REPRODUCING JACK PINE BY THE SHELTERWOOD METHOD IN NORTHERN LOWER MICHIGAN

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ABSTRACT

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By

Edward Webster Caveney, Jr.

Since the beginning of forest management in Michigan, reproducing jack pine has been a problem. Jack pine is a fire species, and with the exclusion of wild fires, regeneration of the species must be accomplished by other means.

For over 10 years the Forestry Division of the Michigan Department of Natural Resources has been using a 2-cut shelterwood method to regenerate many of the jack pine stands in northern Lower Michigan. No formal evaluation of this method was made until this study was undertaken.

The objective of this study was to evaluate the shelterwood method as it was being used by the Forestry Division of the Michigan Department of Natural Resources to regenerate jack pine. To accomplish this, 42 stands were examined in Otsego, Kalkaska, Crawford, Oscoda, and Ogemaw Counties in central northern Lower Michigan.

The following data were recorded for each stand: (1) soil type, (2) stand age when cut, (3) date cut, (4) volume removed, (5) skidding equipment, (6) cutting specifications (7) residual basal area, (8) ground cover, and (9) reproduction. Within each stand, a residual basal area plot was taken every 4 chains, and 5 mil-acre plots were taken at each residual basal area plot. In the 42 stands, 623 basal area plots and 3,115 mil-acre plots were taken.

Thirty-six percent of the mil-acre plots were stocked with jack pine. The individual stands varied between 8 percent and 67 percent stocked. On the average, there were 754 jack pine seedlings per acre, and for individual stands this varied from 80 to 2,349 seedlings per acre.

Twenty-four variables for each stand were used for multiple regression analysis. Two final prediction equations were computed; one for predicting percent of mil-acres stocked with jack pine, and the other for predicting jack pine seedlings per acre.

Residual basal area of jack pine was found to have an effect on stocking. High residual basal areas (70 square feet) were found to have highest stocking of newly established seedlings. However, growth was inhibited by these high basal areas. Average stocking was highest under 40 square feet of residual basal area.

Open-coned trees were found to be very important in the residual stand. The stocking was increased with increasing amounts of open-coned trees.

Both the height of ground cover and its components had effects on stocking. Stocking was highest where ground cover was less than 6 inches high and where its components were mainly reindeer lichen, litter, and green mosses.

The stocking increased as the number of years since cutting increased. Stands cut 1 growing season before the study were only 8 percent stocked, while stands cut 9 years before the study were 55 percent stocked.

Many stands were found to be converting to low quality oak. It was determined that this conversion could be greatly reduced, if not stopped, by the removal of the oak as soon as possible in the life of the stand.

The shelterwood method accomplishes quite well the multiple-use objectives of the Forestry Division. This method fits in well with the wildlife management and recreational management objectives.

The shelterwood method seems to be well adapted to reproducing jack pine in northern Lower Michigan. If more open-coned trees are retained in the seed cut, the percent of open-coned trees can be expected to increase in future stands which will make this method even more successful than it has been in the past.

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INTRODUCTION

Jack pine[1] is a very important species in the forests of Michigan. In the State Forests of northern Lower Michigan, the jack pine type occupies 252,000 acres, just over 14 percent of the total forest area.

The demand for jack pine timber is very good. The stumpage prices in some areas of northern Lower Michigan are over $4.50 per cord. In this same area the demand for jack pine is greater than the allowable cut. Therefore, it is desirable to increase the production of jack pine.

Ever since Michigan's forests began to be managed, regenerating jack pine has been a problem. During and after the logging of the virgin timber, forest fires burned across Michigan unchecked. As jack pine is a "fire species," its area increased. Forest fires are now infrequent, and other methods of regenerating jack pine must be used.

Almost every silvicultural method of regenerating jack pine has been tried with varying degrees of success. For over 10 years, the Michigan Department of Natural

[1]Scientific names of species encountered in this study are listed in Appendix 1.

Resources has been using a form of the shelterwood method for regenerating many stands in the State Forests of northern Lower Michigan. Since no formal evaluation of this method had been made, this study was begun in the summer of 1968.

The objectives of this study are to evaluate the shelterwood method for regenerating jack pine in Michigan's Lower Peninsula, to determine its success, and to analyze the effects various conditions have on the stocking that is obtained. Based on the results, recommendations are made as to the suitability of the shelterwood method for regenerating jack pine under various conditions.

REVIEW OF LITERATURE

Jack pine is a short-lived, small to medium tree. Its range extends from northern New England to the Lake States and across Canada to the foothills of the Rockies. It is the most northern American pine (17).

Jack pine is a pioneer species and is adapted to growing on very dry sandy or gravelly soils where other species have difficulty surviving. However, it grows best on well-drained loamy sands where the mid-summer water table is 4 to 6 feet below the surface (17).

Over most of its range, jack pine bears serotinous cones which open only after being subjected to high temperatures. The melting point of the bonding material at the tips of the cone scales is 122°F (50°C) (5).

The serotinous nature of jack pine apparently varies with the age of the stand as well as with the locality. Greater seed dispersal has been noted in 20-year-old stands than in 40- or 60-year-old stands. The 4-year average seedfall in the younger stands was 147,000 seeds per acre and 35,000 seeds per acre in the older stands (7). Along the southern edge of its range, jack pine bears nonserotinous cones which promptly open upon ripening and disperse their seeds during September or

October (17). In a seed source test plantation, open-coned trees appeared most frequently in sources from Lower Michigan, southern and western Minnesota, New Brunswick, and Maine (15).

The results of a one parent progeny test demonstrate that the open-coned characteristic is highly heritable, in that the progenies derived from open pollinated, open-coned mother trees showed a cone type ratio of 1 closed : 2 open : 1 mixed (14). This indicates that if only open-coned trees are favored, their percentage can be increased from very little to 50 percent in one generation.

The effective range of jack pine seed dissemination is about 2 tree heights. However, beyond 1 tree height, it is relatively low (17).

Jack pine seed usually germinates within 15 to 60 days after dissemination. The highest survival follows germination in the early spring (17).

Several studies have demonstrated that shade is an important factor in reducing mortality caused by heat and drought. Germination decreases significantly if seeds are exposed to sunlight for more than 4 hours per day, probably as a result of higher temperature and reduced surface moisture (10). The survival of 1- and 2-year-old seedlings was 29 to 33 percent and growth was 1 to 2 inches in the open, compared to 62 to 77 percent and 2 to 5 inches under 56 percent full sunlight (17). A study in Michigan found that shade definitely improved germination and early survival of seedlings (3).

Seedling establishment is best on mineral soil. In the Lake States, the chances that a seed will germinate and the seedling survive 2 years, is 9 to 12 times as great on mineral soil as on undisturbed soil (17). The reason humus is usually such a poor seedbed can be explained in terms of moisture relations. A study in Manitoba compared germination and early development on three types of seedbeds--mineral soil, mixed mineral soil, and humus--on fresh to moderately moist soils. In years of above normal precipitation, all three seedbeds were favorable (7).

