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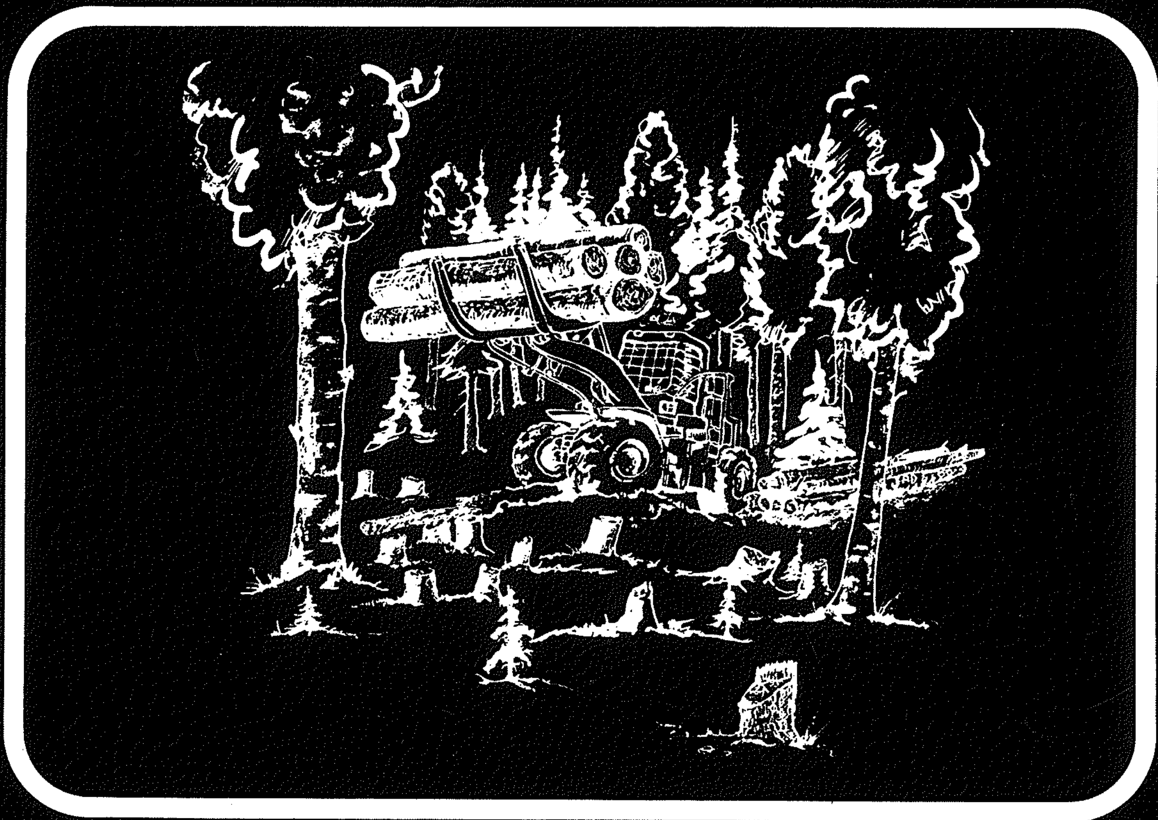

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LOGGING HARDWOODS TO REDUCE DAMAGE TO WHITE SPRUCE UNDERSTORY

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ABSTRACT

Hardwood stands with spruce understory were logged to preserve the understory trees in sufficient numbers to form valuable stands. Conventional mechanized felling in hardwood stands destroyed 40%, damaged 16%, and left undamaged 44% of the spruce understory. Skidding increased destruction by 19% but reduced damaged trees by 4%, leaving 30% of all original trees unscathed. A separate study in a similar stand minimized logging damage to spruce understory through special efforts in planning, design, operator training, and close supervision. About 75% of the original spruce trees remained undamaged after logging that removed approximately 70% of the merchantable hardwoods. Recommendations include use of 10-m^2 quadrats to determine prelogging and postlogging understory stocking, incentives and penalties based on logging performance with respect to change in stocking, specialization of some logging contractors, use of more-suitable equipment, use of the herringbone pattern of logging in extensive and dense understory, and logging when the temperature is above -10° C.

