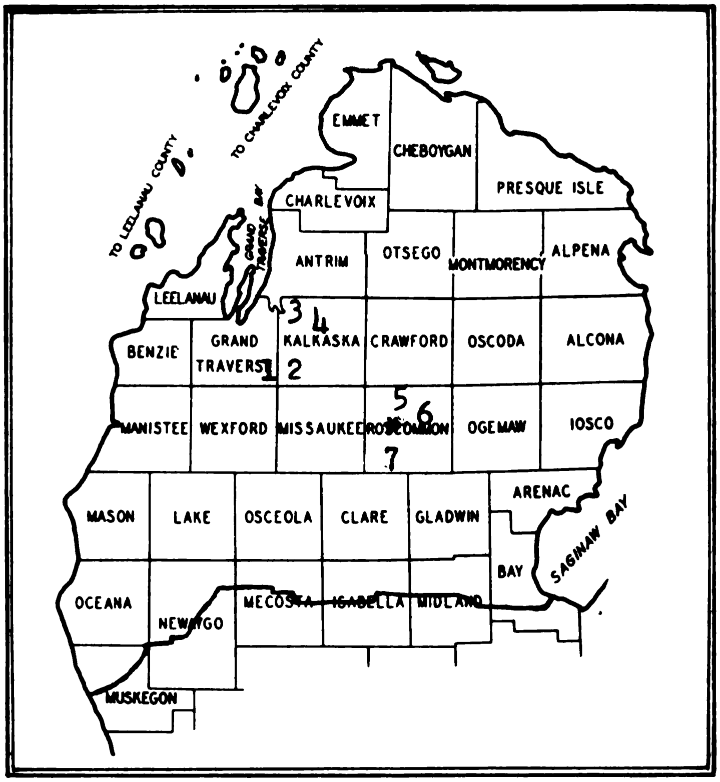

Figure 2. Location of swamps studied.

Region II

1. Fife Lake Outlet Swamp
2. Gould Creek Swamp
3. Round Lake Swamp
4. Little Rapid River Swamp
5. Dead Stream Swamp
6. St. Helen Swamp
7. Bear Creek Swamp

* Houghton Lake Wildlife Experiment Station, The Heights

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The relative ability of an area to grow trees, that is its site quality, is difficult to determine in such uneven-aged stands. Both Bowman (1944) and Nelson (1951), working in spruce-fir and white cedar stands respectively, decided that the usual method of site quality determination, the height attained by dominant trees (those taller than average receiving full light from above and some light from the sides) in relation to their age, is not reliable in uneven-aged stands. Relative site quality in the present study was judged by ring counts of the last one-half inch of radius of dominant trees in each swamp, as obtained by increment borer at a height of ten inches, and by soil type. These methods are among those suggested by Bowman (1944) for use in spruce-fir stands, but similar standards have not been set up for white cedar stands. In the present study the stands appeared to divide logically into two groups which are arbitrarily called good and medium site quality, see Table I.

While these swamps served as deeryards in the winter, the relative degree of use by deer varied considerably. For this study it was necessary to classify them according to this utilization in order to compare the effects of self-pruning and deer use. Three general classes were set up similar to those used by Duvendeck (1952):

1. Areas unbrowsed or lightly browsed (referred to simply as unbrowsed hereafter). These were characterized (1) by the absence of a browse line on white cedar, (2) American yew (Taxus canadensis), most preferred food of this region (Duvendeck, 1952) usually present in the understory and largely unbrowsed (Figure 3), and (3) most live white cedar twigs unbrowsed (Figure 4) and most dead white cedar twigs ending in fine tips and not broken or chewed off (Figure 5).

TABLE I

SITE QUALITY OF SWAMPS STUDIED

	Good Quality Sites			Medium Quality Sites			
	Round Lake Swamp	Gould Creek Swamp	Fife Lake Outlet Swamp	Dead Stream Swamp	Bear Creek Swamp	St. Helen Swamp	Little Rapid River Swamp
Average no. of rings in last 1/2 inch of radius on dominant trees	5.3	6.5	7.1	9.3	9.5	9.5	10.4
Soil type	Lupton muck(1)	Lupton muck(1)	Lupton muck(3)	Rifle peat(2)	Lupton muck(2)	Rifle peat(2)	Lupton muck(1)

(1) Veatch, Schoenmann, Foster, and Lesh (1927).

(2) Veatch, Schoenmann, and Moon (1924).

(3) Unpublished soil survey field sheets, 1952, Soil Conservation Service, Traverse City, Michigan.

Figure 3. Heavy growth of American yew at the Fife Lake Outlet Swamp.

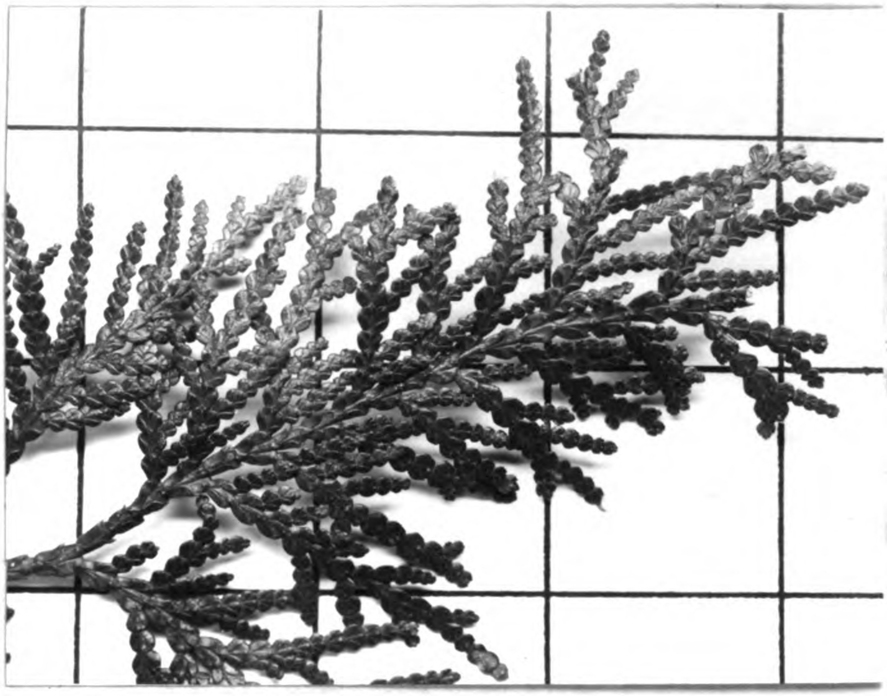


Figure 4. Closeup of an unbrowsed white cedar branchlet showing the typical fan-shaped arrangement. (Squares are one inch on a side.)

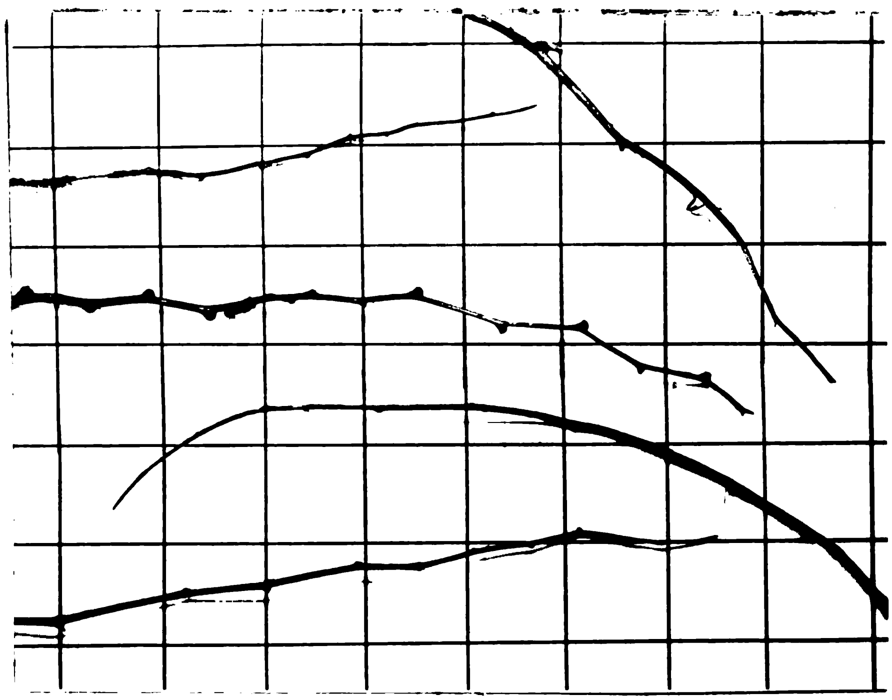


Figure 5. Unbrowsed dead cedar branchlets showing the fine tips. (Squares are one inch on a side.)

2. Areas moderately browsed. These were characterized by (1) many noticeably browsed white cedar twigs (Figures 6 and 7) but usually no distinct browse line, (2) American yew often present but living individuals less than six inches in height (Figures 8 and 9), and (3) second choice and starvation food species such as winterberry (Ilex verticillata), willow (Salix spp.), speckled alder (Alnus rugosa), balsam fir (Abies balsamea), and black spruce (Picea mariana) (Duvendeck, 1952) were largely unbrowsed.
3. Areas overbrowsed. These were characterized by (1) distinct browse lines on white cedar (Figure 1) with most of the branchlets broken or chewed off, (2) moderately to heavily browsed on second choice and starvation food species, and (3) understory largely lacking or very open (Figure 10).

Of the swamps studied, Fife Lake Outlet Swamp, Gould Creek Swamp, Round Lake Swamp, and Little Rapid River Swamp were of the first class, Dead Stream Swamp was of the second type, and St. Helen Swamp and Bear Creek Swamp were of the third category.

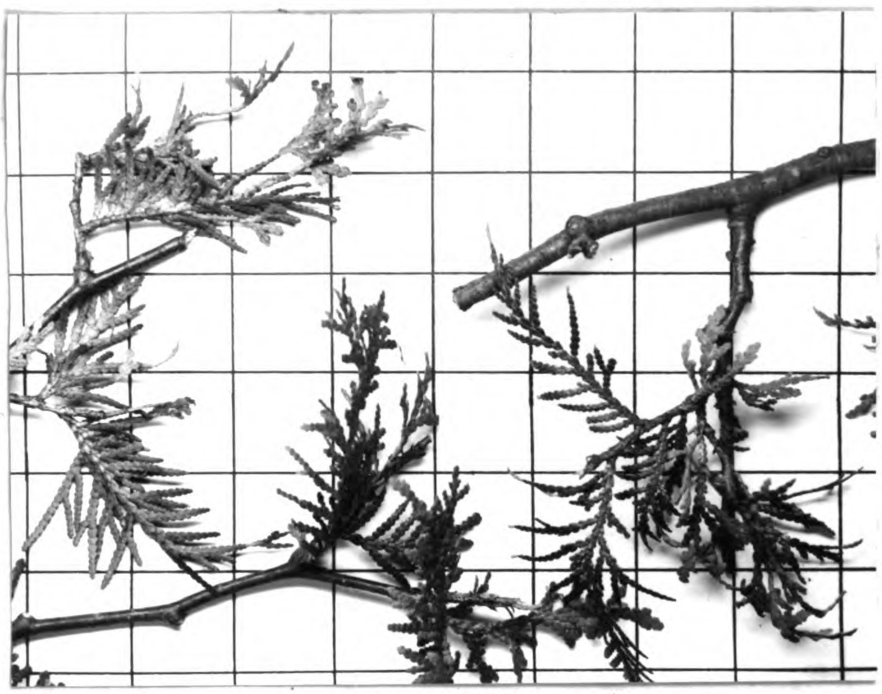


Figure 6. White cedar branchlets partially browsed by deer. (Squares are one inch on a side.) Compare these with branchlet in Figure 4.