Seedling growth is very slow for the first 3 years, and then increases rapidly the fourth and fifth years (1). The average heights of wild seedlings is 2 inches at 1 year, 6 inches at 2 years, and 1 to 3 feet at 4 years (17).

Jack pine is a very intolerant species, yet young seedlings can exist in light as low as 2.4 percent full sunlight. Under mature jack pine stands, seedlings are most frequent and abundant in light intensities of 11 to 30 percent of full sunlight, but greatest height growth is obtained in 52 percent of full sunlight (17). As was pointed out before, shade is an important factor in early survival of jack pine seedlings. The amount of shade seems to have little effect. It is believed that the complex shade patterns cast by slash and snags on burned-over areas contribute substantially to the densely stocked stands that result (7).

Most fully stocked natural jack pine stands of today are the result of wild fires (17). The crowns of the dead trees in a natural stand that has burned provide both seed and shade (8). There are from 400,000 to 2,000,000 seeds stored in the cones on an acre of mature jack pine (8,17). The shade provided by the dead crowns is beneficial for germination and establishment by giving protection from high temperature and excessive moisture loss (1,3,7).

Burning will not bring about jack pine regeneration from seed in slash. If the fire is hot enough to prepare the seedbeds and open the cones, the seed in the slash is destroyed. Therefore, enough trees must be left after the harvest to reseed the area (1,3,7). As many as 75 trees per acre may need to be left (19).

Jack pine can be successfully regenerated by fire if the depth of the humus is substantially reduced by burning, and the seedbeds created are adequately seeded (3,7).

The traditional clearcut method of cutting the trees and piling the slash does not result in adequate regeneration in many instances (7,9,11). On five clearcut areas in Canada, the range in stocking was 2 to 16 percent (7).

For success with the clearcutting method, there are two additional treatments which must be applied. First, the site must be scarified with something like an Athens disk to prepare a seedbed. Second, the cone-bearing slash must be scattered over the area in such a way that the cones are within 1 foot of the ground (4,7, 8,9,11). Higher temperatures are reached near the ground so the cones readily open and disperse their seed (4,7,17). In a Minnesota stand which was disked, logged, and the slash scattered, the stocking was 45 percent after 5 years (4). The Society of American Foresters suggests that unless 40 percent or more of the area is adequately stocked at the time of harvest, soil scarification or planting should be considered (16).

It is believed by some foresters that clearcut strips could be an improvement over clearcutting large areas, if the strip width and strip direction are properly chosen to suit the site and local climate. In one study, cut strips 66 feet wide, with 132 feet uncut between the strips, resulted in 45 percent stocking (11). In a study in Manitoba where clearcutting, seed tree cutting, and strip cutting were compared, the best results were obtained with strip cutting. At the end of 3 years, 14 percent of the mil-acres sampled were stocked (7).

A specific comment on using the shelterwood method to regenerate jack pine comes from Barrett (2, p. 108), where he recommends what appears to be a 2-cut shelterwood:

> A decision as to harvest method will be affected by the relative abundance of serotinous and open cones present on the trees. If open cones predominate, a seeding cut may be made about 5 years in advance of the final harvest cut. This should remove over half the total volume, leaving the larger-crowned trees with good cone crops. The final harvest should be made as a clearcutting as soon as regeneration is established.

STUDY AREA

The study area included State Forest lands in Otsego, Kalkaska, Crawford, Oscoda, and Ogemaw Counties in central northern Lower Michigan (Figure 1). The townships from within these counties were selected by the regional and district foresters of the Forestry Division, Michigan Department of Natural Resources, and included T32N, R1W in Otsego County; T27N, R5W in Kalkaska County; T25N, R4W and T27N, R1W in Crawford County; T28N, R1E and T27N, R2E in Oscoda County; and T24N, R1E in Ogemaw County. Within these seven townships, all stands that had been partially cut between 1958 and 1966 with the objective of regenerating them were included in the study. Several stands could not be used because they had been burned or the residual basal area had been cut.

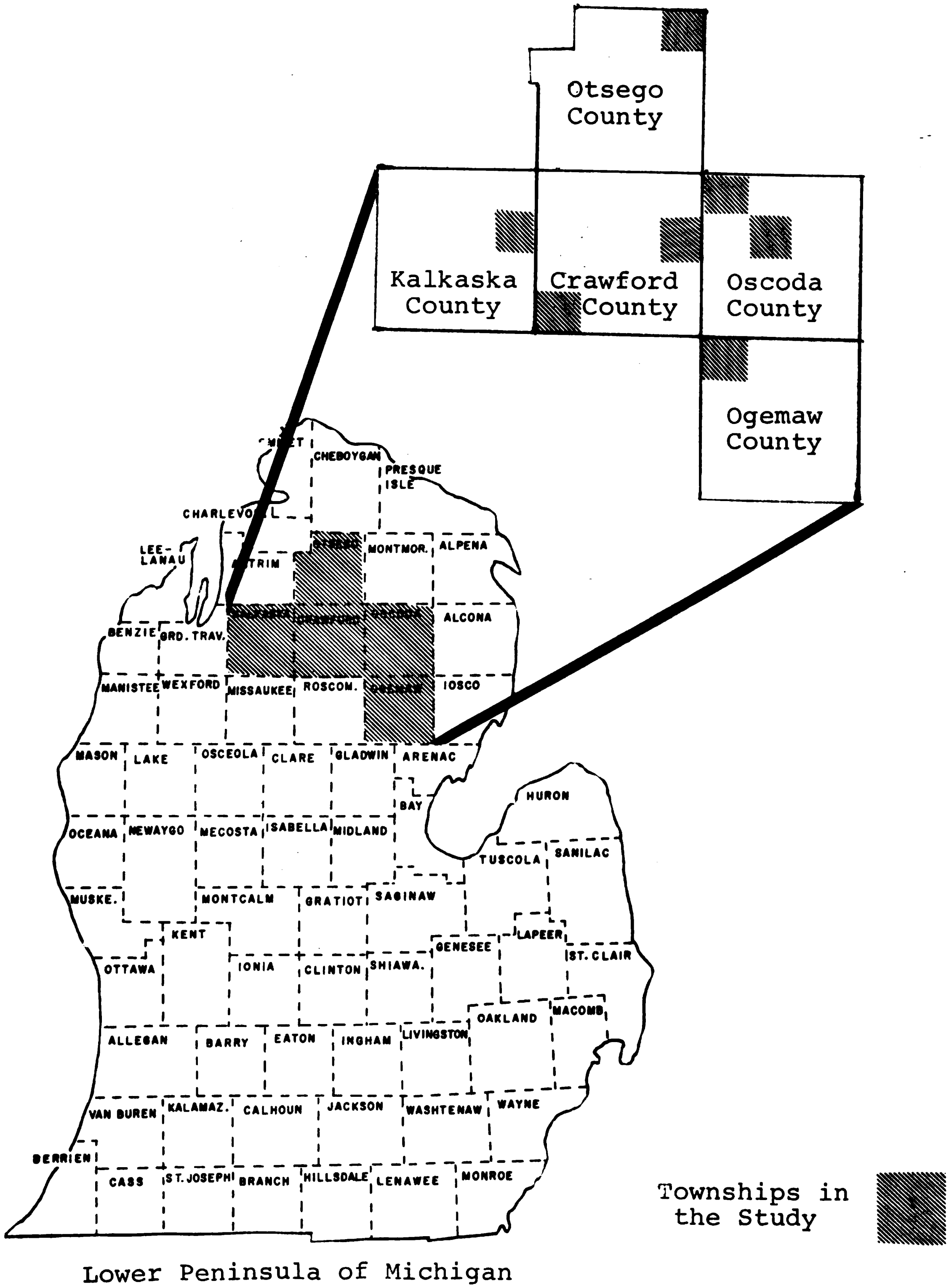

Figure 1. Michigan's lower peninsula showing the study area, and the townships involved in the study.

