RESEARCH NOTES

BRITISH COLUMBIA FOREST SERVICE
VICTORIA, BRITISH COLUMBIA, CANADA

No. 67 1974

EFFECTS OF CUTTING METHOD, SLASH-DISPOSAL TREATMENT, SEEDBED PREPARATION AND CONE HABIT ON NATURAL REGENERATION OF LODGEPOLE PINE IN THE SOUTH-CENTRAL INTERIOR OF BRITISH COLUMBIA

by

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ABSTRACT

A study of lodgepole pine clear-cuts in the south-central Interior showed that, for most areas, the quantity and quality of seed on the ground and slash-borne following logging is sufficient for natural regeneration. Seed supply is severely reduced when slash is broadcast burned.

Minimum stocking may be secured by three years after logging but distribution of seedlings is usually poor. The amount of stocking is limited by seed distribution and the quality and quantity of favourable seedbed. Size of area is not a specific limiting factor to regeneration. Site preparation is necessary to achieve maximum stocking within minimum time.

Overstocking is common in lodgepole pine stands with a serotinous (closed) cone habit. It is related to distribution of cones, germinative capacity of seed, large number of seed per cone and nature of seed release. The amount of overstocking may be controlled through site preparation.

Management of lodgepole pine requires only a recognition of basic silvicultural principles.

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INTRODUCTION

Lodgepole pine (*Pinus contorta* var. *latifolia*, Engelm.), indigenous to the Interior of the Province, extends from Lat. 49°N to Lat. 60°N and from Long. 114°W to Long. 136°W. It occurs in either pure or mixed stands from approximately 1500 feet to over 5000 feet elevation within the Montane, Columbian and Boreal forest regions. Within this area are approximately 18.7 million acres of lodgepole pine (B. C. Forest Service 1957).

Many research investigations have been made on the silvical aspects of lodgepole pine and valuable information has been provided, but their relationship to lodgepole pine types in British Columbia have not been completely known. Armit (1966) reviewed past studies and presented an analysis of silvical aspects and problems associated with lodgepole pine in the North Central Interior of the Province. A recent report (Lotan, 1970) presents a thorough review of the literature on cone characteristics of lodgepole pine and presents results of further research on cone serotiny.

Over the past decade the cut of lodgepole pine has increased from roughly 50 MM cubic feet annually to approximately 200 MM cubic feet annually. This increase in volume of cut has been largely from clearcuts which have varied from small blocks of 20 acres to extensive areas of over 500 acres. Logging has been to close-utilization standards. Slash-disposal has varied from broadcast burning, windrowing and burning, or scarification to skidding of total trees to landings and burning of tops at landings. In the latter case the areas have either received no further treatment or have been scarified. The effects of these slash-disposal treatments and seedbed preparation methods have been studied to a limited extent (Armit, 1966) but many questions respecting the regeneration of lodgepole pine remain unanswered. Answers are required as to where and why regeneration is not successful; what conditions lead to overstocking; what the relationships are between regeneration and cone habit, slash-disposal treatment and site preparation method; and the effects of site and size of clearcut on natural regeneration. The need to obtain answers to these questions, and to determine the applicability of known information on lodgepole pine to the variable conditions in the Interior of the Province, prompted a study commencing in 1971.

The ultimate objective will be to provide silvicultural prescriptions for securing acceptable stocking levels of lodgepole pine natural regeneration.

METHODS AND MATERIALS

Logged areas of lodgepole pine were sampled in a systematic pattern for type of seedbed, density of cone-bearing slash, the number of open and closed cones on the ground and in the slash, the number of seedlings by age-class and the class of seedbed on which they occurred. In addition, information was recorded on history of logging, vegetation, soils, site, elevation, aspect, slope and climate.

An evaluation of type of cone habit, size of cone crop, and potential seed supply available to the logged areas was made where marginal stands were judged as similar to cutover areas.

Cones collected from fresh tops were dissected for counts of seed per cone and seeds were tested for viability.

DEFINITIONS

Seedbed - Milacre plots were classed as mineral, disturbed, undisturbed, other, and no seedbed, depending upon which seedbed covered fifty percent of more of the plot. However, if a milacre plot contained one square foot or more of mineral soil or burned mineral soil it was classed as a mineral seedbed.