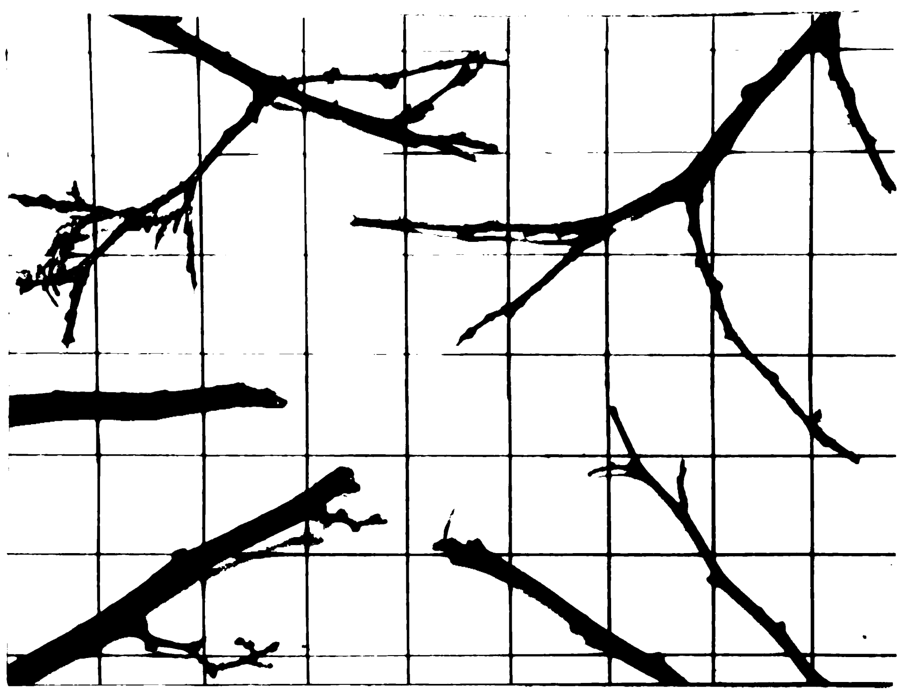


Figure 7. Dead white cedar branchlets in various degrees of browsing. Compare these with unbrowsed dead branchlets in Figure 5.

Figure 8. American yew from the Dead Stream Swamp. Individuals of this size are occasionally found in moderately browsed swamps and rarely in overbrowsed swamps. A museum special snap trap indicates scale.

Figure 9. Heavily browsed American yew in the Dead Stream Swamp. Indications are that this species was very prevalent in nearly all cedar swamps before deer became over abundant.

Figure 10. Heavily browsed, "park-like" interior of St. Helen Swamp.

COMPOSITION OF WHITE CEDAR SWAMPS

Gates (1942) indicated that all boggy areas in this region would theoretically become covered in time with the white cedar type and remain as such as long as water conditions remain favorable. White cedar, however, is not the sole woody occupant of this cover type. A survey of the relative abundance of various woody species in the white cedar swamps used in the present investigation was carried out to locate possible study plots. Belt transects ten feet wide were placed in portions of the three most extensive swamps, the Little Rapid River Swamp, the Dead Stream Swamp, and the St. Helen Swamp. These were located mechanically east to west and placed so as to divide the swamps into equal portions but keeping the total transect length less than fifty chains (3,300 feet) long. All woody species two feet tall or above were tallied in diameter classes of inch intervals, i.e., 0 to 3/4 inch (diameter "0" in this study includes all individuals from 2 to 4 1/2 feet in height), 1 inch to 1 3/4 inches, etc. for each chain length (66 feet) of transect.

The computed total trees per acre of all species were found to range from about 1,980 to 3,850, see Tables II, III and IV. Overall percentages of white cedar ranged from 49 percent to 65 percent with at least one white cedar tree recorded in every chain length in the Dead Stream and St. Helen Swamps and 29 out of 34 chains in the Little Rapid River Swamp. Chain lengths which were judged to be in pure stands of white cedar amounted to 60 percent in the Little Rapid River Swamp, 54 percent

TABLE II

COMPOSITION OF LITTLE RAPID RIVER SWAMP [1]

Species	Diameter In Inches										
	0-3/4	1-1 3/4	2-2 3/4	3-3 3/4	4-4 3/4	5-5 3/4	6-6 3/4	7-7 3/4	8-8 3/4	9-9 3/4	10 and Over	Total
White cedar	345	306	223	194	119	62	35	13	13		8	1,320
Balsam fir	98	31	23	21	13	6		2	2	4		200
Black spruce	12	31	44	36	42	10	12		4			193
American larch[2]	15	64	539	33	21	12						684
Hemlock	6	13	12	15	2	4		2		2	12	70
American yew	177											177
White pine					8		2		2		10	22
White birch	6	6	13	10	6	6	10	4			2	63
Quaking aspen	4	2	2		2		4				4	18
Red maple	19	6	8	4	10	6	4	2	2			61
Speckled alder	668	6										674
Red raspberry	73											73

TABLE II continued

Species	Diameter In Inches										
	0-3/4	1-1 3/4	2-2 3/4	3-3 3/4	4-4 3/4	5-5 3/4	6-6 3/4	7-7 3/4	8-8 3/4	9-9 3/4	10 and Over	Total
Labrador tea	17											17
Mountain maple	65											65
Swamp fly honey-suckle	8											8
Alternate-leaved dogwood	4											4
Red-osier dogwood	2											2
Willow species	106	4										110
Winter-berry	38	2										40
Balsam pop-lar	6				2							8
Fire cherry	27	15	10									52
Juneberry	21	8										29
Common el-derberry	2											2

1. Figures are computed individuals per acre, based on four 10-foot belt transects comprising .51 acres.
2. For scientific equivalents see Appendix B.

TABLE III

COMPOSITION OF DEAD STREAM SWAMP*

Species	Diameter In Inches										
	0-3/4	1-1 3/4	2-2 3/4	3-3 3/4	4-4 3/4	5-5 3/4	6-6 3/4	7-7 3/4	8-8 3/4	9-9 3/4	10 and Over	Total
White cedar	304	712	391	286	166	174	92	68	26	8	10	2,237
Balsam fir	292	514	212	120	35	26	18	6	5	2	4	1,234
Black spruce	2		12	14	6	3		3	5			45
American larch			5	2					2			9
White pine											2	2
White birch	12	126	86	49	17	3	2	2	2		7	306
Red maple		3		3	2							8
Black ash	3		3		2							8
Speckled alder	623	622	86	2								1,333
Red-osier dogwood	6											6
Willow species		6	5	3								14
Winter-berry	66	6										72

* Figures are computed individuals per acre, based on two 10-foot belt transects comprising .66 acres.

TABLE IV

COMPOSITION OF ST. HELEN SWAMP*

Species	Diameter In Inches											
	0-3/4	1-1 3/4	2-2 3/4	3-3 3/4	4-4 3/4	5-5 3/4	6-6 3/4	7-7 3/4	8-8 3/4	9-9 3/4	10 and Over	Total
White cedar	115	336	257	257	180	52	46	27	11		3	1,284
Balsam fir	3	3	5	8	11	5				3		40
Black spruce		3	3	5	3	5						19
American larch	8	79	106	106	68	27						394
White pine											3	3
White birch		11	41	38	41	19	22	3	8			183
Quaking aspen		3	3				3		3	5	3	20
Red maple	3	8	5	11		3	5					35
Speckled alder	1,133	126										1,259
Willow species			3	3								6
Fire cherry			3									3
Juneberry	3											3

* Figures are computed individuals per acre, based on two 10-foot belt transects comprising .36 acres.

in the Dead Stream Swamp, and 42 percent in the St. Helen Swamp. Aggregations of trees having 80 percent of the main crown canopy composed of white cedar were classed as pure stands.

Other important tree species were American larch (*Larix laricina*), balsam fir, black spruce, and white birch (*Betula papyrifera*). These occurred regularly, but in varying amounts.

The major shrub species present were speckled alder, winterberry, various willows, and mountain maple (*Acer spicatum*). Speckled alder was the only shrub present in abundance, computed to vary from about 675 to 1,335 stems per acre. The other species were computed to average less than 75 stems per acre.

Herbaceous plants were not surveyed to determine relative abundance, but the majority of the more common or conspicuous species in all seven swamps studied were collected and placed in the herbarium at the Houghton Lake Wildlife Experiment Station. A list of these occurs in Appendix B.

GENERAL METHODS

In order to determine the effects of age and growth on browse production it was necessary to measure browse abundance, diameter, height, age, and amount of light received for a number of trees in various types of stands. To accomplish this, 37 quadrats were established in the major types of pure white cedar stands which were found in the swamps under study.

Quadrats used in this study were circular and 1/100th-acre in size. These quadrats for the most part were placed in closed stands of trees, that is, where the crown canopy appeared to be 75 percent or more complete. In addition, a number of single trees from more open stands were examined. Trees below two feet in height were not considered since these were generally unavailable to deer during the yarding season in this latitude.

Aldous (1944), Davenport, Shapton, and Gower (1944), Krefting (1951), and Nelson (1951) are among biologists who used volume estimates to determine browse abundance. Clipping and weighing as done by Dalke (1941), Haugen (1948), and Aldous (1952), although slow and tedious, appears to be the most reliable means of securing actual measurements of the amount of browse present. This technique was utilized in the present study. On the trees studied, available winter browse was considered as being all living leaves and twigs up to a diameter to one-fourth inch between the heights of two and seven feet from the average ground level of the tree. Field observations indicated that these limits were the usual maximum limits of winter deer browsing on white cedar in the deeryards under study, although in some cases deer do browse foliage above seven feet, below two feet, and twigs beyond one-fourth inch diameter (Figures 11 and 12). Clippings from each tree were removed with pruning shears and placed in a numbered paper bag. The contents of these bags were weighed on a beam balance within the same day clipping was done since weight changes through water loss were found to be quite rapid.

Figure 11. Heavily browsed young white cedar trees resulting from being placed in with penned deer at Ogemaw State Game Refuge. These deer were well fed before the trees were placed in the enclosure.

Figure 12. Deer sometimes obtain foliage higher than they can reach by breaking off the brittle frozen branches and tips. Photograph taken in the Dead Stream Swamp.

FACTORS INFLUENCING BROWSE PRODUCTION

Browse Production As Affected By Tree Size

The Lake States Forest Experiment Station (1940) has published some figures on the average amount of browse available from various sized unbrowsed white cedars from ground level to a height of seven feet. Working near Dukes in the Upper Peninsula of Michigan, they (Experiment Station personnel and members of the C.C.C.) found the peak of browse production was reached by trees of three inches diameter. No data were given as to type of stand or what was considered available browse. It became evident, however, in the early phases of the present study that amount of browse as related to tree size was somewhat different in the swamps under study.

In the present study trunk diameters were measured to the nearest one-fourth inch usually with tree calipers, averaging the smallest and largest diameters. Where trunks were irregularly shaped or very large the average diameter was computed from the circumference as measured with a steel tape. Heights of individuals 12 feet or less were measured directly to the nearest foot with yardsticks. For larger trees, a number of individuals of representative sizes in each quadrat were measured to the nearest foot using an Abney combination hand level or Christman-type hypsometer and the heights of others were estimated from those measured. Procedures used in clipping browse are given previously.

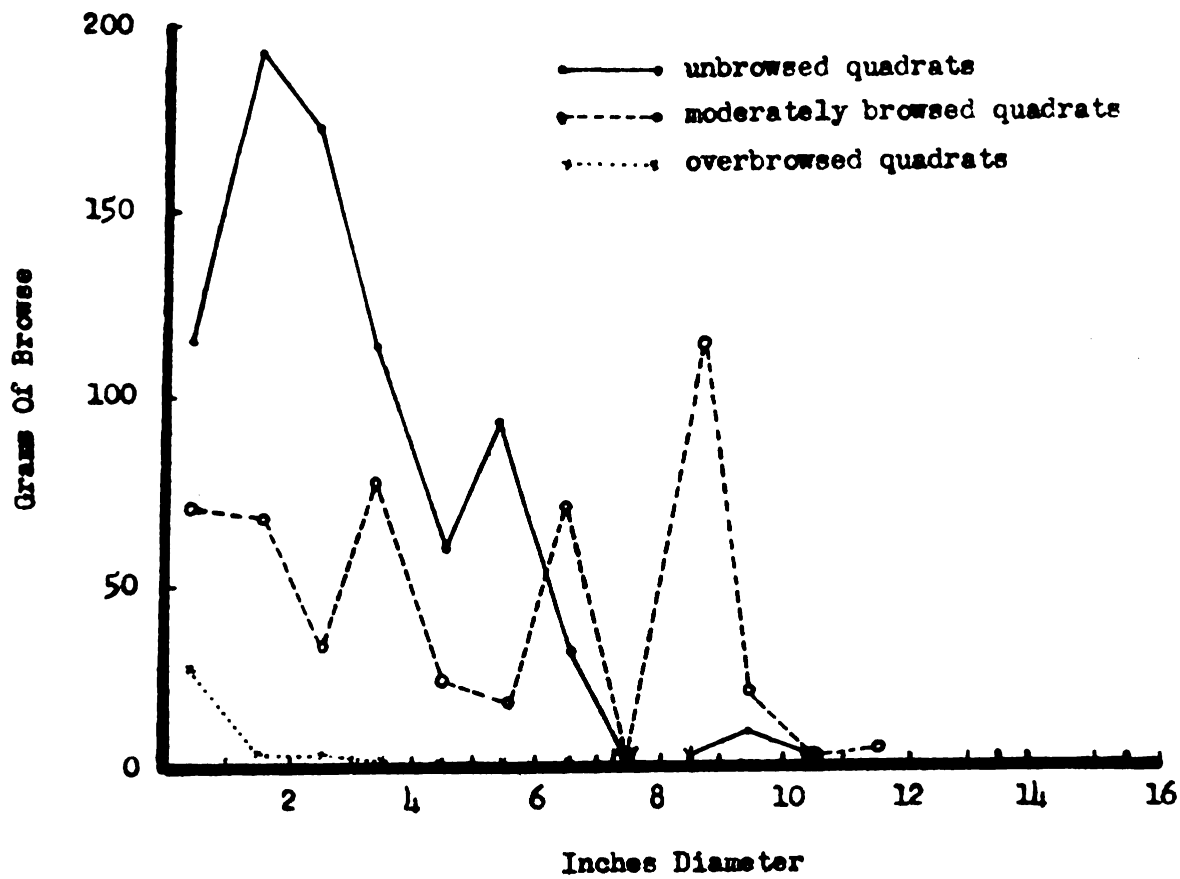
Data from clipping 614 white cedars from eighteen unbrowsed 1/100th-acre quadrats were grouped into diameter classes of inch intervals as 0 to 3/4 inch, 1 to 1 3/4 inches, etc. The average browse present was then determined for each diameter class.