FIELD PROCEDURES

For every stand included in the study, the following information was gathered:

1. Location
2. Acreage
3. Soil type
4. Age of stand at time of cutting
5. Date of cutting
6. Volume removed per acre
7. Logging equipment used
8. Cutting specifications

Most of this information was available on the timber cutting permit in the files at the office of each State Forest. Information on the logging equipment was obtained during interviews with the Forestry Division Area Foresters and technicians. The age of the stand at the time of cutting was determined by boring residual trees and subtracting the time since cutting from the total age. Ring counts were also made on several stumps in each stand.

Within the stand, BAF 10 residual basal area point samples and mil-acre plots were taken. Every 4 chains within each stand, the residual basal area of jack pine and any other species was recorded on a point sample.

Also recorded was the basal area of any jack pine mortality that had occurred since the cutting. Basal area of open-coned (nonserotinous) trees was recorded. Basal areas were determined using a wedge prism.

At every residual basal area point sample, 5 mil-acre plots were taken to sample reproduction, which was recorded in three height classes: less than 1 foot, 1 to 3 feet, and over 3 feet. Also recorded on each mil-acre plot was the percent of ground cover, its major components, and its height by one of three height classes: less than 6 inches, 6 to 18 inches, and over 18 inches.

A 5-foot aluminum pole was used to mark the center of each mil-acre plot. A meter stick with a woven wire loop on one end was used to determine mil-acre plot boundaries. One mil-acre plot was established at the center of the basal area plot and the other four were one-quarter chain north, east, south and west of the basal area plot center.

Data were gathered from 42 stands, in which 623 basal area point samples and 3,115 mil-acre plots were taken.

The following stocking guide set forth by Candy (6) was used to evaluate reproduction in this study:

Stocking Class	Stocked Quadrats Percent
Fully Stocked	80 to 100
Well Stocked	60 to 79
Moderately Stocked	40 to 59
Under Stocked	20 to 39
Failure	Less than 20

RESULTS AND DISCUSSION

Results for the 42 stands are presented in Table 1. It is obvious that some stands regenerated very well and some very poorly. The data that are of the most interest are the percentages of mil-acres stocked with jack pine, and the average number of jack pine seedlings per acre. Of the 3,115 mil-acre plots taken, 1,119 or 36 percent were stocked with jack pine. There were 2,349 jack pine seedlings on the 3,115 plots, for an average of 754 seedlings per acre.

If the 42 stands are classified by Candy's (6) guide, there are 2 well stocked, 13 moderately stocked, 20 under stocked and 7 failures. The distributions of the stands by both percentage of mil-acres stocked, and jack pine seedlings per acre are given in Table 2.

Data for each stand and mil-acre plots were punched into computer cards and processed by three computer routines. The stand data were processed by the least squares (LS) and the least squares delete (LSDEL) routines. Then the data from the 3,115 mil-acre plots were processed to determine for each variable the percent of plots stocked with jack pine reproduction.

Table 1.

Summary of data for all stands.

Loc.	Stand No.	Average Residual Basal Area: Total	Average Residual Basal Area: Open Coned	Plots Stocked: With Any-thing	Plots Stocked: With Jack Pine	Seedlings per Acre: Jack Pine	Seedlings per Acre: Red Oak	Seedlings per Acre: Red Pine	Seedlings per Acre: Aspen	Seedlings per Acre: White Pine	Seedlings per Acre: Red Maple	Yr. Cut	Stand Age When Cut	Stand Area	Soil Type	Volume Removed Per Acre	Skidding Equipment Used	Cutting Specifications
		Sq. ft.	Sq. ft.	--Percent-		------------		-Number-		--------------			Yrs.	Acres		Cords		
T27N, R1W	1	31	9	34	29	647		19	190			62	55	34	Grayling sand	3.7	Crawler Tractor	Marked to Cut
	2	33	10	77	63	1,100	400	67				60	65	10	Grayling sand	5.0	Crawler Tractor	Diameter Limit
	3	34	10	45	35	710	370					63	40	30	Grayling sand	5.5	Crawler Tractor	Marked to Cut
	4	32	8	36	28	500	233	8				65	55	37	Grayling sand	9.5	Crawler Tractor	Unknown
	5	18	6	17	16	168						65	65	40	Grayling sand	8.6	Crawler Tractor	Marked to Leave
T25N, R4W	6	16	4	68	8	80	800		600			62	65	10	Kalkaska sand	4.0	Crawler Tractor	Marked to Leave
	7	22	7	68	30	480	1,040		560			64	55	20	Grayling sand	7.3	Crawler Tractor	Marked to Leave
	8	20	6	66	34	714	143	29	657			63	45	11	Grayling sand	6.0	Crawler Tractor	Marked to Leave
	9	46	18	34	29	742						62	50	12	Saugatuck sand	10.0	Crawler Tractor	Marked to Leave
	10	24	6	57	29	371	171		771			62	55	14	Grayling sand	10.0	Crawler Tractor	Marked to Cut
T32N, R1W	11	43	4	70	8	204	383			466	900	67	55	19	Roselawn sand	12.5	Crawler Tractor	Marked to Leave
	12	50	14	58	48	875		150	250	150		62	60	13	Rubicon sand	5.0	Horse Skid	Marked to Cut
	13	20	4	60	28	720			760			66	55	8	Emmet	6.9	Crawler Tractor	Marked to Leave
	14	47	15	80	50	1,040		60	360	600		61	45	20	Rubicon sand	5.7	Crawler Tractor	Marked to Cut
	15	41	10	50	40	594			67	167		59	50	8	Rubicon sand	10.0	Unknown	Marked to Leave
	16	57	12	54	38	780		36	324	148		63	50	80	Rubicon sand	10.0	Crawler Tractor	Marked to Cut
	17	62	20	44	36	1,200		40				62	65	10	Emmet	5.0	Crawler Tractor	Marked to Cut
	18	25	8	60	47	1,320			396			61	55	13	Rubicon sand	6.5	Crawler Tractor	Marked to Cut
	19	52	11	76	9	304		18	1,145	364	491	63	48	18	Roselawn sand	4.9	Crawler Tractor	Marked to Cut
	20	26	6	51	44	932		22		44		64	65	15	Rubicon sand	7.8	Crawler Tractor	Marked to Cut
T27N, R2E	21	40	10	52	14	140	860	20				64	50	17	Grayling sand	7.4	Crawler Tractor	Unknown
	22	37	7	77	17	467	1,033		167			60	50	10	Grayling sand	3.8	Unknown	Marked to Leave
T28N, R1E	23	34	5	76	37	528	1,114					63	60	25	Grayling sand	7.8	Crawler Tractor	Diameter Limit
	24	28	10	64	40	760	720					61	60	10	Grayling sand	6.0	Crawler Tractor	Marked to Leave
	25	34	3	50	22	240	980					61	55	20	Grayling sand	6.2	Crawler Tractor	Marked to Leave
	26	40	8	46	45	990		18				63	60	65	Grayling sand	6.2	Crawler Tractor	Diameter Limit
	27	28	6	22	22	280						61	55	16	Grayling sand	4.8	Wheel Tractor	Marked to Leave
	28	42	6	48	45	763						61	50	35	Grayling sand	6.7	Wheel Tractor	Marked to Leave
	29	38	10	50	50	1,075						60	60	30	Grayling sand	4.5	Wheel Tractor	Diameter Limit
	30	38	5	57	10	133	533					62	55	15	Grayling sand	9.0	Crawler Tractor	Marked to Cut
	31	34	5	55	29	520	330		400		70	63	55	36	Grayling sand	4.9	Wheel Tractor	Marked to Leave
	32	30	8	50	21	455	730					62	55	50	Grayling sand	5.1	Crawler Tractor	Diameter Limit
	33	39	6	70	31	488	1,200	13				60	60	26	Grayling sand	8.1	Crawler Tractor	Marked to Leave
T27N, R5W	34	31	6	49	37	943	286					60	55	12	Grayling sand	7.0	Unknown	Diameter Limit
	35	11	4	25	23	425						66	60	15	Rubicon sand	9.0	Unknown	Marked to Leave
	36	26	10	36	36	735	27					64	60	100	Grayling sand	7.0	Unknown	Marked to Cut
	37	24	8	51	45	764	36		36			60	50	21	Grayling sand	7.5	Unknown	Diameter Limit
	38	32	14	38	38	711		44				60	55	15	Grayling sand	6.5	Unknown	Marked to Cut
T24N, R1E	39	44	12	87	67	2,349	760	200				63	55	22	Grayling sand	4.0	Truck Skid	Marked to Cut
	40	39	6	69	48	930	820	50				61	50	68	Grayling sand	6.0	Wheel Tractor	Marked to Cut
	41	42	12	72	57	1,657	363	58				59	50	72	Grayling sand	6.0	Crawler Tractor	Marked to Cut
	42	50	6	71	47	840	933	133				60	55	32	Grayling sand	6.0	Wheel Tractor	Marked to Cut
Average		35	8	53	34	702	343	23	153	51	37		55					