RESUME

Des peuplements de feuillus avec sous-étage d'Epinette ont été exploités afin de préserver les arbres de sous-étage en nombre suffisant pour former des peuplements de valeur. L'exploitation classique utilisant la machinerie dans les peuplements de feuillus a détruit 40%, endommagé 16% et laissé intact 44% du sous-étage d'Epinette. Le débusquage a augmenté de 19% la destruction mais a réduit de 4% les dégâts causés aux arbres, laissant intacts 30% de tous les arbres d'origine. Une étude séparée effectuée dans un peuplement similaire a minimisé les dégâts d'exploitation au sous-étage d'Epinette au moyen d'efforts spéciaux de planification, de conception, de formation des opérateurs de machines et d'une surveillance serrée. Environ 75% des sujets d'Epinette n'ont pas subi de dégâts, suite à une exploitation ayant enlevé approximativement 70% des feuillus marchands. Les recommandations incluent l'emploi de quadrats de 10 m^2 pour déterminer la préexploitation et la postexploitation du matériel sur pied de sous-étage, des incitations et pénalités fondées sur la performance de l'exploitation quant au changement du matériel sur pied, la spécialisation de certains exploitants, l'utilisation d'équipement plus adéquat et du modèle d'exploitation en chevrons dans les sous-étages étendus et denses, de même que l'exploitation effectuée lorsque la température est supérieure à -10° C.

CONTENTS

FIGURES

TABLE

NOTE

The exclusion of certain manufactured products does not imply rejection nor does the mention of other products imply endorsement by the Canadian Forestry Service.

INTRODUCTION

In Saskatchewan the Mixedwood Section (B.18a) of the Boreal Forest Region (Rowe 1972) occupies nearly 120 000 km^2 (Kabzems *et al.* 1976). Forests of white spruce (*Picea glauca* [Moench] Voss) and aspen (*Populus tremuloides* Michx.) constitute the largest and most productive timber resource, especially in the Hudson Bay region. Unfortunately, concentration of forest industries, wildfires, and repeated high grading of white spruce have caused critical imbalances in terms of species and age classes.

Since 1961, MacMillan Bloedel annually has clear-cut about 2300 ha of aspen for waferboard manufacture, cutting primarily in stands without major softwood (white spruce) understories. Because of the depletion of pure stands within an economical distance, hardwood logging is now undertaken in aspen and balsam poplar (*Populus balsamifera* L.) stands that frequently have in their understories major components of white spruce regeneration or advance growth (Figs. 1 and 2). These are referred to as problem stands.

Until recently, conventional logging of hardwoods in problem stands has destroyed or damaged the spruce understory at almost all density levels (Fig. 3). This destruction is unacceptable to the industries that depend on white spruce and to the Saskatchewan government, which is responsible for and expends large amounts of money on white spruce reforestation.

The value of the spruce understory can only be estimated. From the point of replacement cost, Ball (1980) found that for successfully established white spruce plantations on similar sites the cost after 5 years was approximately $1 per metre of aggregate height. For 800 evenly distributed 25-year-old understory spruce trees per hectare, the aggregate height is nearly 5000 m.

If 800 white spruce per hectare could be protected during the logging of aspen, the benefits would justify a more costly aspen harvesting system. The problem of spruce understory destruction during hardwood logging therefore became the subject of studies with the following objectives:

1. Assess the loss of and damage to spruce understory at various densities during conventional aspen harvesting.

2. Develop an economically feasible logging method for minimizing damage to the spruce understory.

This report summarizes three case studies: The first two studies address the first objective, and the third satisfies the second objective. The investigations were conducted during winter logging operations because problem stands are usually harvested in the winter to take advantage of the frozen, hard ground on these generally wetter sites.

STUDIES I AND II

Description of the Study Areas

Study areas I and II are located about 30 km southeast of Hudson Bay, Saskatchewan, and are typical of the Carrot River Lowlands (Kabzems *et al.* 1976). Three adjoining hardwood stands (HD4)[1] totaling approximately 60 ha were selected because their conditions were typical of problem stands; that is, a generally dense but somewhat clumpy spruce understory was growing under an excellent stand of mixed aspen and balsam poplars (Figs. 4 and 5). Having flat topography and moist, calcareous clay loams, the sites are considered very productive for both spruce and aspen and supported an average of 326 m^3 (stacked) of merchantable hardwoods per hectare before logging (Figs. 6 and 7).

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[1] HD4 is conventional Saskatchewan terminology:
H = Hardwood cover type (more than 75% hardwoods by volume).
D = Density class D (71-100% crown cover).
4 = Height class 4 (21.4 + m).

Figure 1. White spruce under aspen in natural succession.

Figure 2. Dominance of white spruce coincides with deterioration of the hardwood resource.

Figure 3. Spruce understory is frequently destroyed in hardwood logging operations.