Results indicated that the greatest amount of available browse was found on trees in the diameter class 1 to 1 3/4 inches (Figure 13). Other important diameter classes, in order, were 2 to 2 3/4 inches, 0 to 3/4 inch, and 3 to 3 3/4 inches. Above a diameter of 7 3/4 inches almost no browse was present (Figures 13, 14 and 15). The graph of the data (Figure 13) presents a regular curve except for data for the size classes 5 to 5 3/4 inches and 9 to 9 3/4 inches which appear higher than they should. These two irregularities may indicate that the samples were not large enough to secure a completely representative group of trees in every case. It seems probable that the general progress of self-pruning in relation to tree size in the swamps studied would approximate that curve drawn through these data so that it smooths out these two irregular humps.

Examination of the data from the individual quadrats separately revealed that in most cases this same general browse trend was present (Table V). However, since these unbrowsed quadrats represented a variety of stand types, the total weight of forage present varied from none to 30,581 grams (Appendix A, Table XI). This, together with the fact that two quadrats had no trees below a diameter of 3 inches and nine had none below 1 inch, is no doubt responsible in large part for the general browse curve, as described above, not being evident in the data from every quadrat. Furthermore, there was a relatively small number of trees present in the various size classes per quadrat

FIGURE 13

MEAN BROWSE PER TREE



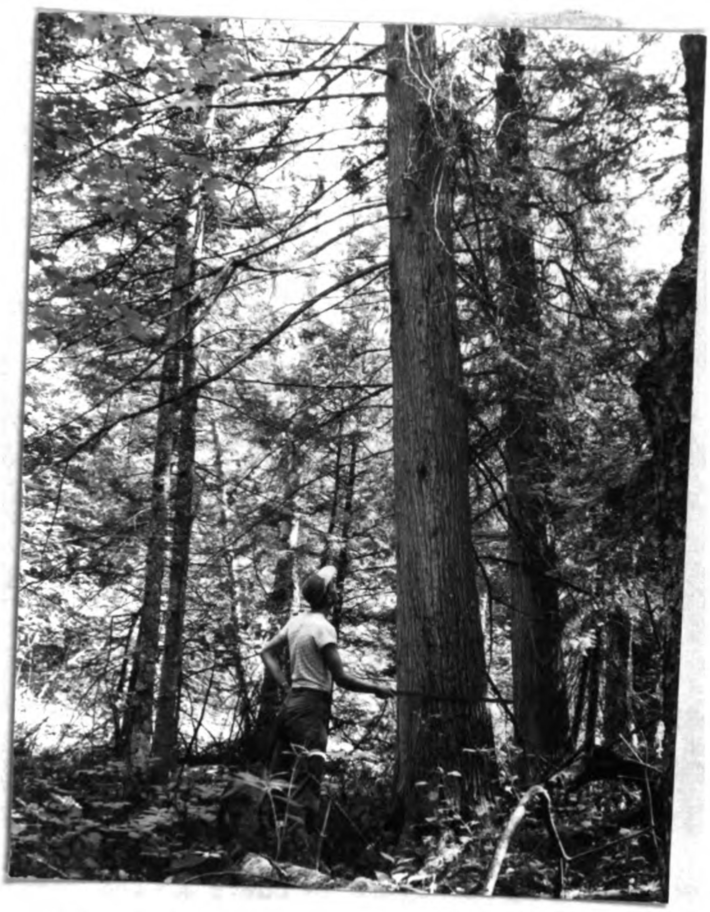


Figure 14. A portion of the Little Rapid River Swamp which had a stand of mature white cedars. Note the lack of available browse. The white cedar, diameter 23 1/4 inches, in the foreground was the largest encountered during the study.

Figure 15. A stand of large white cedar six to 12 inches in diameter at the Fife Lake Outlet Swamp showing the lack of cedar browse which resulted largely from natural pruning. Note the American yew in the left foreground.

TABLE V

MEAN BROWSE PER TREE,

Quadrat	Diameter In Inches						
	0-3/4	1-1 3/4	2-2 3/4	3-3 3/4	4-4 3/4	5-5 3/4	6-6 3/4
A1		39.2	0	0	0		0
A2		6.0	0	.2	0	3.0	0
A3		0	11.0	0	0	0	
A4		.5	1.8		0		
A5	81.0	95.4	75.2	1.0	6.5	0	
B1	176.5	188.3	75.5	7.0	18.8		0
D1				4.0	0	0	0
D2				0	0		0
E1	94.6	48.0	19.4	5.9	0		
E2	91.1	217.2	203.9	267.5		33.0	
F1		4.0	0	0	0	2.0	
F2		0	36.0	0	0	0	0
F3		103.5	9.2	13.0	22.0		72.3
F4	0	44.1	.7	0	0	0	0
F5	75.0	107.3	6.3	0	.8		
F6	103.5	169.0	329.2	68.4	0	265.0	0
F7	177.3	773.6	572.0	716.0	1,230.0		
F8	109.8	622.6	1,351.8	667.6		559.0	196.0

TABLE V continued

UNBROWSED QUADRATS

Diameter In Inches					
7-7 3/4	8-8 3/4	9-9 3/4	10-10 3/4	13-13 3/4	15-15 3/4
	0				
				0	0
	0				
4.0					
0		0	0		
		0	0		
0					
0	0				
0					
	0	22.0			

when compared to the combined totals from all quadrats which increases the chance of getting unrepresentative individuals.

For comparison the data from 287 trees in the ten moderately browsed quadrats and 307 trees in the nine overbrowsed quadrats were also grouped by diameter classes and graphed (Figure 13 and Tables 6 and 7).

The browse curve as related to size exhibited by the trees from the moderately browsed quadrats was very irregular and failed to show any definite trends. The height of the curve from the moderately browsed trees lies below corresponding points of that for the unbrowsed quadrats in the diameter range from 0 to 6 3/4 inches. Beyond seven inches diameter, however, the height of the former's curve surpasses that of the latter in all instances but one, where they both are zero. No positive explanation could be found for the failure of the moderately browsed trees to produce a browse curve that even approximates the trend established by the unbrowsed trees. Probably some of this discrepancy is the result of the typical haphazard feeding of deer under relatively good food conditions as described by Burt (1946). In addition it appears from the data that moderate browsing by deer may actually stimulate browse production. Aldous (1952) found this to be true. In his studies annual clipping of 25 percent and 50 percent of the foliage present below seven feet on two groups of trees, averaging fifteen feet tall, produced 25 percent and 12.3 percent more browse respectively over a six year period than was present at the beginning of the study. Furthermore this stimulation of browse production might be even more apparent if there was not an annual removal on all trees such as doubtless happens in the wild under conditions of moderate browsing. It is logical to assume that trees having the

TABLE VI

MEAN BROWSE PER TREE,

Quadrat	Diameter In Inches					
	0-3/4	1-1 3/4	2-2 3/4	3-3 3/4	4-4 3/4	5-5 3/4
G1		46.8	62.3		21.0	3.6
G2	71.0	62.5	24.8	0	13.2	0
G3	34.5	26.4	15.5	0	0	0
G4		108.0	6.0	189.0	19.8	0
G5		68.6	39.4	13.6	83.5	2.5
G6		108.0	27.0	0	1.9	
G7	33.3	39.3	68.3	66.0		
G8	19.1	16.0	1.3	1.2	7.0	0
G9		30.4	3.9	0	0	0
H1	136.8	347.3	207.5	303.1	191.0	201.0

TABLE VI continued

MODERATELY BROWSED QUADRATS

Diameter In Inches					
6-6 3/4	7-7 3/4	8-8 3/4	9-9 3/4	10-10 3/4	11-11 3/4
10.0	0				
0	0				
				0	
211.0	0	0	50.0		5.0
91.8	0				
	0		0		
	28.0				
	0				
				0	0
		228.0			

TABLE VII

MEAN BROWSE PER TREE, OVERBROWSED QUADRATS

Quadrat	Diameter In Inches								
	0-3/4	1-1 3/4	2-2 3/4	3-3 3/4	4-4 3/4	5-5 3/4	6-6 3/4	7-7 3/4	8-8 3/4
I1	27.0	15.1	5.2	0	0	1.0			
I2		4.6	4.7	0	0	1.2	0	0	0
I3		5.3	0	0	0	0			
I4		8.3	10.0	0	0	0	0		
S1		1.7	.2	0	0		0		
S2		1.1	.1	0	0				
S3		0	0	0	0	0	0		
S4		0	0	0	0	0	0	0	
S5		.6	0	0	0	0			

most browse present normally, that is those smaller than seven inches in diameter, would be subject to heavier browsing.

Small trees, especially those below seven feet tall, seemed unable to withstand even moderate browsing. Half of the study quadrats had no trees below one inch in diameter.

The browse curve (Figure 13) for the overbrowsed trees was uniformly low with the peak in the smallest size class and a progressive decline to the size class 3 to 3 3/4 inches. Only one tree was present in the nine quadrats below a diameter of one inch so that in all probability size class 1 to 1 3/4 inch was of greater overall importance. Virtually no browse was present in trees larger than a diameter of 3 3/4 inches. Aldous (1941) also found that in white cedars of two inches or greater diameter most of the regeneration of browsed or clipped branches occurred above the seven foot line. Thus where the foliage on virtually all trees is severely browsed annually there is little chance for larger trees to maintain available browse.

Adverse influence of deer browsing is well illustrated by comparison of the browse curves of the unbrowsed and overbrowsed trees (Figure 13). Most of the difference in magnitude between these curves can be attributed to deer browsing. Comparison of the unbrowsed and moderately browsed trees also shows the adverse effect of deer, but not as well because of the irregular character of the data from the moderately browsed trees in the fore part of the curve. As mentioned above, moderate browsing may stimulate browse production. However, trees above seven inches in diameter, where this was especially apparent, were of little overall importance in the area studied because of their relatively low numbers and relatively low amounts of browse present per tree.

Relationship of tree height to browse production was not attempted because the relationship between diameter and height was found to be essentially the same in all swamps studied (Appendix A, Tables XII to XVIII). Only those trees examined from the Fife Lake Outlet Swamp were found to differ in the height to diameter relationship from trees in the other swamps. A statistical F test (Snedecor, 1950) of the heights of trees 3 to 3 3/4 inches diameter from each swamp indicated a highly significant difference between swamps. Subsequent statistical T tests (Snedecor, 1950) showed trees from Round Lake to be significantly higher than the trees from other swamps.

Browse Production As Affected by Light

Light readings were made to measure the amount of light which reached the available browse zone in the quadrats for the purpose of determining the effects of light on browse production. The instrument used was a Weston Master II photographic exposure meter to which an Invercone was attached. The Invercone is a plastic diffusing cone which allows taking of incident light readings with this meter. Information supplied by the Weston Electrical Instrument Corporation indicated the Weston meter with Invercone registers light on the scale in units equal to one twenty-fifth foot candles and has an angle of acceptance of light slightly over 180° (Menton, 1952). This angle would tend to allow for some changes in position of the sun and still give comparable readings.