Table 2.--Jack pine stocking, by mil-acres stocked, and seedlings per acre.

Mil-Acres Stocked with Jack Pine	Number of Stands
Percent	
0 to 20	7
21 to 30	10
31 to 40	11
41 to 50	11
51 to 70	3
	42

Jack Pine Seedlings Per Acre	Number of Stands
Number	
0 to 300	7
301 to 600	11
601 to 900	13
901 to 1,200	8
1,201 to 2,500	3
	42

Data for the following 24 variables were used for each stand:

1. Percentage of mil-acres stocked with jack pine.
2. Total residual basal area in square feet per acre.
3. Residual basal area of jack pine in square feet per acre.
4. Residual basal area of open-coned jack pine in square feet per acre.
5. Residual basal area of red pine in square feet per acre.
6. Residual basal area of white pine in square feet per acre.
7. Residual basal area of aspen in square feet per acre.
8. Residual basal area of red oak in square feet per acre.
9. Residual basal area of jack pine mortality in square feet per acre.
10. Jack pine seedlings per acre.
11. Red pine seedlings per acre.
12. White pine seedlings per acre.
13. Aspen sprouts per acre.
14. Red oak seedlings per acre.
15. Red maple seedlings per acre.
16. Number of years since stand was cut.
17. Age of the stand when cut.
18. Location: T32N, R1W
19. Location: T27N, R5W
20. Location: T25N, R4W
21. Location: T27N, R1W
22. Location: T28N, R1E
23. Location: T27N, R2E
24. Location: T24N, R1E

The first analysis had as its dependent variable the percentage of mil-acre plots stocked with jack pine. The least squares (LS) routine showed that 80 percent of the variability could be explained by all 22 variables. (Because the variables mil-acre plots stocked with jack pine and jack pine seedlings per acre were so closely related, they were used only as dependent variables.)

When the location variables were dropped from the model, the resulting variability accounted for was 71 percent. Therefore, the variability explained by location is 9 percent.

Next, the least squares delete (LSDEL) routine was used for the remaining 15 variables, so that it would delete those variables, one at a time, that could not meet the 10 percent minimum significance. This procedure retained 9 variables, accounting for approximately 67 percent of the variability (Table 3).

There are two variables in this grouping which make a prediction equation impractical for use in the field. These are red pine seedlings per acre and red maple seedlings per acre. Since the study plots were taken several years after cutting, the red pine and red maple seedlings would not be present to measure in a newly cut stand. Also, a forester might find it too time consuming to take reproduction plots. Unfortunately, these two variables are quite important in accounting for the variability. I believe the reason for this is the similarity in sites and environment favorable for red pine and jack pine reproduction, and the dissimilarity in sites and environment favorable for jack pine and red maple reproduction.

To develop a formula that would be of practical use in the field, red pine seedlings per acre and red maple seedlings per acre were dropped from the model, and

Table 3.--Regression coefficients for the percent of mil-acre plots stocked with jack pine (LSDEL routine).

Variable	Regression Coefficient	Standard Partial Regression Coefficient	Significance[a]
Constant	.2144	---	.002
Total Residual Basal Area	.0803	6.48589	.024
Residual Basal Area of Jack Pine	-.0790	-6.29540	.025
Residual Basal Area of Open Coned Trees	.0103	.23844	.093
Residual Basal Area of Red Pine	-.0959	-2.42678	.011
Residual Basal Area of White Pine	-.1019	-1.44801	.007
Residual Basal Area of Aspen	-.0741	- .55505	.035
Residual Basal Area of Red Oak	-.0831	-2.16234	.017
Red Pine Seedlings per Acre	.0020	.60905	<.0005
Red Maple Seedlings per Acre	.0006	- .67201	.030

[a]Minimum significance: 10 percent.

the following 9 variables were included in the LSDEL routine: residual basal area; residual basal area of open-coned trees; residual basal area of jack pine, red pine, white pine, aspen, and red oak; residual basal area mortality; and age. The minimum significance was set at 10 percent. One variable, the residual basal area of open-coned trees, was forced to remain in the model, because this is the only seed source in a stand and must be considered when the stand is cut. The variability explained by all 9 variables was 45 percent. After the deletion, 4 variables remained, accounting for 44 percent of the variability (Table 4). These variables were residual basal area of jack pine, residual basal area of open-coned trees, residual basal area of white pine, and residual basal area of mortality. The analysis of variance for the regression showed this model to be significant at <0.0005.