Seedbed Occurrence - The actual seedbed on which each individual seedling occurs.

Serotiny - This is the condition of a mature cone remaining 'closed'. 'Closed cone' is equivalent to 'serotinous cone'. The term serotinous is derived from the Latin *serus*, meaning late (Lotan, 1970). Serotinous cones do not open at maturity because of a resin bond between the cone scales. When subjected to temperatures of 45°C to 50°C (Clements, 1910; Crossley, 1956b), the resin bond breaks, the cones are free to open and seed stored for many years may be released.

Cone Habit - The term 'cone habit' referes to the cone condition exhibited by stands or trees within a stand. For this study, stands were classed as serotinous if 80 percent or more of the cone-bearing dominant and co-dominant trees bore serotinous (closed) cones; nonserotinous (open) if 20 percent or less of cone-bearing dominant and co-dominant trees bore serotinous cones; and mixed (open and closed) where cone-bearing dominants and co-dominants bore more than 20 percent but less than 80 percent serotinous cones.

Stored Sound Seed - The amount of viable seed available in serotinous (closed) cones.

Potential Available Seed Supply - This is the amount of viable seed contained in a stand of lodgepole pine prior to logging or other disturbance. That is, the biotic potential for restocking. In the study this amount was determined, from uncut stands adjacent to logged areas, using estimating methods developed by Lotan and Jensen (1970). The method used has a potential for rough estimates only but required measurements are relatively simple. The number of serotinous cones per acre are estimated from:

$$Y = (1.925\ d.b.h.^2 - 1.371\ Age + 3.411\ tpa - 0.00615\ tpa^2 + 46.2)^2.$$

Where: Y = the number of serotinous cones per acre.

d.b.h. = mean plot diameter at breast height in inches (merchantable trees only)

age = mean plot age in years (merchantable trees only)

tpa = number of serotinous cone type trees per acre.

The 'potential available seed supply' was obtained by multiplication of number of serotinous cones per acre by average number of viable seed per cone.

Viable Seed Per Cone - Approximately 50 cones from each stand sampling area were dissected to obtain an average number of seed per cone. Standard germination tests for lodgepole pine (24-hour cold soak followed by 2 weeks stratification) were conducted to obtain percentage viability of seed and number of viable seed per cone.

Actual Available Seed Supply - This term refers, in this study, to the amount of viable seed in cones on the ground or in the slash following logging or site preparation treatments. Amounts were derived by converting milacre plot tallies of serotinous cones and viable seed per cone to acre figures.

Vegetation Site-type - Logged areas were described for vegetative site in accordance with classifications developed by Illingworth and Arlidge (1960). Where more than one vegetative site-type was present on a large area the site-type covering the largest portion of the area was selected as representing that area. Therefore, any references to vegetative site-type are general references only and should not be construed as being reliable correlations.

The Calamagrostis (C), or pinegrass, vegetative site-type was classified as C+, C, or C- depending upon the amount of intermixing of other site-types, that is, whether average, slightly above or slightly below average.

Stocked Quadrat - A milacre quadrat was considered stocked if containing three or more germinants, two or more 1-year-old seedlings, or one or more 2-year-old or older seedlings, or equivalent combinations.

RESULTS

A. Cone Production, Seed Yield, and Viability

The number of stored sound seed per acre is an estimate of biotic potential for regeneration. Therefore, it is useful prior to logging to be able to predict whether trees on a specific area bear sufficient closed cones to provide viable seed for restocking.

The serotinous cone habit of lodgepole pine can be extremely variable. A stand may be serotinous, nonserotinous or have trees with both types of cones side by side. Also, it is possible for individual trees within a stand to bear both open and closed cones.

Many theories have been advanced regarding the variability of cone habit. These have ranged from effects of soils and site (Mason 1915; Bates 1930) to genetic characteristics (Crossley 1956a; Lotan 1967; Teich 1970). Some relationships have been found between cone habit and crown-class and between cone habit and age-class (Clements 1910; Crossley 1956a; Armit 1964). There have also been suggestions of geomorphic variability (Trappe and Harris 1958; Lotan 1967 and 1968; Illingworth 1970).

In this study, nineteen uncut stands were sampled and data were collected on a number of habitat factors which might show correlation with cone habit, the primary objective being to determine whether simple methods were available for determining adequacy of seed supply for natural regeneration.