In general the procedures of Sather (1951) were followed here in taking the readings. The instrument was held horizontally (light-receiving surface pointed upward) at a height of about 6 1/2 feet with five readings being made in each quadrat, the center and where the four cardinal compass directions intersected the quadrat boundaries. A reading was then taken in a nearby opening as soon as possible thereafter to determine the maximum possible light which could be received at that time. Using these figures the percentage of available light for each quadrat was computed for each as:

$$\frac{100 \text{ x sum of 5 readings in quadrat}}{5 \text{ x reading in open}}$$

This procedure, as described above, measured the amount of light coming through the overhead canopy of leaves and reaching the top of the zone where deer browse is produced, thus allowing some comparisons between browsed and unbrowsed quadrats. Where openings existed adjacent to the quadrats, however, light which entered the quadrat below 6 1/2 feet was not measured accurately and therefore percentages of available light as computed above for such quadrats does not give a true picture. No method was devised which seemed to correct for this.

Since equipment was not available earlier, all readings were made during July, August, and early September of 1952, except in two quadrats (E1 and E2) where readings were made in January, 1953. Time of the readings for 25 quadrats were between 11 A.M. and 2 P.M., seven were between 2 P.M. and 3:25 P.M. and one was at 4:30 P.M. Readings in eight quadrats were made with the sky partially obstructed by uniform haze so that readings in the open were only about one-third that on a cloudless day, seven were done when the sky was uniformly cloud covered and only about one-sixth normal brightness, with the remaining eighteen on bright cloudless days. No readings were made in four quadrats. Sather (1950) indicates that comparative values for percentage of total sunshine may be obtained on either clear days or those with uniform cloud cover and this seemed to be true in the present study. Despite the differences in time during the taking of readings in the various quadrats the values obtained are objective and believed to be much more accurate than could be gotten from a subjective appraisal of the crown density.

It should be kept in mind that any conclusions regarding the effects of light intensity may also be the result in part of other factors. Oosting (1950) points out that differences in root competition for water and minerals can influence growth under the same light conditions. Furthermore, Daubenmire (1947) says that reduction of light by a canopy of vegetation also results in changes in wind, relative humidity, soil moisture, and temperature. Because of the complexities involved no attempts were made to measure these other factors in this study.

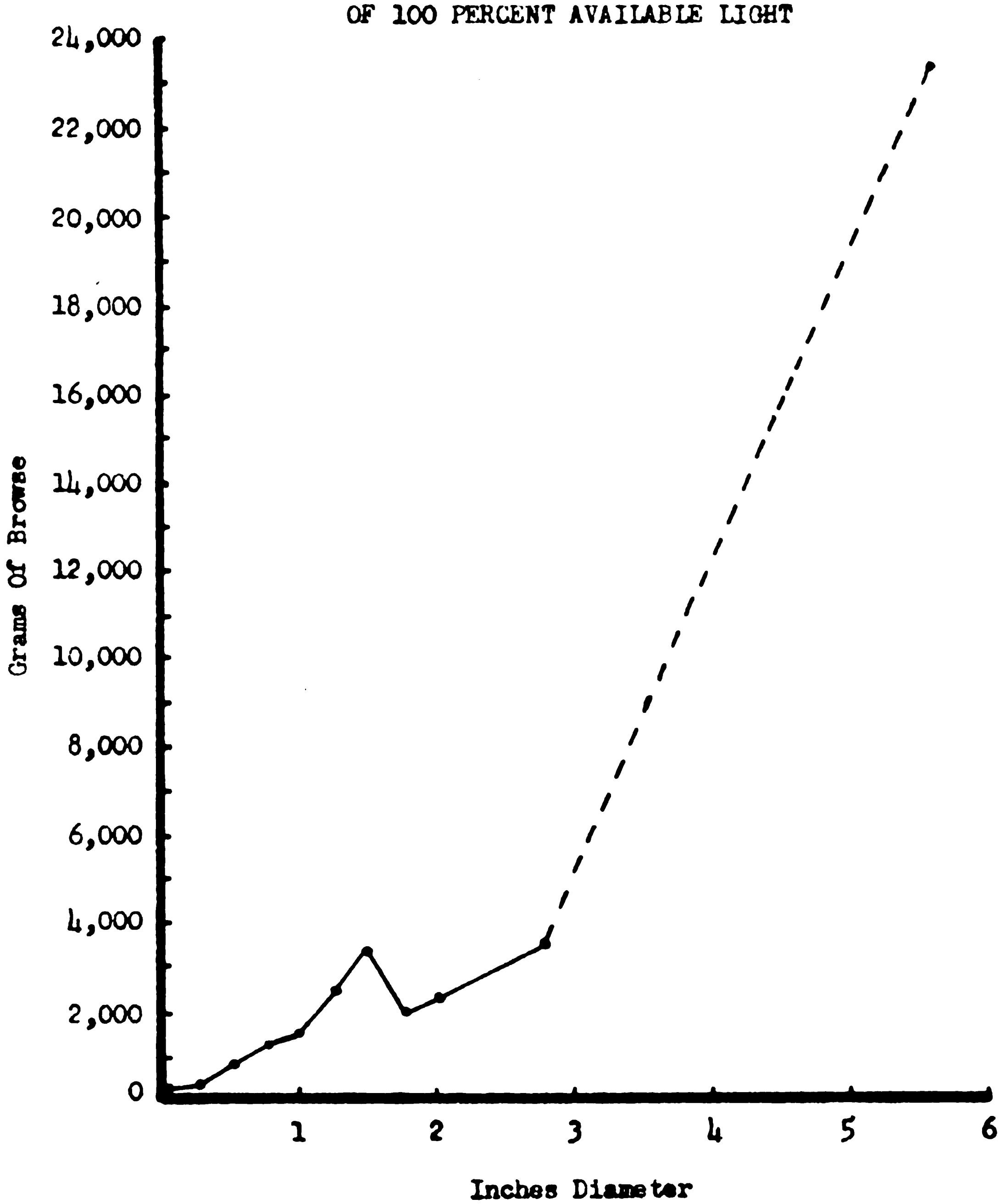
The maximum browse per tree was produced where the available light was 100 percent. Under these conditions there was almost no natural pruning and limited clipping studies indicated the larger the tree the more the available deer browse. Since no unbrowsed trees above a diameter of three inches were found growing in the open in the swamps studied, only one individual larger than this size was clipped. A tree 5 1/2 inches in diameter from an upland site at the Kellogg Bird Sanctuary in Kalamazoo County yielded slightly over 51 pounds of browse when clipped and its associates appeared to have about the same amount (Figure 16). The Sanctuary tree appears to have more browse than the trend of curve established by the smaller trees suggests trees of this size would have (Figure 17). Nevertheless, examination of a greater number of trees in the larger diameter classes would of course be necessary to determine the actual trend of the browse curve.

Figure 16. Under relatively ideal conditions in the open with little competition for light, cedar produces its highest browse yields. The above clipped tree from an upland site at the Kellogg Bird Sanctuary yielded slightly over 51 pounds.

FIGURE 17

BROWSE AS RELATED TO SIZE UNDER CONDITIONS

OF 100 PERCENT AVAILABLE LIGHT



A series of seven trees from 1 to 1 3/4 inches in diameter under conditions of 100 percent available light were found to average 4.0 times as much available deer browse as twenty trees in this size range where the available light was about one-half (52 percent) the maximum. The single Sanctuary tree had 75.6 percent as much browse as the entire 1/100th-acre area of quadrat F8 which had 93 trees above two feet tall.

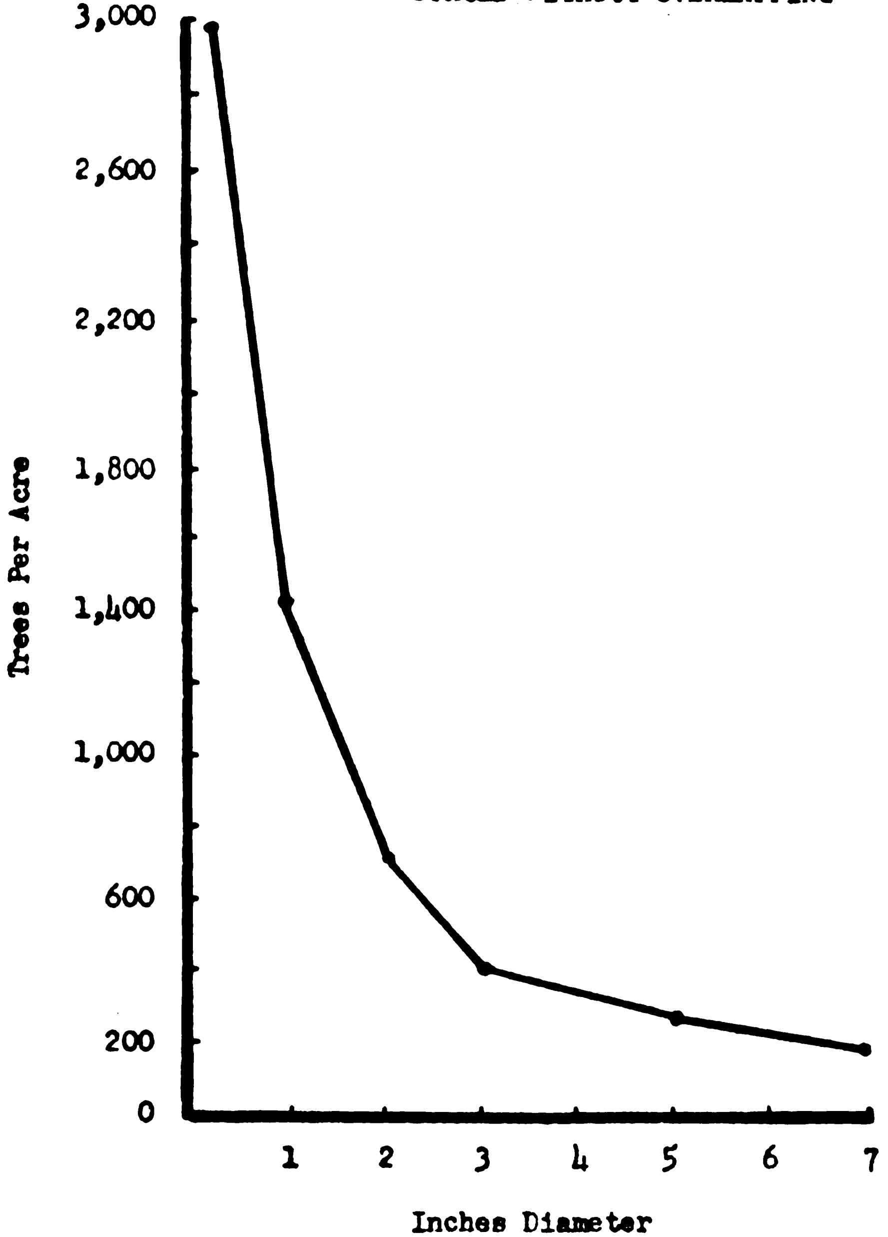
A series of measurements were taken to determine the average number of trees of different sizes which could occupy an acre without overlapping or adversely shading adjacent trees. These data were then graphed (Figure 18). From this graph it can be computed, for instance, that trees of one inch in diameter equally spaced would average about 1,400 trees per acre. Using figures obtained from clipping two trees of this size an acre would contain 3,983 pounds of available deer browse. Similarly an acre of trees 5 1/2 inches in diameter, each having as much browse as the Sanctuary tree, would contain about 11,985 pounds.

Light was able to penetrate the crown cover to a much greater extent in quadrats of dense young stands with 5,000 to 9,000 trees above two feet in height per acre than in quadrats located in more mature stands with only 900 to 1,900 trees per acre. The crown cover in both types of stands, however, appeared almost as dense to the eye. For example, in quadrat F8 with 93 white cedars above two feet tall, 52 percent of the available light penetrated the crown to a height of 6 1/2 feet while in quadrat A4 with nine white cedars, only 0.6 percent of the available light was recorded. Correlation analysis (Hagood and Price, 1952) between the number of trees per quadrat and the percentage of available light (percent transformed to arc sin after Snedecor, 1950)

FIGURE 18

AVERAGE NUMBER OF TREES PER ACRE

SPACED WITHOUT OVERLAPPING



on the unbrowsed quadrats revealed a highly significant association ($r = .841^{**}$). That is, there was a direct relationship between the number of trees per quadrat and the relative amount of light received at 6 1/2 feet from the ground level.