If a prediction equation with the coefficients for these variables is used soon after a stand is cut, the expected value for residual basal area of mortality must be estimated. From my data, the average mortality was 3.8 square feet per acre, but it varied from 0 to 15 square feet per acre for the 42 stands. This estimated basal area of mortality must be subtracted from the actual residual basal area of jack pine to obtain the value for residual basal area of jack pine for insertion in the equation.

Table 4.--Regression coefficients for the percent of mil-acre plots stocked with jack pine (LSDEL routine).

Variable	Regression Coefficient	Standard Partial Regression Coefficient	Significance[a]
Constant	0.1879	---	0.002
Residual Basal Area of Jack Pine	0.0041	0.32948	0.041
Residual Basal Area of Open Coned Trees	0.0107	0.24887	0.116
Residual Basal Area of White Pine	-0.0295	-0.41921	0.002
Residual Basal Area of Mortality	-0.0111	-0.26338	0.045

[a]Minimum significance: 10 percent

An example of using the prediction equation is as follows:

Residual basal area of open-coned trees	= 15 square feet per acre
Residual basal area of jack pine	= 40 square feet per acre
Residual basal of white pine	= 0 square feet per acre
Residual basal area of mortality	= 5 square feet per acre

Then:

$$Y = 0.1879 + 15(.0107) + 40(.0041) - 5(.0111)$$

Y = 46 percent of the mil-acres are stocked with jack pine

This equation can be used to predict the future stocking of a recently cut stand.

The next analysis considered jack pine seedlings per acre as the dependent variable. The 22 variables were analyzed on the LS routine, and they explained 81 percent of the variability. When the location variables were dropped, the remaining variables accounted for 71 percent of the variability. Thus, the variability attributed to location was 10 percent.

Next the 15 variables, excluding location, were analyzed by the LSDEL routine, and they accounted for 71 percent of the variability. The minimum significance was again set at 10 percent, and the nonsignificant variables were deleted, leaving the same 9 variables as before. The 9 accounted for 68 percent of the variability. The resulting regression coefficients are presented in Table 5.

Table 5.--Regression coefficients for the number of jack pine seedlings per acre (LSDEL routine).

Variable	Regression Coefficient	Standard Partial Regression Coefficient	Significance[a]
Constant	330.92	---	.082
Residual Basal Area	228.71	6.1435	.028
Residual Basal Area of Jack Pine	-225.16	-5.9670	.029
Residual Basal Area of Open Coned Trees	32.85	0.2540	.069
Residual Basal Area of Red Pine	-276.76	-2.3286	.013
Residual Basal Area of White Pine	-254.76	-1.2039	.021
Residual Basal Area of Aspen	-282.98	-0.7050	.007
Residual Basal Area of Red Oak	-245.23	-2.1211	.017
Red Pine Seedlings per Acre	6.86	0.6891	<.0005
Red Maple Seedlings per Acre	- 1.57	-0.5631	.062

[a]Minimum significance: 10 percent.

Again, red pine seedlings per acre and red maple seedlings per acre were included in the 9 significant variables. Consequently, an LSDEL was applied to the 9 variables that are easy to measure in an inventory. The minimum significance was set at 10 percent, and residual basal area of open-coned trees was forced to remain in the model. Before deletion, the model explained 41 percent of the variability, and after deletion, leaving only four variables, the variability accounted for was 37 percent. The resulting regression coefficients are presented in Table 6.

The analysis of variance for the regression showed this model to be very significant, with an F value of 5.45, significant at the 0.001 level.

An example of estimating the number of jack pine seedlings per acre is as follows:

Residual basal area of jack pine	=	40 square feet per acre
Residual basal area of open-coned trees	=	15 square feet per acre
Residual basal area of aspen	=	0 square feet per acre
Residual basal area of mortality	=	5 square feet per acre

Then:

$$Y = 158.41 + 40(14.53) + 15(34.46) - 5(31.66)$$

$$Y = 1{,}098 \text{ jack pine seedlings per acre}$$

This formula can best be used to predict the number of jack pine seedlings right after a stand has been cut.

Table 6.--Regression coefficients for the number of jack pine seedlings per acre (LSDEL routine).

Variable	Regression Coefficient	Standard Partial Regression Coefficient	Significance[a]
Constant	158.41	---	0.375
Residual Basal Area of Jack Pine	14.53	0.3850	0.025
Residual Basal Area of Open Coned Trees	34.46	0.2665	0.113
Residual Basal Area of Aspen	-92.13	-0.2295	0.095
Residual Basal Area of Mortality	-31.66	-0.2507	0.068

[a]Minimum significance: 10 percent.

These models are only applicable to the 2-cut shelterwood method, as all the data were gathered from stands treated this way. The prediction equations, however, should be useful even when a 3-cut shelterwood method is used. For the preparatory cut, professional judgment will be the best guide in selecting the trees to leave. In marking for the seed cutting, the prediction equations should be helpful in leaving enough of the best trees.

The reproduction information for several stands indicates that they are converting from the jack pine type to some other type (Table 1). On the better sites, the conversion is from jack pine to white pine, red maple, red pine, aspen, and red oak. Stands numbered 6, 11, and 19 show such conversion underway. On these sites, conversion is probably desirable, and would be difficult to combat anyway. However, stands on the poorer sites are converting to low quality red oak. Examples of this are stands numbered 7, 21, 22, 23, and 25. From a timber management standpoint, such conversion is not desirable, since the oak is of low quality and has little market value. In these stands, the oak was not cut or treated with a silvicide at the time of harvesting, so that an oak seed source is left as well as undesirable competition for jack pine reproduction. This study indicates that any oak not cut should be treated with silvicide or otherwise eliminated as early as possible in the life of the stand.

To demonstrate the importance of removing any residual basal area of red oak from the stand, I analyzed the data with the LSDEL routine, with red oak seedlings per acre as the independent variable. Nine variables easy to measure were used: total residual basal area, residual basal area of jack pine, residual basal area of open coned trees, residual basal area of red pine, white pine, aspen, red oak, residual basal area of mortality, and age. These nine variables accounted for 62 percent of the variability in red oak seedlings per acre. The minimum significance was set at 5 percent. After deletion, only residual basal area of red oak and residual basal area of red pine were left, and the variability explained was 54 percent. If the residual basal area of red oak were deleted, the variability accounted for would drop to 2 percent. The analysis of variance showed the regression was significant at the <0.0005 level (Table 7.)

These results show that to maintain the jack pine type where red oak is a threat, the oak must be removed. Conditions under an overstory are more favorable for red oak reproduction than for jack pine because the red oak has greater tolerance and a greater ability to germinate and survive on undisturbed sites (17).

The percent of mil-acres stocked with jack pine reproduction on each soil type encountered in the study was determined (Table 8). For those soil types on which

Table 7.--Regression coefficients for the number of red oak seedlings per acre (LSDEL routine).