Of the nineteen stands sampled for cone habit, two were nonserotinous, seven were serotinous and ten were mixed.

Generally, a significantly higher percentage of cone-bearing trees in the dominant and co-dominant classes bore serotinous cones than did the intermediate and suppressed classes (Table 1), indicating some relationship between serotiny and crown-class. However, it is also apparent that when a stand is definitely serotinous all crown-classes bear a high percentage of serotinous cones. In stands with mixed serotiny there appears to be much variation in percent of serotinous cones borne by the different crown-classes. Nevertheless, the percentage of cone-bearing dominants and co-dominants with serotinous cones yields a fair estimate of cone habit and sound seed store.

No correlation was evident between cone habit and age or between cone habit and elevation.

There was some correlation between cone habit and vegetative site-type. The lowest quality sites were nonserotinous whereas the highest quality sites were mainly serotinous. Further investigation of the relationship between vegetative site-type and cone habit would be required before any definite correlations could be stated.

Estimates, by formula, of the serotinous cones per acre as a basis for 'potential' seed supply varied from an average of 34,000 per acre for stands with a nonserotinous cone habit, to 190,000 per acre for stands with a mixed cone habit, to 276,000 per acre for stands with a serotinous cone habit. On the basis of actual cone counts on trees within a few stands, the fomula estimates are conservative.

Seed yield from cones was variable, ranging from 0 to 70 seeds per cone, with an average of 24 seeds per cone. These results are similar to reported seed per cone variations (Armit 1966; Bates 1930; Clements 1910; Tackle 1961). Viability of the seed samples ranged from 54 to 93 percent with 70 percent of the samples showing viability of 80 percent and higher. There was no correlation between seed viability and cone habit.

The 'potential' seed supply produced averages of 39,000 seed per acre for stands with a nonserotinous cone habit, 3.7 million

TABLE 1 - Serotinous Cones and Seed Production

Area	% Serotinous Trees (1) D + C	(2) I + S	Estimated No. Cones/Acre (Formula)	Actual Tree Count of Cones/Acre	Potential Viable Seed per Acre	Available Viable Seed/Acre	Stand Age	Vegetative Site	Elevation
Full Tree, No Site Preparation									
1	57	28	210,902		3,922,777	360,189	95-105	CA	3800
2	62	44	194,944		3,987,874	493,635	130-160	C-	43-5000
3	62	44	194,944		3,987,874	711,388	130-160	C-	43-5000
4	62	44	194,944		3,987,874	711,388	130-160	C-	43-5000
5	62	44	194,944		3,987,874	711,388	130-160	C-	43-5000
6	33	31	156,806		3,123,576	223,423	90-120	CA	3200
7	33	31	156,806		3,123,576	157,587	90-120	CA	3200
8	33	31	156,806		3,123,576	157,587	90-120	CA	3200
9	91	45	122,640		2,343,650	595,104	95-105	CM	4600
10	93	78	277,684		7,164,247	634,912	80-95	C+	3300
11	46	33	203,028	45,900	5,603,573	188,453	95-105	CA	4150
12	46	33	203,028		5,603,673	438,564	95-105	CA	4150
13	78	44	263,711	389,550	6,091,724	563,409	90-105	CA	4150
14	78	44	263,711		6,091,724	563,409	90-105	CA	4150
15	94	89	124,862		2,240,024	535,688	90-120	CM	4500
16	57	28	210,902		3,922,777	678,156	95-105	CA	3800
17	57	28	210,902		3,922,777	678,156	95-105	CA	3800
18	55	24	146,115		2,559,935	96,886	110	C	3800
19	60	61	171,399		3,054,330	297,826	70-95	C	4000
20	16	7	64,357		No cone collection		70-130	CA	2500
21	7	0	4,555		39,173	64,259	85-200	CA	3500
Scarified									
22	82	75	279,999	645,600	3,583,987	281,216	75-110	C	4500
23	52	40	197,722	441,556	2,669,247	81,270	70-90	C	46-4800
24	98	60	862,788		23,347,043	293,330	90-100	CM	46-4700
Windrowed plus Windrowed-Burned									
25	52	40	197,722		2,669,247	113,576	70-90	C	46-4800
26	98	60	862,788		23,347,043	241,916	90-100	CM	4500
27	98	60	862,788		23,347,043	332,567	90-100	CM	45-4600
28	98	60	862,788		23,347,043	320,390	90-100	CM	45-4600
29	100	80	84,571		1,505,364	77,964	95-135	C	4300
36	55	24	146,115		2,559,935	86,724	110	C	3800
Broadcast Burned									
30	98	60	862,788		23,347,043	177,514	90-100	CM	4500
31	35	30	161,465		2,528,542	55,750	200	AL	5500
32	52	40	197,722		2,669,247	8,950	70-90	C	46-4800
33	52	40	197,722		2,669,247	32,805	70-90	C	46-4800
34	52	40	197,722		2,669,247	14,634	70-90	C	46-4800
35	100	100	180,235	253,760	2,627,826	18,954	95-210	CM	44-4700