Results also pointed to a direct relationship between the amount of available light which a quadrat received and the amount of browse present. Correlation analysis between the amount of light (percent transformed to arc sin) and browse on the unbrowsed quadrats showed a highly significant association between these two variables ($r = .768^{**}$). Light readings and browse present for the various quadrats is shown in Appendix A, Table XI.

Major exceptions of the unbrowsed quadrats to the general axiom stated above, that the more light received through the crown cover the more the available browse present, are quadrats B1 and F6. Quadrat B1 had 13.6 times the average amount of browse present in the six other unbrowsed quadrats with available light below two percent, while quadrat F6 had 68.2 times the average amount of browse present in the three other unbrowsed quadrats with available light between two percent and three percent. The apparent reasons for their relatively high browse production seemed to be close proximity to openings. F6 actually had open edges on about one-third of its periphery, while about one-half the circumference of quadrat B1 was approximately ten feet from an extensive clearing. These data support field observations which indicated the favorable effect of open edges on browse present (Figures 19 and 20).

For comparison correlation analyses were made on the amount of light (percent transformed to arc sin) received and the browse present

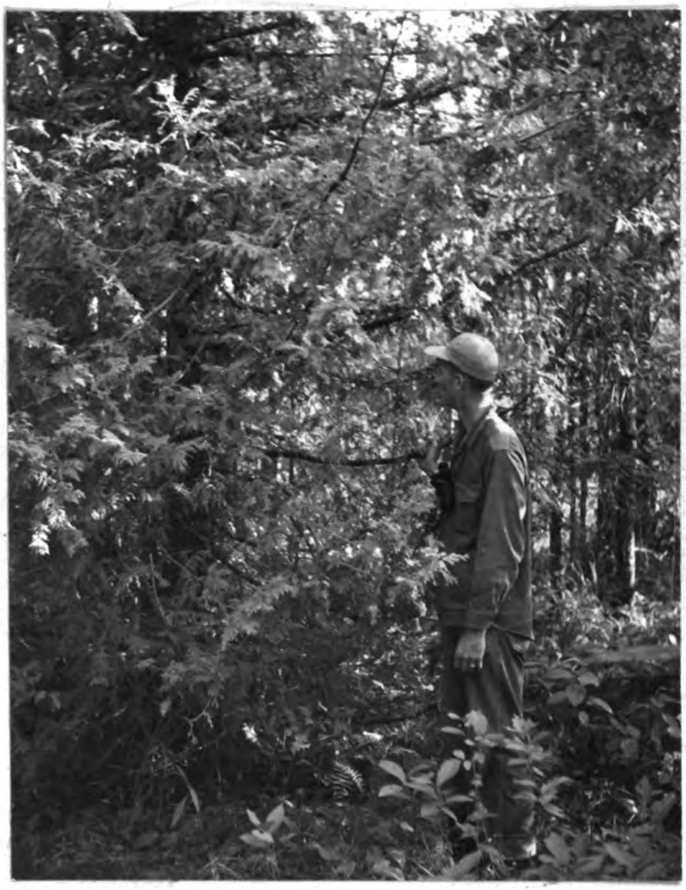


Figure 19. Under conditions where relatively high amounts of light reach the zone of browse production, larger trees retain living branches within reach of deer. This white cedar of six inches diameter was located in the Little Rapid River Swamp.

Figure 20. Open edges, like this one at the Gould Creek Swamp, produce some of the higher yields of available browse.

on six moderately browsed and nine overbrowsed quadrats. Light readings and browse present for the various quadrats are shown in Appendix A, Table XI.

In the moderately browsed quadrats no significant association was found (r = .656). The cause of this lack of association is difficult to explain. The four moderately browsed quadrats receiving less than ten percent of the possible light actually averaged 3.3 times as much browse as did the eleven unbrowsed quadrats (not including B1 or F6) in this light range. This again, though, lends support to the supposition that moderate browsing by deer may stimulate browse production as was suggested previously when discussing tree size and browse relationships.

The overbrowsed quadrats likewise did not show a significant association, the correlation coefficient being relatively small and negative (r = -.076). These swamps had been so severely overbrowsed that little or no foliage below seven feet was present, even where the available light reached 49.6 percent (quadrat S3).

Browse Production As Affected By Age And Site Quality

The ages of small trees were determined by cutting the stems at a height of ten inches and counting the annual rings in the field. Ages of trees about one-fourth inch diameter and above were determined by increment borings. Cores were taken at ten inches from the average ground level on each tree. This was the lowest height at which the instrument could be used conveniently. Usually cores were extracted and placed in numbered envelopes. Ages were then determined in the laboratory with hand lens or binocular microscope. It was not possible to age all individuals, since some trunk centers were rotten, very large, or irregular and the centers could not be located.

An increment borer was found to be quite satisfactory for age determination in white cedar. The dark winter wood is easily distinguished from the lighter colored spring wood. Although Harlow (1927) indicates that ring counts are unsatisfactory because heart rot occurs in about eighty percent of the older trees, in the present study only six percent of the total trees examined had butt rot severe enough so that they could not be totally aged.

As might be expected, it is generally true that in a given location the larger a white cedar is the greater its age (Appendix A, Tables XII to XVIII). Individual white cedar trees, however, may survive for long periods without hardly any perceptible diameter growth. For example, in the Dead Stream Swamp a tree 1 3/4 inches in diameter was found to be 111 years old and another two inches in diameter was 107 years old. Both trees were about twice as old as the average of similar sized trees from this swamp.

Less extreme cases of age differences for similar sized trees were often found in the same 1/100th-acre quadrat. Age ranges of twenty years were commonly found so that where a number of similar sized trees were present in a quadrat some consideration of the age factor alone in influencing browse production was possible.

Correlation analyses were made on age and browse production of 11 groups of similar sized trees from various quadrats, Table VIII. Highly significant associations between age and browse production were found only for those groups of trees from quadrats F7 and F8 of zero diameter, the respective correlation coefficients being r = .635** and r = .826**.

TABLE VIII

TREE AGE AND BROWSE

Quadrat	Tree Diameter	Tree Age	Browse
F7	0 (2 - 4.5 feet tall)	6 years	3 grams
		7 "	8 "
		8 "	4 "
		9 "	14 "
		10 "	13 "
		12 "	19 "
		13 "	33 "
		14 "	157 "
		15 "	105 "
		15 "	13 "
		15 "	60 "
		16 "	52 "
		16 "	60 "
		16 "	8 "
		17 "	5 "
		17 "	32 "
		17 "	74 "
		18 "	54 "
		19 "	41 "
		21 "	391 "
		28 "	116 "
		29 "	106 "

TABLE VIII continued

Quadrat	Tree Diameter	Tree Age	Browse
F7	0 (2 - 4.5 feet tall)	33 years	27 grams
		39 "	391 "
		41 "	111 "
		46 "	282 "
F8	0 (2 - 4.5 feet tall)	9 years	0 grams
		9 "	18 "
		9 "	32 "
		9 "	18 "
		9 "	44 "
		11 "	13 "
		13 "	37 "
		14 "	35 "
		14 "	43 "
		14 "	20 "
		15 "	35 "
		15 "	37 "
		15 "	16 "
		15 "	3 "
		15 "	10 "
		16 "	23 "
		16 "	36 "
		17 "	14 "
		17 "	40 "
		18 "	67 "

TABLE VIII continued

Quadrat	Tree Diameter	Tree Age	Browse
F8	0 (2 - 4.5 feet tall)	18 years	42 grams
		18 "	33 "
		18 "	43 "
		19 "	36 "
		19 "	29 "
		20 "	55 "
		20 "	60 "
		20 "	13 "
		21 "	9 "
		22 "	40 "
		22 "	154 "
		22 "	14 "
		24 "	54 "
		24 "	63 "
		26 "	70 "
		26 "	97 "
		27 "	45 "
		27 "	39 "
		28 "	187 "
		30 "	119 "
		32 "	189 "
		33 "	106 "
		33 "	97 "
		35 "	134 "

TABLE VIII continued

Quadrat	Tree Diameter	Tree Age	Browse
F8	0 (2 - 4.5 feet tall)	36 years	86 grams
		42 "	206 "
		43 "	187 "
		43 "	180 "
E1	1/2 inch	12 years	82 grams
		21 "	34 "
		22 "	12 "
		27 "	45 "
		29 "	229 "
		30 "	65 "
		31 "	106 "
		35 "	156 "
		35 "	74 "
F8	1/2 inch	21 years	179 grams
		33 "	248 "
		35 "	184 "
		37 "	361 "
		37 "	160 "
		38 "	370 "
		39 "	251 "
E1	1 inch	28 years	1 grams
		37 "	41 "
		37 "	163 "

TABLE VIII continued

Quadrat	Tree Diameter	Tree Age	Browse
E1	1 inch	38 years	44 grams
		41 "	104 "
		42 "	27 "
		45 "	22 "
E1	1 1/4 inch	35 years	284 grams
		39 "	55 "
		39 "	17 "
		42 "	8 "
		43 "	91 "
		44 "	124 "
F8	1 1/4 inch	25 years	721 grams
		27 "	512 "
		38 "	320 "
		41 "	186 "
		41 "	209 "
		43 "	586 "
		43 "	391 "
		45 "	805 "
		47 "	910 "
E1	1 1/2 inch	38 years	4 grams
		43 "	28 "
		44 "	2 "
		45 "	0 "

TABLE VIII continued

Quadrat	Tree Diameter	Tree Age	Browse
E1	1 1/2 inch	45 years	8 grams
		48 "	0 "
F6	1 1/2 inch	36 years	184 grams
		36 "	439 "
		39 "	0 "
		39 "	389 "
		44 "	33 "
		45 "	0 "
		46 "	27 "
		48 "	34 "
		49 "	0 "
		52 "	15 "
A5	2 to 3 inches	43 years	16 grams
		49 "	52 "
		53 "	60 "
		54 "	13 "
		58 "	17 "
		58 "	27 "
		59 "	11 "
		61 "	4 "
		63 "	13 "
		63 "	11 "
		63 "	0 "
		66 "	5 "

TABLE VIII continued

Quadrat	Tree Diameter	Tree Age	Browse
El	2 to 3 inches	36 years	0 grams
		39 "	0 "
		41 "	5 "
		42 "	53 "
		44 "	6 "
		44 "	38 "
		46 "	0 "
		46 "	11 "
		47 "	67 "
		48 "	14 "

In addition a significant association was found in the 1 1/2 inch trees in quadrat F6, the correlation coefficient being r = -.698*. With all other groups of trees tested there were no significant associations. The correlation coefficients for these were: quadrat E1, 1/2 inch trees, r = .379; quadrat F8, 1/2 inch trees, r = .439; quadrat E1, 1 inch trees, r = .134; quadrat E1, 1 1/4 inch trees, r = -.531; quadrat F8, 1 1/4 inch trees, r = .047; quadrat E1, 1 1/2 inch trees, r = -.209; quadrat A5, 2 to 3 inch trees, r = -.005; and quadrat E1, 2 to 3 inch trees, r = .352.

Possibly in the two size classes where highly significant associations were found, minor height differences caused by differences in age, rather than age itself, were responsible since heights of trees of zero diameter, as defined, vary from 2 to 4 1/2 feet in height. Small variations in height would be of much greater importance in trees averaging three or four feet in height than those of larger size. Variations in height, however, do not seem to account for the significant association between age and browse for trees of 1 1/2 inch diameter in quadrat F6. Here the correlation coefficient (r) is negative, meaning that a decrease in browse was associated with an increase in age. The reverse situation was found in the two groups of trees where highly significant associations were found and in five of the eight groups where no significance was found. While in some instances age itself may appear to influence browse production, overall it does not seem to be an important factor in this respect.

Where site quality differed (see Section on LOCATION AND CLASSIFICATION OF SWAMPS STUDIED) the ages of trees of the same size, of course, did differ. That is, for a given size the average age of trees from medium sites were greater than trees from good sites (Appendix A, Tables XII to XVIII). It is conceivable, therefore, that rate of growth due to site quality differences might modify the amount of browse present per tree.

To determine if site quality differences affected browse production on similar sized trees portions of two swamps of different site quality, Little Rapid River and Round Lake, were selected for study. Twelve trees from the Little Rapid River Swamp and 16 from the Round Lake Swamp were clipped, aged, and measured. These trees, three to six feet tall, were on previously clear-cut areas and were growing with little competition for light or root space so that differences in growth rate were most likely due to differences in site quality. The trees from the medium quality site required an average of 2.1 times as long to reach a given size as did those from the good quality site (Table IX).