Variable	Regression Coefficient	Standard Partial Regression Coefficient	Significance[a]
Constant	75.499	---	0.217
Residual Basal Area of Red Oak	77.380	0.7350	<0.0005
Residual Basal Area of Red Pine	28.149	0.2601	0.024

[a]Minimum significance: 5 percent.

Table 8.--Jack pine reproduction stocking on various soil types.

Soil Type	Mil-Acres Sampled	Mil-Acres Stocked With Jack Pine
	Number	Percent
Grayling Sand	2,405	37
Rubicon Sand	485	40
Roselawn Sand	115	7
Emmet	50	32
Saugatuck Sand	35	29
Kalkaska Sand	25	8

jack pine formed a part of presettlement natural vegetation as described by Veatch (18), the stocking is above the average of 36 percent for all plots. The soil types on which jack pine was not a part of the natural vegetation include Roselawn, Emmet, Saugatuck, and Kalkaska.

The effect of the season of cutting could not be determined because most stands were cut during more than one season, and it was impossible to tell which part of each stand was cut during which season.

In all stands, cutting specifications had been imposed to define the residual stand that would be left after cutting. Three such cutting specifications had been used: (1) diameter limit, (2) marked to leave, and (3) marked to cut. In Table 9, reproduction results following cutting using these specifications are compared.

The stands marked to leave had the least jack pine reproduction. Stands that were marked to leave averaged 10 square feet per acre less residual basal area than stands marked to cut. Perhaps not enough trees were marked to leave, and the best trees to leave were not included. Also, less residual basal area of open-coned trees was left in the stands marked to leave (Table 9). This indicates that if more care were taken in marking the trees to leave, the jack pine reproduction results would be more favorable.

Table 9.--Jack pine stocking following cutting under three different cutting specifications.

Cutting Specification	Mil-Acres Sampled	Mil-Acres Stocked with Jack Pine	Residual Basal Area per Acre Total	Residual Basal Area per Acre Open Coned
	Number	Percent	Sq. Ft.	Sq. Ft.
Marked to Cut	1550	41	39.7	10.4
Diameter Limit	510	37	33.1	7.9
Marked to Leave	815	27	29.9	6.6

Next, the effect of the skidding equipment used in the logging is examined (Table 10). As can be seen, the results vary considerably, and are difficult to explain. The sample was small for those stands that were truck and horse skidded. This small sample may not be representative of the situation. Stocking in stands where skidding was with a wheel tractor is significantly higher than in stands where a crawler tractor was used. It is believed that the differing effects of skidding would be caused by different amounts of site disturbance. This may be influenced more by how the wood was moved rather than what machine moved it. More mineral soil would be exposed if the wood was dragged rather than moved on a trailer, and this information was not available. In truck skidding, the truck was driven through the stand and the wood was loaded directly onto the truck.

Table 10.--Jack pine stocking as affected by skidding equipment used.

Skidding Equipment Used	Mil-Acres Sampled	Mil-Acres Stocked With Jack Pine
	Number	Percent
Crawler Tractor	1,905	33
Wheel Tractor	545	42
Truck	60	67
Horse	40	48

Many plots had reproduction of other species on them in addition to jack pine (Table 11). Only red pine and red maple vary enough from the average for all species to be significant. Conditions and sites that are favorable for red pine reproduction are also favorable for jack pine, while conditions and sites favorable for red maple reproduction are not favorable for jack pine. These same relationships were indicated earlier in the regression analyses.

Table 11.--Stocking with other reproduction in addition to jack pine.

Reproduction in Addition to Jack Pine	Mil-Acres Sampled	Mil-Acres Stocked with Jack Pine
	Number	Percent
Red Pine	56	65
Red Oak	571	40
White Pine	114	37
Aspen	177	34
Red Maple	58	21
Other[a]	43	42

[a]Includes white oak, spruce, balsam fir, and beech.

Both the total residual basal area and the residual basal area of open-coned trees affected stocking with jack pine reproduction (Tables 12 and 13). The stocking is given by three seedling height classes to demonstrate the effect of increasing shade on seedling growth. Adequate shade is important for the early establishment of jack pine seedlings, because of decreased competition from ground cover and more favorable moisture conditions for germination. However, too much shade is detrimental to seedling growth.

The amount of residual basal area in open-coned trees is very important in the establishment of a new stand as it is the only seed source from which the new stand can be regenerated. Only stands with 0 or 50 square feet of residual basal area in open-coned trees had lower stocking than the average for all plots (Table 13). The reason that percent stocking falls off after a residual open-coned basal area of 30 square feet is that the total residual basal area is probably in excess of 70 square feet, which becomes too high for good seedling development. If only the open-coned residual basal area had been left, stocking would most likely have continued to increase. Of all the plots with open-coned trees, 40 percent are stocked with jack pine, while only 30 percent of the plots without open-coned basal area are stocked. This again demonstrates the importance of open-coned trees as a seed source for obtaining reproduction.

Table 12.--Jack pine stocking under varying residual basal areas of jack pine.

Residual Basal Area of Jack Pine per Acre	Mil-Acres Sampled	Mil-Acres Stocked with Jack Pine Seedling Height Class in Feet			
		Less Than 1 Foot	1-3 Feet	More Than 3 Feet	All Seedlings
Sq. Ft.	Number	-------	-------Percent	-------	-------
0	235	4	11	4	16
10	525	8	22	11	33
20	725	12	23	12*	36
30	530	16	24	8	36
40	405	28	27*	8	46*
50	245	19	24	7	38
60	245	30	19	6	41
70	90	34*	16	2	38
80	50	14	00	00	14

*The highest stocking in each height class.

Table 13.--Jack pine stocking under varying residual basal areas of open-coned trees.

Residual Basal Area of Open-Coned Trees per Acre	Mil-Acres Sampled	Mil-Acres Stocked with Jack Pine
Sq. Ft.	Number	Percent
0	1,326	30
10	1,203	39
20	390	43
30	120	43
40	60	38
50	15	33

The open-coned residual basal area is so important that it would be useful to have a guide to the amount of open-coned trees to be left to assure reproduction success. Of the 42 stands examined in this study, 22 of them had 8 or more square feet per acre of open-coned trees. Of the 22 stands, 16 were above average stocking and 6 were below average stocking. Of the 20 stands with less than 8 square feet per acre of open-coned trees, only 6 were above average stocking and 14 were below average. From this it is evident that at least 8 square feet of basal area in open-coned trees should be left per acre to obtain reasonable success.

A major competitive factor in the germination and establishment of jack pine is ground cover. In this study, three items of information were obtained for the ground cover on each plot: (1) percentage of area covered by ground cover, determined by ocular estimation; (2) maximum height of ground cover on the plot; and (3) the major components or species of ground cover on a plot.