(1) Percent of total number of trees within a crown-class with serotinous cone habit.

(2) Dominant and Co-dominant, Intermediate and Suppressed Crown-classes.

seed per acre for stands with a mixed cone habit, and 6.1 million seed per acre for stands with a serotinous cone habit. These estimates are simlar to those predicted by (Bates, 1930; Boe, 1956; Crossley, 1955; Tackle, 1964), but higher than those estimated by Smithers (1961).

Nonserotinous cones were not collected for extraction and testing of seed but reports (Bates 1930; Boe 1956; Crossley 1955 and Tackle 1964) indicate that annual seedfall from this source (nonserotinous stands) varies from 10,000 to 500,000 seed per acre depending upon age of stand, stand density and geographic location.

The 'potential' seed supply never remains *in situ* when an area is logged. Fifty percent or more of the cones and seed may be removed in tops if tops are skidded to landings. Some cones and seed are buried and destroyed by logging equipment. Some losses may occur if an area is scarified and very large losses occur if an area is broadcast burned. In any event, the seed remaining on an area following logging and site preparation constitutes the 'available' seed supply. This supply can be further reduced by losses to rodents, adverse micro-climate, etc., or if cones do not receive radiant energy and open releasing seed soon after felling (Ackermann 1966; Tackle 1954).

Within the areas examined there did not appear to be any correlation between the 'available' seed supply (seed or cones per acre) and the 'potential' seed supply (seed or cones per acre). Size of area logged, season of logging, logging method or time elapsed since logging had no apparent effect on the 'available' to 'potential' ratio. With no site preparation following logging the 'available' to 'potential' seed ratio is 1 to 12. That this ratio is effectively reduced by site preparation is apparent by the ratios of 1 to 42 for scarification and 1 to 52 for windrowing and burning. Less reduction of the 'potential' seed supply appears to occur from drag scarification than from bulldozer blade scarification but this factor would require further study to determine any actual relationship.

Following broadcast burning, only one out of every 146 potential seeds remain available for regeneration purposes and the viability in many instances is suspect.

On the basis of estimated requirements of 30 to 50 viable seed to produce one established seedling (Lotan, 1964) or 10 seeds per spot to produce a 4- to 5-year-old seedling (Prochnau, 1963), there are sufficient quantities of 'available' seed to more than adequately restock all areas provided seedbed is favourable, cones and seed are fortuitously distributed over favourable seedbeds, and all other conditions are favourable for germination and survival.

B. Seed - Seedbed Distribution and Regeneration

On logged areas, with no site preparation, the distribution of mineral seedbeds averaged only 20 percent of the total area. This was increased to 45 percent by broadcast burning, to 50 percent by scarification, and to 72 percent by windrowing. Summer logging produced more mineral seedbed (26 percent) than winter logging (12 percent) but the amount of disturbed seedbed was greater from winter logging (24 percent) than from summer logging (16 percent). Overall, the amount of favourable seedbed produced from summer logging is approximately the same as that produced from winter logging.

TABLE 2 - Seedbed Distribution (Percent of Area)

Site Preparation	Seedbed			
	Mineral	Disturbed	Undisturbed	Other (1)
No Preparation	19.6	19.0	54.0	7.4
Scarified	49.6	27.1	16.2	7.1
Windrowed	71.7	15.7	5.3	7.3
Broadcast Burned	44.8	6.5	7.8	40.9

(1) Other seedbed also includes No seedbed.