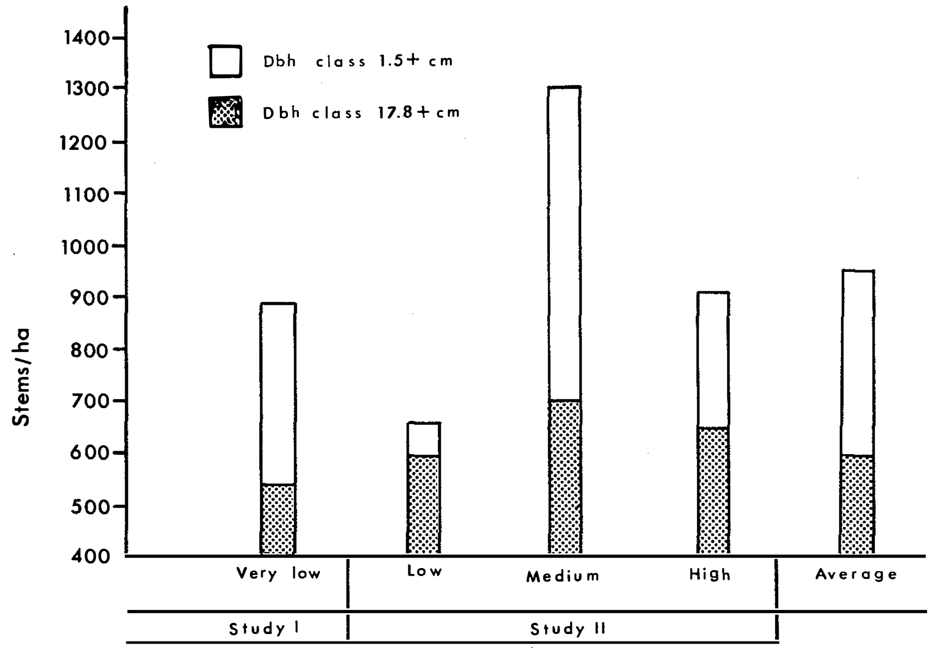

Figure 4. Hardwood overstory density prior to logging for studies I and II and their combined average.

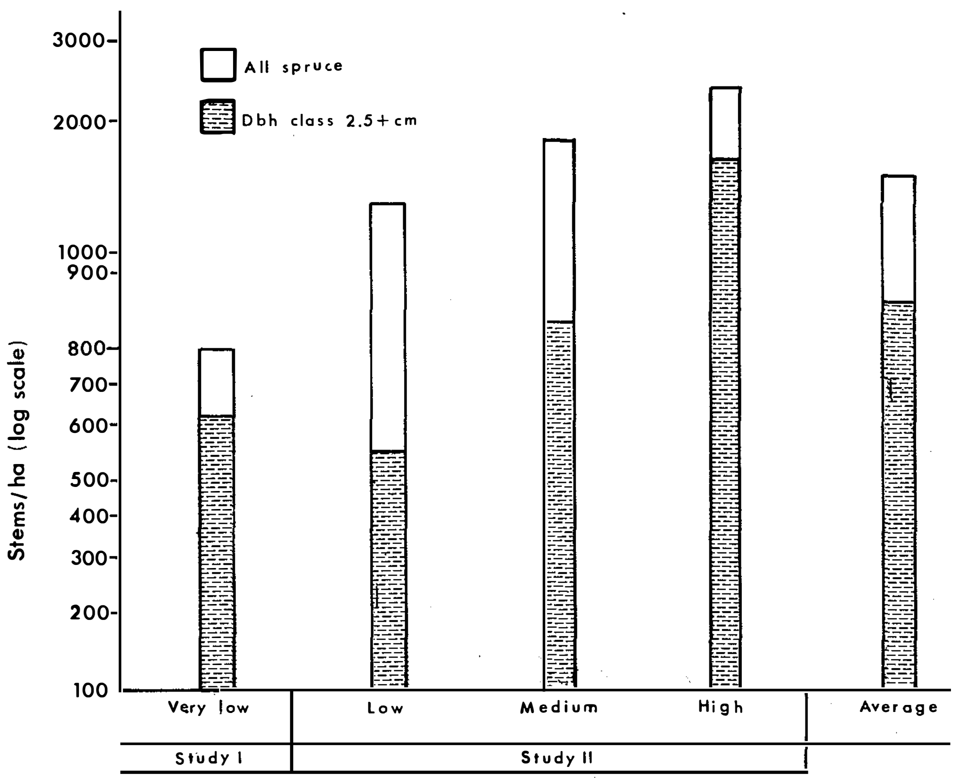

Figure 5. Spruce understory density prior to logging for studies I and II and their combined average.

Figure 6. Study I area prior to logging.

Figure 7. Study II area prior to logging.

Figure 8. Hardwood felling by mechanical equipment.