The percent of ground cover proved useless, since nearly all plots had 100 percent ground cover. The height of the ground cover influenced the amount of jack pine reproduction; the taller the ground cover, the lower the percentage of plots stocked with jack pine (Table 14). Varying ground cover components also affected jack pine stocking (Table 15). Reindeer lichen had the highest percent of plots stocked. Green moss and litter were also significantly above the average. The reason for this is that the competition by these ground cover components is not great. Reindeer lichen lacks a root system so it is not demanding on soil moisture. Also, when the reindeer lichen is disturbed, it remains so for a relatively long period. It is interesting to note that 62 percent of all the plots with reindeer lichen were stocked with jack pine, regardless of whether the lichen was of first, second, or third importance on the plot. Plots dominated by slash, blueberry, and bracken fern are below the average stocking of 36 percent. Bracken fern in many instances forms a dense cover and is over 3 feet tall. Blueberry also forms dense cover, particularly in accumulations of slash. Slash

Table 14.--Effects of ground cover on jack pine stocking.

Height of Ground Cover	Mil-Acres Sampled	Mil-Acres Stocked with Jack Pine	
Inches	Number	Number	Percent
6	73	41	56
6 to 18	1,679	698	42
Over 18	1,363	380	29

Table 15.--Jack pine stocking with various ground cover conditions.

Major Ground Cover Component	Mil-Acres Sampled	Mil-Acres Stocked with Jack Pine
	Number	Percent
Reindeer Lichen	163	76
Green Mosses	33	55
Litter	178	47
Bearberry	128	43
Grasses	1,091	39
Sweetfern	86	37
Bracken Fern	355	32
Blueberry	757	28
Slash	288	16
Other[a]	36	22

[a]Includes juneberry, willow, raspberry, and cherry.

on the plots was generally not light and scattered, but accumulated in piles over 3 feet high.

The stocking of an area with jack pine reproduction increases with number of years after cutting (Figure 2). It takes several years to adequately stock a stand, and stocking will continue to improve with time. It is probably advisable to have 7 to 10 years between the seed cut and the removal cut in a 2-cut shelterwood system. However, if 3 cuts are used, perhaps 10 years would be long enough between the preparatory cut and the removal cut.

The Shelterwood Method and Multiple-Use Management

For any forest reproduction method to be used with success, it must be compatable with the management objectives of the ownership. The owner or agency concerned here is the Michigan Department of Natural Resources. The management objectives for the State Forests call for management for sustained multiple-use:

> In state forest management all known uses are carefully weighed and the combination of uses believed to give the greatest benefit to the largest number for the longest time are pursued to the extent of funds and personnel available. (12, p. 1)

The objectives also state that where possible, timber management will be used as the principal tool to achieve other multiple-use management objectives.

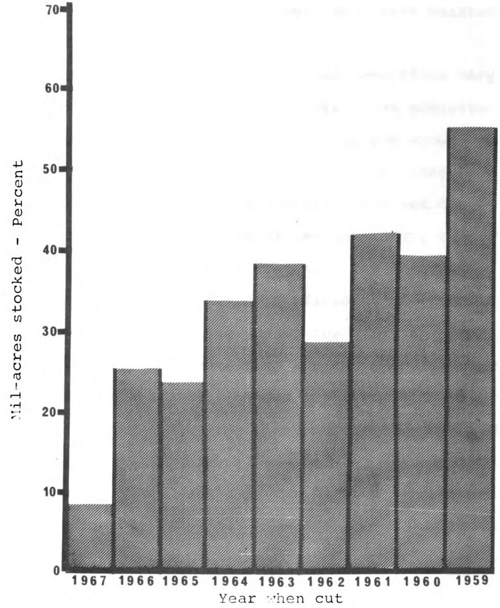

Figure 2. Jack pine stocking by year of cutting.

Specifically, the objective of jack pine management is to retain the jack pine type on soils suited to it, and to manage stands in a manner that will produce optimum quantities of jack pine timber compatable with maintenance of desirable wildlife habitat.

The shelterwood method meets these objectives very well. It can be used only where there is an adequate number of open-coned trees, but where there are enough open-coned trees, reproduction can be obtained at less cost than either by planting or by scarification and clearcutting. Since the ground cover and understory vegetation are likely to be more diversified with the shelterwood method than with clearcutting, conditions for wildlife will be more favorable. The resulting stand is likely to be more patchy or irregular than a plantation, with more edge effect for wildlife. Figure 3 illustrates the clumpy nature of a mature jack pine stand and the reproduction 7 years after a shelterwood cut was made.

Michigan is very deeply concerned with and involved in outdoor recreation. This means that as a public agency, the Forestry Division of the Department of Natural Resources must be concerned with the aesthetics of its forest lands. In some instances, cutting practices will have to be modified if management programs are to not only be continued but expanded. The shelterwood method goes hand-in-hand with maintaining an aesthetically pleasing forest landscape.

Figure 3.--A mature jack pine stand showing the clumpy nature of the residual stand and the reproduction 7 years after a shelterwood cutting was made. The habitat is more diversified than on clearcut areas or in a plantation, and thus more favorable for wildlife. Stand number 37 in Kalkaska County, stocked with 764 seedlings per acre.

The public sometimes reacts unfavorably to drastic changes in the forest such as a clearcutting. Figures 4 and 5 illustrate some unfavorable aspects of a clearcutting in jack pine.

The cuttings in the shelterwood method may go practically unnoticed by the public, as the mature stand disappears in stages, so that when the final cut is made, the reproduction is already several feet high. If a 3-cut shelterwood method is used, with 10 to 20 years between the preparatory and removal cuts, the reproduction may be more than 5 feet tall when the residual stand is removed. Figures 6 and 7 show stands that were cut using the shelterwood method, which are ready for the removal cut to be made.

Perhaps the shelterwood method does not result in as much reproduction as quickly as would a clearcutting with scarification and slash scattering or followed by planting. However, there may be serious doubt whether planting is advisable from an economic standpoint, and perhaps scarification and slash scattering cannot be justified economically either. In current practice on the state forests, very little scarification and slash scattering are being applied.

Like other silvicultural methods that might be applied to mature jack pine stands, the shelterwood method has some limitations. Often, there is inadequate seedbed

Figure 4.--A jack pine area in Crawford County 2 years after clearcutting. Very little reproduction has become established since the cutting was made. Heavy infestation by the jack pine budworm (Choristoneura pinus Free.) necessitated the clearcutting. The standing dead trees were unmerchantable stems.

Figure 5.--The same stand as shown in Figure 4. Here an attempt was made to screen the clearcut area by retaining a buffer strip along the road. Buffer strips in stands like this, with practically no understory vegetation, are not very effective.

Figure 6.--A jack pine stand 9 years after being cut by the shelterwood method. Stand number 41 in Ogemaw County, with 1,657 jack pine seedlings per acre. The removal cut could be made at any time.

Figure 7.--Stand number 39 in Ogemaw County 5 years after a shelterwood cutting, and now ready for the removal cutting. This stand has 2,349 jack pine seedlings per acre. The measuring stick in the photograph is 1 meter long.

preparation with conventional logging methods. Perhaps this is not any less satisfactory than if the stand is clearcut.

In areas where open-coned trees do not amount to at least 8 square feet of basal area per acre, success is not assured with this method because the seed source is inadequate.