Data were grouped in three diameter classes of one-fourth inch intervals. Although the mean browse per class was somewhat higher for the Little Rapid River trees (poorer site) in two of the three classes, statistical F tests indicated that for a given diameter within the ranges studied there was no significant difference between the two swamps in the weights of browse from trees of comparable size.

From these data, then, site quality differences, like tree age differences, do not appear to be important in influencing browse production except indirectly as they influence tree size.

TABLE IX

WEIGHTS OF BROWSE FROM TREES IN TWO

Diameter Classes						
	0 Inch				1/4 Inch	
	Little Rapid River Swamp		Round Lake Swamp		Little Rapid River Swamp	
	Browse	Age	Browse	Age	Browse	Age
	132 grams	15 years	77 grams	8 years	472 grams	12 years
	96 "	12 "	49 "	8 "	173 "	18 "
	81 "	16 "	143 "	8 "	150 "	17 "
	143 "	16 "	119 "	9 "	231 "	16 "
	458 "	16 "				
	236 "	14 "				
Mean:	191 grams	15 years	97 grams	8.2 years	256 grams	15.7 years

TABLE IX continued

SWAMPS OF DIFFERENT SITE QUALITY

Diameter Classes					
1/4 Inch		1/2 Inch			
Round Lake Swamp		Little Rapid River Swamp		Round Lake Swamp	
Browse	Age	Browse	Age	Browse	Age
188 grams	7 years	885 grams	39 years	775 grams	9 years
187 "	7 "	400 "	14 "	472 "	12 "
295 "	9 "			671 "	14 "
313 "	9 "				
210 "	9 "				
456 "	9 "				
439 "	10 "				
473 "	9 "				
342 "	9 "				
333 grams	8.7 years	642 grams	24 years	639 grams	11.7 years

MANAGEMENT PROBLEMS AND SUGGESTIONS

Management of white cedar for deer browse production encompasses two major problems. Probably the foremost is that of controlling deer numbers. No management of white cedar for browse production seems possible where deer are so numerous as to overbrowse their range.

In the present study the overbrowsed swamps had virtually no white cedar foliage remaining while forage amounts in the moderately browsed areas were noticeably less, at least in trees smaller than six inches in diameter. Duvendeck (1952) found in the overbrowsed areas of Michigan's Region II that white cedar had become so heavily eaten as to produce little or no available browse through growth, regneration, or reproduction. Similarly Aldous (1952) found in his clipping studies of trees averaging seven and 15 feet tall in closed stands that even when only 25 percent of the foliage was removed annually, there was a decline in the browse present over a six-year period. He concluded that white cedar trees under seven feet tall could maintain a constant food supply only if the annual removal of foliage was something less than 15 percent. In trees larger than seven feet tall, however, even light annual clipping of the foliage, while it did stimulate browse production somewhat, caused a steady decline in the browse present.

A second major problem is one of forest economics. Smith (1948) states that in Michigan the main uses of white cedar are for posts and poles. Seven-foot posts require a tree of at least six inches diameter. Watson (1936) indicated that while six-inch trees would produce posts, the stumpage value per tree increased markedly in value with increases in diameter and height. He pointed out, for instance, that the stumpage value of a tree 10 inches in diameter is five cents while that of a tree 6 inches in diameter is only one cent. Above a diameter of ten inches, however, the increase in value with increased size is relatively much smaller. Personal conversations with foresters of the Houghton Lake and Ogemaw State Forests reveals that at present stumpage values for 6 and 10-inch trees is approximately ten and twenty cents respectively.

From the game management standpoint trees above a diameter of six inches in closed stands have small amounts of available deer browse. In fact it was found in the present study that the browse supply declines quite rapidly with increases in size beyond a diameter of 1 3/4 inches even where unbrowsed. On the average, for good quality site, from ten to twenty years was required beyond 1 3/4 inches diameter, or 45 to 55 total years to produce seven-foot posts. Trees on medium sites required twenty to thirty years or 65 to 75 total years to reach this size. There was, therefore, a considerable gap in years from the peak of browse production to the time a tree can be cut for a seven-foot post.

On public land where income to surrounding communities from sportsmen and tourists may be greater than from posts, management of white cedar as an aid in maintaining relatively high deer population levels may well be economically justifiable.

In managing white cedar swamps primarily for deer food, trees in closed stands should be cut soon after they reach two inches in diameter so that younger individuals of greater browse regeneration powers can take their place. For best results trees should not be allowed to grow beyond four inches in diameter. Trees of four inches were found to average approximately the same browse per tree as those only zero to three-fourths inches diameter. Thus beyond four inches diameter there would be less browse than could be gotten from much younger trees. Furthermore, these young trees have their most productive period ahead of them. Probably trees from zero to four inches diameter could be used for some products such as various types of stakes, which would held defray cutting expenses. Nelson (1951) has suggested cutting methods to use in different types of white cedar stands when management is for browse production.

From field observations and clipping studies, it appears that small openings placed in closed stands of trees would result in substantial increases in deer browse. For best results, openings should be maintained and not allowed to grow up into undesirable species. However, where pure stands of young white cedar present themselves it would be best, of course, to allow these trees to grow. The most efficient size, shape, and spacing of openings will have to be determined by further study. For this purpose Aldous (1941) has suggested openings of one-eighth to one-fourth acre in size spaced one-fourth to one-half mile apart, these openings to be gradually cleared over three to five seasons.

In open stands where it was found that larger trees tended to have more browse, the rate of foliage regeneration after removal by clipping or deer is not known. Perhaps light browsing would allow a continuous food supply until the trees were grown large enough to cut profitably for forest products. For maximum deer browse in such open stands the trees would have to be periodically thinned so that the branches of adjacent trees do not shade each other. Frequency of thinnings, of course, would be dependent on the growth rate.

Some distinction should perhaps be made between swamps of different site quality in regard to management. Medium quality sites under light deer utilization apparently will supply deer browse for a longer period than will those from good quality site, because trees from the former sites would be in the more productive size classes for a longer period, the growth rate being slower. Wherever possible poorer quality sites should be managed primarily for deer food rather than forest products since the slower average tree growth appears to benefit browse production but not wood production.

SUMMARY

1. Deer browse clipping studies to determine the effects of age and growth on foliage production were carried out in seven cedar swamps located in northern Lower Michigan. Four swamps were relatively unbrowsed, one was moderately browsed, and two were overbrowsed.
2. All white cedars in thirty-seven 1/100th-acre quadrats and a number of individual trees were clipped, aged, and measured in diameter and height. Light readings were taken to determine the light reaching the browse producing zone.
3. In the unbrowsed closed stands the peak in browse production per tree was found to be in trees 1 to 1 3/4 inches in diameter with little browse present beyond eight inches diameter. Moderately browsed and overbrowsed trees did not follow this trend because of the effects of deer utilization.
4. Results suggested that moderate browsing stimulated browse production.
5. Browse present on trees growing under conditions of 100 percent available light was directly related to tree size.
6. A highly significant association was found between the amount of light received and browse production under unbrowsed conditions. Openings adjacent to quadrats caused relatively more browse to be present. No significant associations between light and browse were present under moderate or overbrowsed conditions.
7. Tree age or site quality differences alone were found to have little influence on the browse present.

8. There was a considerable gap in years between the point of maximum deer browse production and the time when a tree could be cut for seven-foot posts.

9. Management to provide more deer food should aim toward cutting trees after they reach two but before they reach four inches in diameter, creating small openings throughout closed stands, and continual thinning in more open stands to prevent branches of adjacent trees from overlapping. Poorer quality sites especially should be managed primarily for deer food wherever possible.

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APPENDIXES

APPENDIX A: TABLES

TABLE X

LOCATION OF QUADRATS AND INDIVIDUAL TREES

Swamp	Quadrats	County	Location Sub-division	Sec-tion	T	R
Fife Lake Outlet Swamp	D1, D2	Grand Traverse	SW 1/4 SE 1/4	24	25N	9W
Gould Creek Swamp	E1, E2	Kalkaska	SW 1/4 SW 1/4	19	25N	8W
Round Lake Swamp	B1, Individual trees	"	NE 1/4 SW 1/4	21	28N	8W
Little Rapid River Swamp	A1, A2	"	NW 1/4 SW 1/4	8	27N	7W
" " "	F1, F2	"	NW 1/4 SW 1/4	8	27N	7W
" " "	A3, A4, A5	"	NE 1/4 SW 1/4	8	27N	7W
" " "	F3, F4, F5	"	NE 1/4 SE 1/4	7	27N	7W
" " "	F6	"	NW 1/4 SE 1/4	7	27N	7W
" " "	F7	"	NE 1/4 NW 1/4	7	27N	7W
" " "	F8, Individual trees	"	SE 1/4 NW 1/4	7	27N	7W
Dead Stream Swamp	G1, G2, G3, G4, G5	Roscommon	SE 1/4 NW 1/4	33	24N	4W

TABLE X continued

Swamp	Quadrats	County	Location Sub-division	Sec-tion	T	R
Dead Stream Swamp	G6	Roscommon	NW 1/4 NE 1/4	4	23N	4W
" " "	G7, G8, G9	"	NE 1/4 NW 1/4	33	24N	4W
" " "	H1	"	SW 1/4 SE 1/4	34	24N	4W
Bear Creek Swamp	I1, I2, I3, I4	"	SE 1/4 SE 1/4	30	22N	4W
St. Helen Swamp	S1, S2, S3, S4	"	SE 1/4 SE 1/4	15	23N	1W
" " "	S5	"	NE 1/4 SE 1/4	15	23N	1W

TABLE XI

DESCRIPTION OF STUDY PLOTS

Quadrat	Basal Area Of Living Cedars	Number of Living White Cedars	Percent Available Light	Total White Cedar Browse
Unbrowsed				
A1	98 sq. in.	13	2.4	196 grams
A2	181 " "	15	2.4	14 "
A3	230 " "	15	6.8	11 "
A4	359 " "	9	.6	8 "
A5	282 " "	69	18.0	4,632 "
B1	205 " "	25	1.6	2,292 "
D1	338 " "	10	1.1	0 "
D2	351 " "	12	1.9	12 "
E1	171 " "	71	11.8	3,993 "
E2	120 " "	71	44.0	10,680 "
F1	197 " "	21	1.6	18 "
F2	192 " "	20	2.4	146 "
F3	300 " "	16	1.8	527 "

TABLE XI continued

Quadrat	Basal Area Of Living Cedars	Number of Living White Cedars	Percent Available Light	Total White Cedar Browse
Unbrowsed				
F4	207 sq. in.	25	1.4	445 grams
F5	308 " "	24	3.7	810 "
F6	216 " "	55	2.6	8,105 "
F7	117 " "	50	36.0	19,159 "
F8	158 " "	93	52.0	30,581 "
Moderately browsed				
G1	281 sq. in.	23	4.9	797 grams
G2	270 " "	27	2.3	719 "
G3	278 " "	44	2.4	762 "
G4	401 " "	15	not taken	843 "
G5	337 " "	23	not taken	1,212 "
G6	332 " "	18	not taken	337 "
G7	106 " "	39	28.0	1,696 "

TABLE XI continued

Quadrat	Basal Area Of Living Cedars	Number of Living White Cedars	Percent Available Light	Total White Cedar Browse
Moderately browsed				
G8	272 sq. in.	46	2.3	331 grams
G9	396 " "	22	11.0	183 "
H1	192 " "	31	not taken	7,074 "
Overbrowsed				
I1	234 sq. in.	52	10.8	462 grams
I2	335 " "	20	4.3	42 "
I3	367 " "	46	5.0	79 "
I4	237 " "	28	10.0	123 "
S1	180 " "	35	4.2	31 "
S2	290 " "	48	4.3	24 "
S3	276 " "	22	49.6	0 "
S4	237 " "	19	3.1	0 "
S5	283 " "	37	24.5	5 "

TABLE XII

RELATIONSHIPS OF AGE AND HEIGHT TO DIAMETER, ROUND LAKE SWAMP*

Diameter (Class marks in inches)	Age In Years				Height In Feet			
	No.	Mean	Range	Standard Deviation	No.	Mean	Range (nearest foot)	Standard Deviation
0	5	8.2	8-9	.4	5	3.4	3-4	.5
1/4	9	8.7	7-10	1.0	9	5.4	5-6	.5
1/2	5	10.8	9-14	2.2	5	7.0	6-8	.2
3/4	2	22.5	20-25	3.5	2	9.0	7-11	2.8
1	1	25.0			1	13.0		
1 1/4	3	28.7	28-29	.6	3	14.0	11-16	2.6
1 3/4	2	26.5	26-27	2.2	2	17.0	16-18	1.4
2	1	27.0			1	15.0		
2 1/4	1	32.0			1	25.0		
3	1	29.0			1	22.0		
3 1/4	2	32.5	30-35	3.5	2	25.0		
3 1/2	1	32.0			1	23.0		
4	1	35.0			1	29.0		
4 1/4	4	32.8	30-35	2.0	4	27.2	26-29	1.3

TABLE XII continued

Diameter (class marks in inches)	Age In Years				Height In Feet			
	No.	Mean	Range	Standard Deviation	No.	Mean	Range (nearest foot)	Standard Deviation
4 3/4	1	31.0			1	28.0		
6	1	34.0			1	27.0		
8 1/4	1	40.0			1	31.0		

* Includes all individual and quadrat trees.