If mineral seedbeds are assumed to be the most favourable medium for lodgepole pine establishment, with disturbed seedbeds slightly less favourable, then these seedbeds must receive a fair portion of the cones (seed) distributed during logging or site preparation. On the areas with no site preparation there were, on the average, a significantly lesser number of cones distributed on mineral seedbeds than for any other class of seedbed (Table 3). Nevertheless,

TABLE 3 - Cone Distribution, Percentage Stocking, and Seedling Distribution by Seedbed

Treatment	Number of Areas	Average Years Since Treatment	Number of Cones per Milacre				Number of Seedlings per Milacre				Percent Stocked				Number of Seedlings per Stocked Quadrat			
			M	D	U	O	M	D	U	O	M	D	U	O	M	D	U	O
No Site Prep.	21	2.0	19.9	19.5	20.6	20.8	1.8	1.5	0.9	0.5	22.5	18.0	10.0	6.6	6.6	7.0	7.9	6.6
Scarified	3	1.3	14.3	13.9	9.4	20.6	2.5	0.6	0.2	0	30.2	12.8	2.4	0	6.8	3.7	2.0	0
Windrowed	6	1.3	8.8	8.9	11.2	2.5	3.0	1.2	0.4	1.0	32.3	22.0	3.3	16.6	8.4	3.6	9.0	4.8
Broadcast Burned	6	1.3	3.3	6.4	2.3	1.6	0.6	0.7	0.5	0.2	12.5	13.6	3.9	5.2	3.6	3.6	1.0	2.7

M - Mineral, D - Disturbed, U - Undisturbed, O - Other Seedbeds the advantage of mineral seedbed is evident in that the lesser number of cones produced significantly better stocking, a significantly higher number of seedlings per stocked quadrat, and a higher average number of seedlings per unit area than occurred on any other class of seedbed. These relationships are valid regardless of elapsed time since logging or season of logging. Large numbers of seedlings per stocked unit of area are associated with large numbers of cones per milacre and higher rates of stocking but a large number of cones does not necessarily produce a high rate of stocking or large numbers of seedlings per stocked quadrat.

Disturbed seedbeds do not become as well stocked, produce as many seedlings per stocked quadrat (a desirable feature), or as many seedlings per unit of area from a greater number of cones than which occur on mineral seedbeds.

A small amount of stocking occurs on a large portion of the areas represented by undisturbed and other seedbeds. Many of the cones (seed) on these seedbeds are wasted and could be better utilized on mineral and disturbed seedbeds. This can be accomplished by some form of site preparation.

Scarification, at the same time as increasing the quantity of mineral seedbed, spreads cones more evenly over all seedbeds. Percentage stocking increases on the greater quantity of quality seedbed without a similar increase in number of seedlings per stocked unit of area.

It is possible that scarification or windrowing activity shreds or grinds cones to release and distribute seed, at the same time destroying any evidence that cones had been on the stocked spot.

Windrowing, or windrowing and burning, of slash provides large amounts of favourable seedbed but some of the advantages are lost in that some of the cones and seed are removed from the favourable seedbeds. Percentage stocking is increased but it is only slightly better than on scarified areas while the number of seedlings per stocked quadrat increases considerably.

Broadcast burning destroys most of the cones and seed with the result that stocking is poor. The only benefit is that the average number of seedlings per stocked unit of area is maintained at a low level, that is, overstocking is not as much of a problem as where broadcast burning is not carried out. However, broadcast burning of lodgepole pine slash should only be considered in cases where other slash-disposal methods are not economically feasible or would be more damaging to the ecosystem. Even for sanitation purposes, e.g., areas infected with dwarf mistletoe, broadcast burning should only be used if scarification will not accomplish the objective. Where broadcast burning is used for site preparation, regeneration by artificial methods will be necessary. Broadcast burning of cutover areas produces results unlike those generally accepted for wildfires in uncut stands. Generally, wildfires produce a high proportion of favourable seedbed and provide heat to open cones in the crowns and release copious amounts of seed. The favourable seedbed and seed supply in combination with the dead shade provided by standing burned stems often results in an over-stocked stand of lodgepole pine. The actual number of stems may vary from a few thousand per acre to many thousands per acre depending upon effects of many factors but the end result is undesirable overstocking.