Two-storied stands result in problems with the jack pine budworm. The insects fall off the overstory and onto the reproduction, causing high mortality in many instances. Many stands in this study would have shown more success if there had not been so much seedling mortality caused by the budworm. This was particularly the case in Crawford and Oscoda Counties.

There is a tendency for some stands cut by the shelterwood method to convert to low quality oak. If these stands are to be maintained in jack pine, the oak must be cut or treated with silvicides. This is probably easier to accomplish in a clearcutting than in a shelterwood cutting.

It takes at least two cutting operations to harvest the same material that one operation would in a clearcutting. It is possible that economic returns may not be maximized by having two operations instead of one, but state forestry personnel reported no difficulty in marketing stumpage sales for the various shelterwood cuts without apparent reduction in prices.

The losses due to mortality occurring between the seed and harvest cut must be considered when this method is used. This loss would not occur if the stand were clearcut. In some stands, this loss was substantial, amounting to as much as 15 square feet of basal area per acre. The average loss for all stands was 3.8 square feet per acre. With careful marking, mortality losses can be reduced to a minimum. All trees that are not expected to survive between cuttings should be removed in the seed cut.

SUMMARY AND CONCLUSIONS

The objective of this study was to evaluate the shelterwood method as it is being used in jack pine stands in the state forests in northern Lower Michigan, and to make recommendations as to its continued use. To accomplish this, 42 stands in Otsego, Kalkaska, Crawford, Oscoda, and Ogemaw Counties were examined. Residual basal area data were obtained from BAF 10 point samples taken every 4 chains in each stand. Reproduction data and related information were obtained from 5 mil-acre plots taken at each point sample location.

The average percent of mil-acre plots stocked with jack pine was 36 percent, and there was an average of 754 seedlings per acre. This indicates that the shelterwood method is suited to reproducing jack pine in the study area and perhaps elsewhere if there are ample open-coned trees in the stands.

Several stands are converting to low quality oak. The most important factor associated with conversion to oak is the amount of oak residual basal area left after the seed cut is made in the stand. The oak should be removed before or at the time of the seed cut if the jack pine type is to be maintained.

Three types of cutting specifications had been used in the stands that were included in the study: marked to cut, marked to leave, and a diameter limit. Reproduction success was highest in the stands that were marked to be cut because a greater residual basal area was left, which included more basal area of open-coned trees than in the other cutting specifications.

When percent of plots stocked was related to the residual basal area of jack pine, it was found that a relatively high residual basal area was favorable to jack pine seedling establishment. The percent of plots stocked with jack pine less than a foot tall was greatest in stands with 70 square feet of residual basal area per acre. Seedling development, however, was favored by less residual basal area. Percent of plots stocked with reproduction over 3 feet tall was greatest in stands with 20 square feet of basal area per acre. This indicates that perhaps a 3-cut shelterwood may be more desirable than a 2-cut procedure. The environment for seedling establishment would be good following the preparatory cut. The established seedlings would then respond to the partial release following the seed cutting. Additional seedling establishment will occur following the seed cut before the removal cut is made.

In general, stocking will increase as the residual basal area of open-coned trees is increased. Therefore, every effort possible should be made to make the residual basal area 100 percent open-coned trees.

Ground cover had a significant effect on jack pine reproduction. The more competitive the gound cover, the lower the stocking with jack pine seedlings. On sites where the ground cover was primarily reindeer lichen, reproduction results were satisfactory. On sites where the ground cover was mainly blueberry, bracken fern, or grass, scarification may be desirable. Reproduction in accumulations of slash was sparse.

Jack pine stocking increases as time since the cutting increases. This study indicates that 7 to 10 years following cutting are needed to attain adequate stocking. The resulting stands would still be considered even-aged. If the rotation is 60 years, the regeneration period could be as long as 12 years.

The shelterwood method is well adapted to multiple use management. Timber production is accomplished, and wildlife habitat conditions are more desirable than with clearcut conditions, since the more variable vegetational stages provide food and cover not obtained with clearcutting. The ground cover and understory vegetation are more diversified, and the patchy irregular stand structure provides considerable, highly desirable, edge effect for wildlife. The aesthetic considerations are also favorable with the shelterwood method. The new stand is already established and evident before the mature one is completely removed, avoiding the "denuded" stage in clearcutting procedures. This established advanced reproduction represents the highly desirable aesthetic condition of looking more "natural."

Adequate and in some cases even better results could probably be obtained with a 3-cut shelterwood system. The preparatory cut should be made when the stand is between 40 and 45 years old, favoring the open-coned trees where possible, leaving between 60 to 90 square feet of basal area per acre.

About 5 years later, the seed cut should be made, leaving a residual basal area of 25 to 40 square feet per acre, as much of it as possible in open coned trees. The greater the stocking of reproduction at this time, the lower the residual basal area may be. As much of this residual basal area as possible should be of open-coned trees, at least 8 square feet. Between the ages of 55 and 60 years, the removal cut should be made.

These recommendations may have to be varied somewhat for each individual stand. Also, where stumpage prices would be significantly reduced because the harvest would be spread over 3 operations, the 2-cut shelterwood method would be preferable. Mortality losses between cuts should be checked closely to make certain the extended harvest period does not result in significant wood volume losses.

The shelterwood method with the basic seed and removal cuts appears to be successful in regenerating jack pine stands in the state forests in northern Lower Michigan. It makes possible the realization of multiple-use management objectives for state forest lands. Its success could be improved by minor changes in application, with the most important one being the leaving of as many open-coned trees as possible when the seed cut is made.

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LITERATURE CITED

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APPENDIX

APPENDIX I

SCIENTIFIC NAMES OF SPECIES ENCOUNTERED IN THIS STUDY

A. Tree Species[1]

1. Aspen - *Populus tremuloides* and *Populus grandidentata* Michx.
2. Balsam fir - *Abies balsamea* (L.) Mill.
3. Beech - *Fagus grandifolia* Ehrh.
4. Jack pine - *Pinus banksiana* Lamb.
5. Red maple - *Acer rubrum* L.
6. Red oak - *Quercus rubra* Michx., and *Quercus ellipsoidalis* E. J. Hill
7. Red pine - *Pinus resinosa* Ait.
8. Spruce - *Picea mariana* (Mill.) B.S.P. and *Picea glauca* (Moench) Voss
9. White oak - *Quercus alba* L.
10. White pine - *Pinus strobus* L.

B. Ground Cover Species[2]

1. Bearberry - *Arctostaphyles uva-ursi* L.
2. Blueberry - *Vaccinium* spp.
3. Bracken fern - *Pteridium aquilinum* (L.) Kuhn
4. Cherry - *Prunus* spp.
5. Grasses - *Danthonia spicata* (L.) Beauv. and other xerophytic grasses.
6. Green mosses - *Polytrichum* spp.
7. Raspberry - *Rubus idaeus* L.
8. Reindeer lichen - *Cladonia* spp.
9. Serviceberry - *Amelanchier* spp.
10. Sweetfern - *Comptonia peregrina* (L.) Coult.
11. Willow - *Salix* spp.

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