TABLE XIII

RELATIONSHIPS OF AGE AND HEIGHT TO DIAMETER, FIFE LAKE OUTLET SWAMP*

Diameter (class marks in inches)	Age In Years				Height In Feet			
	No.	Mean	Range	Standard Deviation	No.	Mean	Range (nearest foot)	Standard Deviation
3 1/4	3	54.0	48-58	5.3	3	37.0	31-44	6.6
3 1/2	2	37.0	27-47	14.1	3	30.3	30-31	.6
3 3/4	1	61.0			1	45.0		
4	1	54.0			1	31.0		
4 1/4	1	69+			1	47.0		
4 3/4	2	66.0	65-67	1.4	2	34.5	34-35	.7
5	1	69.0			1	53.0		
5 1/2	1	70.0			1	52.0		
6 1/4	1	67.0			1	52.0		
6 1/2	1	67.0			1	54.0		
6 3/4	1	59.0			1	51.0		
7	1	74.0			1	56.0		
9 1/4	2	66.0	65-67	1.4	2	55.0	54-56	1.4
9 3/4	1	57+			1	58.0		

TABLE XIII continued

Diameter (class marks in inches)	Age In Years				Height In Feet			
	No.	Mean	Range	Standard Deviation	No.	Mean	Range (nearest foot)	Standard Deviation
10	1	77.0			2	56.0	54-58	2.8
10 1/4	1	60.0			1	57.0		
10 3/4	1	67.0			1	54.0		
11 3/4	1	44+			1	58.0		

* Includes all quadrat trees which could be accurately aged, except those marked "+", which were trees that could not be totally aged but were included because they were the only representatives in their respective classes.

TABLE XIV

RELATIONSHIPS OF AGE AND HEIGHT TO DIAMETER, GOULD CREEK SWAMP*

Diameter (class marks in inches)	Age In Years				Height In Feet			
	No.	Mean	Range	Standard Deviation	No.	Mean	Range (nearest foot)	Standard Deviation
0	24	15.7	6-30	6.0	24	3.0	2-4	.3
1/4	5	15.8	11-21	4.8	5	5.0	5	
1/2	15	27.5	12-35	6.2	15	6.1	5-8	1.0
3/4	13	30.8	22-39	6.2	13	8.0	5-9	1.5
1	14	34.6	25-45	6.2	14	9.8	8-14	3.5
1 1/4	12	35.7	24-44	6.7	12	12.6	9-22	3.0
1 1/2	11	38.7	25-48	7.1	11	14.9	11-23	1.4
1 3/4	9	35.7	28-45	5.3	9	13.8	11-16	3.0
2	7	39.1	34-47	4.8	7	16.3	13-21	5.0
2 1/4	5	34.4	24-46	8.2	5	18.6	14-25	5.0
2 1/2	3	46.0	44-48	2.0	3	19.3	18-20	1.2
2 3/4	2	33.5	23-44	14.8	2	22.0	19-25	4.2
3	4	42.2	38-46	4.3	4	21.0	19-25	2.8
3 1/2	4	41.8	32-46	6.5	4	25.0	22-27	2.2

TABLE XIV continued

Diameter (class marks in inches)	Age In Years				Height In Feet			
	No.	Mean	Range	Standard Deviation	No.	Mean	Range (nearest foot)	Standard Deviation
3 3/4	1	42.0			1	19.0		
4	2	46.0	45-47	1.4	2	22.0	19-25	4.2
5 3/4	1	71.0			1	22.0		

* Includes all quadrat trees.

TABLE XV

RELATIONSHIPS OF AGE AND HEIGHT TO DIAMETER, LITTLE RAPID RIVER SWAMP*

Diameter (class marks in inches)	Age In Years				Height In Feet			
	No.	Mean	Range	Standard Deviation	No.	Mean	Range (nearest foot)	Standard Deviation
0	76	20.7	6-46	9.8	76	3.1	2-4	6.0
1/4	15	28.1	12-57	12.9	15	5.2	5-6	.2
1/2	25	33.2	22-47	7.2	25	6.2	5-8	.8
3/4	20	40.0	21-56	8.2	20	8.3	7-14	1.7
1	22	42.0	19-55	8.8	23	10.3	8-15	1.6
1 1/4	30	40.8	25-59	9.5	30	11.8	9-16	2.2
1 1/2	34	44.8	25-59	7.9	35	14.5	9-20	2.9
1 3/4	23	46.0	31-83	10.8	24	17.2	9-22	3.5
2	18	50.7	39-61	6.3	19	16.4	6-23	4.7
2 1/4	14	53.1	42-63	7.7	14	20.3	14-24	3.0
2 1/2	18	53.2	40-66	7.7	19	22.3	16-26	2.4
2 3/4	6	49.2	35-79	15.8	6	21.2	16-25	4.2
3	16	54.5	40-64	8.1	16	24.4	19-30	2.8
3 1/4	13	57.5	38-72	9.6	16	23.4	18-30	4.0

TABLE XV continued

Diameter (class marks in inches)	Age In Years				Height In Feet			
	No.	Mean	Range	Standard Deviation	No.	Mean	Range (nearest foot)	Standard Deviation
3 1/2	11	53.2	35-67	8.9	13	23.7	17-30	4.2
3 3/4	6	66.2	44-92	17.0	9	27.0	15-34	5.0
4	10	64.1	36-138	28.1	11	27.3	23-33	3.4
4 1/4	5	59.6	45-79	14.1	5	30.6	29-33	1.7
4 1/2	7	61.8	41-107	21.1	8	26.0	21-31	3.8
4 3/4	4	57.8	49-67	7.4	6	31.0	28-33	2.2
5	4	58.0	49-74	11.0	5	33.6	28-45	6.7
5 1/4	2	92.5	45-140	67.2	2	25.5	24-27	2.1
5 1/2	5	65.0	58-75	6.8	5	34.6	28-41	5.7
5 3/4	2	69.0	63-75	8.5	3	26.3	24-30	3.2
6	1	70+			1	32.0		
6 1/4	1	48.0			1	36.0		
6 1/2	3	72.3	67-81	7.6	6	34.5	28-42	5.0
6 3/4	1	68.0			1	32.0		
7	1	58.0			2	41.0	35-47	8.5
7 1/4	1	58.0			1	37.0		

TABLE XV continued

Diameter (class marks in inches)	Age In Years				Height In Feet			
	No.	Mean	Range	Standard Deviation	No.	Mean	Range (nearest foot)	Standard Deviation
8	2	67.0	65-69	2.8	2	35.5	30-41	7.8
8 1/4	1	108+			1	40.0		
8 1/2	1	122.0			1	35.0		
9 1/4	1	120.0			2	36.5	36-37	.7
13 3/4	1	61+			1	66.0		
15	1	159.0			1	60.0		

* Includes all individual and quadrat trees which could be accurately aged, except those marked "+" which were trees that could not be totally aged but were included because they were the only representatives in their respective classes.

TABLE XVI

RELATIONSHIPS OF AGE AND HEIGHT TO DIAMETER, DEAD STREAM SWAMP*

Diameter (class marks in inches)	Age In Years				Height In Feet			
	No.	Mean	Range	Standard Deviation	No.	Mean	Range (nearest foot)	Standard Deviation
0	4	22.0	15-32	7.2	4	3.0	2-4	1.0
1/4	2	23.5	16-31	10.6	2	5.0	5	
1/2	7	32.7	23-41	6.4	7	7.1	5-8	1.2
3/4	18	28.4	19-38	3.9	19	8.8	8-11	.8
1	19	41.2	23-77	15.1	19	9.8	8-12	1.3
1 1/4	15	41.8	25-66	13.0	15	11.5	8-15	2.1
1 1/2	21	46.9	18-84	16.9	22	13.6	11-17	1.9
1 3/4	18	56.2	29-111	24.7	18	14.7	9-21	3.8
2	23	52.0	32-107	16.5	27	17.1	11-23	3.5
2 1/4	9	52.8	35-85	14.6	12	16.7	10-22	3.8
2 1/2	21	63.7	28-121	29.0	23	19.0	14-25	3.2
2 3/4	9	60.7	34-126	30.4	9	21.2	19-25	2.0
3	11	57.4	36-108	28.1	11	22.4	17-25	2.8
3 1/4	9	58.2	36-82	15.1	9	21.8	18-26	3.0

TABLE XVI continued

Diameter (class marks in inches)	Age In Years				Height In Feet			
	No.	Mean	Range	Standard Deviation	No.	Mean	Range (nearest foot)	Standard Deviation
3 1/2	10	61.8	34-102	19.9	10	23.9	19-30	4.1
3 3/4	3	60.0	37-88	25.9	3	23.7	21-25	2.3
4	9	68.8	36-125	31.3	9	25.7	21-33	3.9
4 1/4	7	74.3	54-119	24.2	9	26.3	22-34	3.3
4 1/2	6	94.2	46-136	31.5	7	22.3	19-27	3.0
4 3/4	3	77.3	62-98	18.6	4	28.0	20-35	7.2
5	4	114.2	67-154	38.4	4	27.8	26-31	2.2
5 1/4	1	67.0			2	30.0	28-32	2.8
5 1/2	5	72.6	50-93	20.5	5	25.8	21-35	5.8
5 3/4	3	109.7	79-127	27.3	3	31.7	26-35	4.9
6	2	85.0	76-94	12.7	2	29.0	27-31	2.8
6 1/4	1	108.0			1	31.0		
6 1/2	5	105.8	77-158	31.3	6	29.5	28-34	2.3
6 3/4	2	129.5	96-163	47.4	2	26.0	25-27	1.4
7	3	95.3	64-131	39.3	3	33.3	29-40	5.8
7 1/4	2	51.5	43-60	12.0	2	32.5	28-37	6.4

TABLE XVI continued

Diameter (class marks in inches)	Age In Years				Height In Feet			
	No.	Mean	Range	Standard Deviation	No.	Mean	Range (nearest foot)	Standard Deviation
7 1/2	3	69.7	55-85	15.0	3	35.0	31-42	6.0
8	1	86+			1	34.0		
8 3/4	1	81.0			1	30.0		
9	1	126.0			1	37.0		
9 1/4	1	85.0			1	38.0		
10 1/4	2	87.5+			2	35.5	35-36	.7
10 3/4	1	66+			1	34.0		
11	2	87.5+			2	37.5	35-40	3.5

* Includes all quadrat trees that could be accurately aged except those marked "+", which were trees that could not be totally aged but were included because they were the only representatives in their respective classes.