Although clear-cutting does not duplicate the set of conditions similar to those provided by wildfire some overstocking may occur. Logging is a man-controlled operation and the primary objective for regeneration should be satisfactory stocking with acceptable spacing.

The expectation that creation of larger quantities of mineral seedbed by scarification would result in more overstocking was not evident on the areas examined.

There is a trend towards more normal stocking with time elapse following logging or site preparation (Table 4). These trends were supported by data available from a few additional areas which had been examined annually for two years following logging and site preparation.

The reduction in density in relation to time lapse is produced by a combination of mortality and criterion of number of seedlings required for stocking as age of survivors increases.

Table 3 indicates that overstocking with lodgepole pine is a problem but Tables 3 and 4 also show that impact of overstocking is lessened by passage of time and by ensuring good distribution of mineral seedbed. The latter is very important since it is essential for attainment of minimum desirable stocking levels. The necessary quantities of mineral seedbed can be obtained by scarification, or by windrowing where slash conditions warrant such action.

TABLE 4 - Number of Seedlings per Stocked Quadrat in Relation to Treatment and Time

	Years Since Disturbance		
	1	2	3
Treatment			
No Site Preparation	8.6	7.8	5.9
Site Preparation, except Burning	7.6	6.6	No Areas
Additional Areas			
No Site Preparation	7.0	4.8	
Site Preparation	8.1	6.5	

SUMMARY AND CONCLUSIONS

In most stands of lodgepole pine within the south central Interior of British Columbia there are a sufficient number of trees with a serotinous (closed) cone habit to provide for natural regeneration following disturbance. On the average, these cones contain a large number of seed with a medium to high germinative capacity. Nevertheless, there are stands of lodgepole pine which have a nonserotinous (open) cone habit. These comprise only a small percentage of the whole type but are of sufficient extent that they must be recognized. Because of the genetic and phenotypic differences between trees with nonserotinous and serotinous cone habits, blanket silvicultural prescriptions cannot be applied.

Nature's method of reproducing lodgepole pine is by wildfire but the end result is not always suited to man's wood production, recreation, or wildlife management objectives. Attempts to duplicate nature by broadcast burning of slash are actually contradictory to nature. In very rare cases, under certain conditions, attempts to obtain natural regeneration by broadcast burning of slash may be successful but the success ratio is very low.

There is a sufficient store of sound seed in most stands to provide for natural regeneration but these seeds are not distributed evenly over all seedbeds by logging nor is the amount of favourable seedbed (mineral soil) distributed in adequate quantities over the areas. These conditions do not appear to be affected by season or method of logging, or size of area logged.

Although mineral soil appears to be the best medium for lodgepole pine germination, this species does germinate and survive on all seedbeds and, despite the limitations of seed and seedbed distribution, there is a trend towards minimum satisfactory stocking within three years following logging.

Distribution of seed over quality seedbeds, increase in quantity of quality seedbed, and attainment of better than minimum satisfactory stocking within minimum time can be obtained through site preparation techniques such as drag scarification or windrowing. Pre-logging stand conditions will, in most cases, determine the method of post-logging site preparation.

Overstocking is a condition common to lodgepole pine whether regeneration occurs following logging or wildfire. The number of seedlings occurring can be partially controlled by broadcast burning of slash but some overstocking may be more ecologically and economically desirable than slash-disposal treatments which require costly artificial regeneration methods to obtain minimum stocking levels.

The number of seedlings per stocked unit of area can be partially controlled through site preparation, that is, through better distribution of cones and seedbed. Natural mortality over the first few years of stand establishment also lessens the overstocking effect to some extent.

Implementation of specific cutting methods and slash-disposal treatments may be partially dependent upon pathological conditions but is also partially dependent upon cone habit. Stands with 20 percent or less of dominants and co-dominants bearing good crops of serotinous cones may not have a sufficient store of sound seed to regenerate large clearcut areas. In these stands small clearcuts or narrow clearcut strips, leaving of tops with serotinous cones, and scarification may be the best treatment. For regeneration purposes, the size or shape of the clearcut is not a prime importance in stands within which 20 percent of more of dominants and co-dominants bear serotinous cones.

Lodgepole pine is a prolific seed producer and will regenerate itself on sites which are low in nutrient material or are too dry for other species. This is not sufficient reason to assume that adequate regeneration will occur regardless of size of clearcut, time of logging or method of logging.

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