TABLE XVII

RELATIONSHIPS OF AGE AND HEIGHT TO DIAMETER, BEAR CREEK SWAMP*

Diameter (class marks in inches)	Age In Years				Height In Feet			
	No.	Mean	Range	Standard Deviation	No.	Mean	Range (nearest foot)	Standard Deviation
1/2	1	31.0			1	10.0		
3/4	3	38.7	34-47	7.2	3	8.3	8-9	.5
1	13	51.2	35-65	8.6	14	10.6	8-14	1.4
1 1/4	18	53.4	41-74	9.6	18	13.1	10-16	2.6
1 1/2	19	58.7	40-74	8.9	19	14.9	11-20	2.6
1 3/4	19	61.4	50-73	8.1	22	16.0	12-25	3.5
2	17	60.4	35-75	3.8	18	18.7	12-29	4.5
2 1/4	14	59.4	41-73	11.7	15	19.4	12-25	3.2
2 1/2	10	60.3	32-81	16.0	11	22.5	17-27	3.3
2 3/4	3	57.3	46-78	17.9	3	27.3	26-30	2.4
3	8	65.5	55-75	7.0	10	27.8	18-32	4.2
3 1/4	5	68.0	60-74	6.0	5	26.4	22-31	3.6
3 1/2	11	70.4	57-79	4.8	12	26.2	20-34	5.2
3 3/4	4	66.5	61-72	4.6	4	28.2	22-32	5.0
4	9	68.9	54-83	10.0	10	30.1	26-34	2.7

TABLE XVII continued

Diameter (class marks in inches)	Age In Years				Height In Feet			
	No.	Mean	Range	Standard Deviation	No.	Mean	Range (nearest foot)	Standard Deviation
4 1/4	6	67.5	55-81	11.0	9	31.7	27-34	2.5
4 1/2	5	62.6	53-78	10.1	5	30.0	25-34	4.3
4 3/4	3	64.0	47-78	15.7	3	27.7	25-31	3.0
5	4	76.0	66-87	8.8	5	28.0	25-30	2.1
5 1/4	4	72.5	70-80	5.0	4	31.0	25-34	4.1
5 1/2	3	77.7	70-91	11.6	4	32.5	27-40	5.4
5 3/4	2	70.0			2	35.0	33-37	2.8
6	1	66.0			3	32.3	31-34	1.5
6 3/4	1	100.0			1	35.0		
7	1	69.0			1	35.0		
7 1/4	1	80+			1	32.0		
7 1/2	1	75.0			1	29.0		
8	1	80.0			1	49.0		
9 1/2	1	73.0			1	41.0		

* Includes all individual and quadrat trees which could be accurately aged except that one marked "+" which could not be totally aged but was the only representative in its class.

TABLE XVIII

RELATIONSHIPS OF AGE AND HEIGHT TO DIAMETER, ST. HELEN SWAMP*

Diameter (class marks in inches)	Age In Years				Height In Feet			
	No.	Mean	Range	Standard Deviation	No.	Mean	Range (nearest foot)	Standard Deviation
1	9	46.7	35-57	8.4	10	10.0	8-12	1.1
1 1/4	11	50.4	41-63	6.3	11	13.2	10-18	3.0
1 1/2	16	62.8	47-79	8.3	16	14.2	10-19	2.2
1 3/4	14	60.8	46-90	10.3	15	16.7	11-21	2.8
2	12	63.6	51-80	8.1	14	19.1	15-24	2.3
2 1/4	9	65.0	43-76	14.9	11	20.0	17-23	1.9
2 1/2	14	61.0	43-91	12.8	17	20.8	15-25	2.7
2 3/4	5	59.8	49-63	6.0	5	26.4	20-35	5.4
3	6	67.0	54-80	10.0	8	22.6	19-31	3.8
3 1/4	3	66.7	47-94	24.4	4	25.2	21-33	5.3
3 1/2	5	76.8	52-87	10.4	9	25.2	19-37	5.6
3 3/4	4	76.2	57-89	14.1	4	26.8	23-30	3.0
4	5	69.2	56-80	8.6	5	26.8	24-31	2.7
4 1/4	6	70.8	59-86	10.3	6	28.7	23-36	4.4

TABLE XVIII continued

Diameter (class marks in inches)	Age In Years				Height In Feet			
	No.	Mean	Range	Standard Deviation	No.	Mean	Range (nearest foot)	Standard Deviation
4 1/2	7	63.7	52-76	9.1	7	29.1	25-39	5.9
4 3/4	2	74.0	64-84	14.1	2	25.0	20-30	7.1
5	6	76.8	61-89	12.2	6	29.8	26-37	4.3
5 1/2	3	71.0	57-83	13.1	3	30.7	26-36	4.4
6	3	80.7	61-96	17.9	3	32.3	29-35	3.0
6 1/4	2	86.5	86-87	.7	2	37.5	37-38	.7
7	1	99.0			1	32.0		

*Includes all quadrat trees which could be accurately aged.

APPENDIX B: PLANTS FOUND ASSOCIATED WITH WHITE CEDAR

Scientific Name	Common Name
Abies balsamea (L.) Mill.*	Balsam fir
Acer rubrum L.	Red maple
Acer saccharinum L.	Silver maple
Acer spicatum Lam.	Mountain maple
Actaea rubra (Ait.) Willd.	Red baneberry
Adiantum pedatum L.	Maidenhair fern
Alnus rugosa (Du Roi) Spreng.	Speckled alder
Ambrosia artemisifolia var. elatior (L.) Discourtils	Hogweed
Amelanchier laevis Wieg.	Juneberry
Anemone quinquefolia L. var. interior Fern.	Wood anemone
Aralia nudicaulis L.	Wild sarsaparilla
Arisaema triphyllum (L.) Schoot	Small jack-in-the-pulpit
Asclepias incarnata L.	Swamp milkweed
Aster junciformis Rydb.	Aster
Aster laevis L.	Smooth aster
Aster lateriflorus (L.) Britt.	Calico aster
Aster puniceus L.	Purple-stemmed aster
Aster Tradescanti L.	Aster

* Plant names after Fernald (1950).

APPENDIX B continued

Scientific Name	Common Name
Betula lutea Michx. F.	Yellow birch
Betula papyrifera Marsh.	Paper birch
Bidens connata Muhl.	Beggar tick
Botrychium virginianum (L.) Sw.	Rattlesnake fern
Calopogon pulchellus Salisb., R. Br.	Grass-pink
Caltha palustris L.	Marsh marigold
Campanula aparinoides Pursh.	Marsh bluebell
Cardamine pratensis L. var. palustris Wimm. and Grab.	Cuckoo flower
Carex spp.	Sedge
Chamaedaphne calyculata var. angustifolia (Ait.) Rehd.	Leatherleaf
Chelone glabra L.	Turtlehead
Cicuta bulbifera L.	Water hemlock
Circaea alpina L.	Enchanter's nightshade
Cirsium altissimum L. Spreng.	Tall thistle
Cirsium muticum Michx.	Swamp thistle
Clintonia borealis (Ait.) Raf.	Corn-lily
Coptis groenlandica (Oeder) Fern.	Goldthread
Corallorhiza maculata Raf.	Spotted coral-root
Corallorhiza trifida Chatelain	Early coral-root
Cornus alternifolia L. f.	Alternate-leaved dogwood
Cornus canadensis L.	Bunch berry

APPENDIX B continued

Scientific Name	Common Name
Cornus obliqua Raf.	Silky dogwood
Cornus racemosa Lam.	Gray dogwood
Cornus Rugosa Lam.	Round-leaved dogwood
Cornus stolonifera Michx.	Red-osier dogwood
Corylus cornuta Marsh.	Beaked hazelnut
Cypripedium calceolus L. var. pariflorum (Salisb.) Fern.	Small yellow lady's slipper
Cypripedium reginae Walt.	Showy lady's slipper
Decodon verticillatus (L.) Ell.	Swamp loosestrife
Dierville Lonicera Mill.	Bush honeysuckle
Dryopteris cristata (L.) Gray	Crested wood-fern
Dryopteris disjuncta (Ledeb.) C. V. Mort.	Oak fern
Dryopteris spinulosa (O. F. Muell.) Watt	Florist's fern
Epigaea repens L.	Trailing arbutus
Epilobium leptophyllum Raf.	Willow-herb
Equisetum fluviatile L.	Water horsetail
Equisetum palustre L.	Marsh horsetail
Eupatarium fistulosum Barrett	Joe-pye-weed
Fragaria virginiana Duchesne	Wild strawberry
Fraxinus nigra Marsh.	Black ash
Galium asprellum Michx.	Rough bedstraw
Galium trifidum L.	Small bedstraw

APPENDIX B continued

Scientific Name	Common Name
Galium triflorum Michx.	Small bedstraw
Gaultheria hispidula (L.) Bigel	Creeping snowberry
Gaultheria procumbens L.	Checkerberry
Gentiana crinita Froel.	Fringed gentian
Gentiana rubricaulis Schwein	Closed gentian
Habernaria hyperborea (L.) R. Br.	Northern green orchis
Habernaria obtusata (Pursh.) Richards	Blunt leaf orchis
Hieracium canadense Michx.	Canada hawkweed
Ilex verticillata (L.) Gray	Winterberry
Impatiens pallida Nutt.	Jewelweed
Larix laricina (Du Roi) K. Koch	American larch
Ledum groenlandicum Oeder	Labrador tea
Lilium philadelphicum L.	Wood lily
Linnaea borealis L. var. americana (Forbes) Rehd.	Twinflower
Lobelia inflata L.	Indian tobacco
Lobelia Kalmii L.	Kalm's lobelia
Lobelia spicata Lam.	Pale spiked lobelia
Lonicera canadensis Bartr.	American fly honeysuckle
Lonicera oblongifolia (Goldie) Hook. var. altissima (Jennings) Rehd.	Swamp fly honeysuckle
Lycopodium annotinum L.	Bristly clubmoss
Lycopodium obscurum L.	Flatbrand groundpine

APPENDIX B continued

Scientific Name	Common Name
Lycopus uniflorus Michx.	Water horehound
Lycopus virginicus L.	Water horehound
Lysimachia ciliata L.	Fringed loosestrife
Lysimachia thyrsiflora L.	Tufted loosestrife
Maianthemum canadense Desf.	Lily of the valley
Mirabilis nyctaginea (Michx.) Mac M.	Umbrella-wort
Mitchella repens L.	Partridge-berry
Mitella nuda L.	Miterwort
Monotropa uniflora L.	Indian pipe
Myrica Gale L.	Sweet gale
Nemopanthus mucronata (L.) Trel.	Mountain holly
Onoclea sensibilis L.	Sensitive fern
Orchis rotundifolia Banks	Small round-leaved orchid
Osmunda cinnamomea L.	Cinnamon fern
Osmunda regalis L.	Royal fern
Parnassia glauca Raf.	Grass of Parnassus
Picea glauca (Moluch) Voss	White spruce
Picea mariana (Mill.) BSP.	Black spruce
Pinus Strobus L.	White pine
Polygala paucifolia Willd.	Fringed milkwort
Polygonum sagittatum L.	Arrow-leaved tearthumb
Populus balsamifera L.	Balsam poplar
Populus tremuloides Michx.	Quaking aspen

APPENDIX B continued

Scientific Name	Common Name
Prunus pennsylvanica L. f.	Fire cherry
Pteridium aquilinum var. *latiusculum* (Desv.) Underw.	Bracken fern
Pyrola elliptica Nutt.	Shinleaf
Pyrola minor L.	Shinleaf
Pyrola secunda L. var. *obtusata* Turcz.	One-sided pyrola
Pyrus americana (Marsh.) DC.	Mountain ash
Pyrus melanocarpa (Michx.) Willd.	Black chokeberry
Quercus ellipsoidalis E. J. Hill	Jack oak
Ranunculus septentrionalis Poir.	Swamp buttercup
Rhamnus alnifolia L'Her.	Alder-leaved buckthorn
Rhus typhina L.	Staghorn sumac
Ribes americanum Mill.	Wild black current
Ribes lacustre (Pers.) Poir.	Swamp black current
Rosa palustris Marsh.	Swamp rose
Rubus idaeus L.	Red raspberry
Rubus pubescens Raf.	Dwarf raspberry
Salix lucida Muhl.	Shining willow
Salix sericea Marsh.	Silky willow
Sambucus canadensis L.	Common elderberry
Sanicula marilandica L.	Black snakeroot
Sarracenia purpurea L.	Pitcher plant
Scutellaria epilobiifolia A. Hamilton	Skullcap

APPENDIX B continued

Scientific Name	Common Name
Smilacina trifolia (L.) Desr.	Bog solomon-plume
Solidago altissima L.	Goldenrod
Solidago rugosa Ait.	Rough-stemmed goldenrod
Solidago uliginosa Nutt.	Goldenrod
Spiranthes cernua (L.) Richard	Common screw-auger
Spiranthes Romanzoffiana Cham.	Slender lady's tresses
Symplocarpus foetidus (L.) Nutt.	Skunk-cabbage
Taxus canadensis Marsh.	American yew
Tilia americana L.	Basswood
Trientalis borealis Raf.	Star flower
Trillium cernuum L.	Nodding trillium
Tsuga canadensis (L.) Carr.	Hemlock
Vaccinium macrocarpon Ait.	Large cranberry
Vaccinium myrtilloides Michx.	Canada blueberry
Vaccinium Oxycoccus L. var. ovalifolium Michx.	Small cranberry
Viburnum cassinoides L.	Wild raisin
Viburnum trilobum Marsh.	High-bush cranberry
Viola nephrophylla Greene	Blue violet
Viola renifolia Gray var. Brainerdii (Greene) Fern.	White violet