Plot Establishment

In Study I, six line plots (each 6.5 × 201.0 m) were established in November 1974 to measure logging impact on spruce understory. All living trees within 3.25 m of the established center lines were measured and recorded by diameter at breast height (dbh) classes. The 1.5-cm class includes regeneration of less than breast height to those of 1.5-cm dbh.

In Study II in October 1975, identical data were collected from four 20 × 20 m plots in each of three major understory density classes. The purpose of Study II was more specific, namely, to study

1. the influence of varying understory densities on relative amounts of logging damage, and

2. the contribution to overall damage by a) felling and b) skidding.

The density classes were defined by the number of spruce understory trees:

Low:	up to 1400 stems/ha
Medium:	1400-2000 stems/ha
High:	more than 2000 stems/ha.

Felling, Skidding, and Remeasurement

In Study I, all merchantable aspen and balsam poplars were cut with a Case 1150 cleat-tracked feller-buncher in January 1975 (Fig. 8). Delimbing and topping of trees were done by chain saw (Fig. 9). Wheeled cable skidders were used to skid the bunched wood in tree lengths to nearby landings for bucking (Fig. 10). Most tops were lopped at the felling site, but several bunches were skidded to the landings with tops still attached. The logs were loaded onto trucks at the landings (Fig. 11).

Hot-log operation prevented data collection between felling (Fig. 12) and skidding. Due to difficulties in relocating plots following snowfalls and logging, postlogging remeasurement was postponed until spring 1975. At that time, all remaining trees on the line plots were measured, and spruce trees were recorded as undamaged, damaged, or destroyed.

In Study II, logging took place in December 1975. The same equipment was used as in Study I. Some trees with stump diameters near 45 cm exceeded the machine's capacity and were hand felled. Due to very low temperatures (-25°C to -30°C) at the time of felling, many aspen tops shattered on impact. While this eased the work load for the delimbing crew, the cold also made spruce trees and branches extremely brittle and prone to damage.

Plots were relocated between felling and skidding, and a complete tally was made of all undamaged, damaged, and destroyed trees. It was observed that the bunched trees were not always aligned in the primary skidding direction and that the required change of direction caused some further losses of spruce during skidding. The after-skidding (Fig. 13) tally, conducted in the spring of 1976, was identical in method to the one carried out after felling.

Results and Discussion

Results from studies I and II are shown in Figure 14. Damage and destruction do not appear to be related to understory density. Of all spruce advance growth and regeneration, about 44% remained undamaged, 16% was damaged, and 40% was destroyed after felling. Tree destruction was consistently higher among the smaller regeneration, but damage was always higher among the larger trees. Half of the damaged trees suffered only broken branches, and most of those trees are likely to recover. Destroyed trees were uprooted or had broken stems.

Considerable damage and destruction were caused by careless skidding. Skidder operators showed a tendency to skid the wood to the landing and return from there by the shortest route, thus damaging and destroying spruce that could have been saved if the skidder had followed already traveled routes. In Study I, some log bunches were skidded with their tops still attached, result-

Figure 9. Feller-buncher hardwood cutting is followed by chain-saw delimbing and topping.

Figure 10. Manual bucking on prepared landing.

Figure 11. Loading of hardwood bolts.

Figure 12. Small clump of spruce after felling in Study I area.

Figure 13. Study II area after logging.

ing in increased damage. Skidding in Study II increased tree destruction by about 19%. Because some of these destroyed trees had already been damaged during felling, the undamaged tree component was reduced by only 14%.

Whether spruce damage or destruction is related to initial density is less important than the quality and distribution of the remaining spruce. As long as adequate numbers of thrifty individuals are protected, it is unimportant just how many trees are destroyed in dense patches. In fact, thinning out some of the spruce may be beneficial. At low densities, well-spaced trees are of great value, so that the percentage destroyed would have greater importance.

The fact that small trees suffer greater losses is explained by the tendency of an operator to follow the path of least resistance. Operators will avoid a large spruce at the expense of a smaller one, regardless of how it affects stocking.

Very cold temperatures during felling result in higher branch breakage in all density classes. At about -10°C and colder the incidence of breakage increases as temperature decreases.

STUDY III

With the type and magnitude of spruce understory damage during hardwood logging having been detailed, it was thought that losses could be substantially reduced by improved planning, operator education, and supervision.

This proposition was tested in an operational setting in the winter of 1976-77. A test area was located that had about the same number of hardwood stems per hectare as the earlier studies, although the trees were smaller. The purpose of Study III was to preserve as many spruce understory trees as possible within the framework of a slightly subsidized operation.

Area and Stand Description

The area, located approximately 6 km south of Somme, Saskatchewan, was triangular in shape and 16.5 ha in size (Fig. 15).

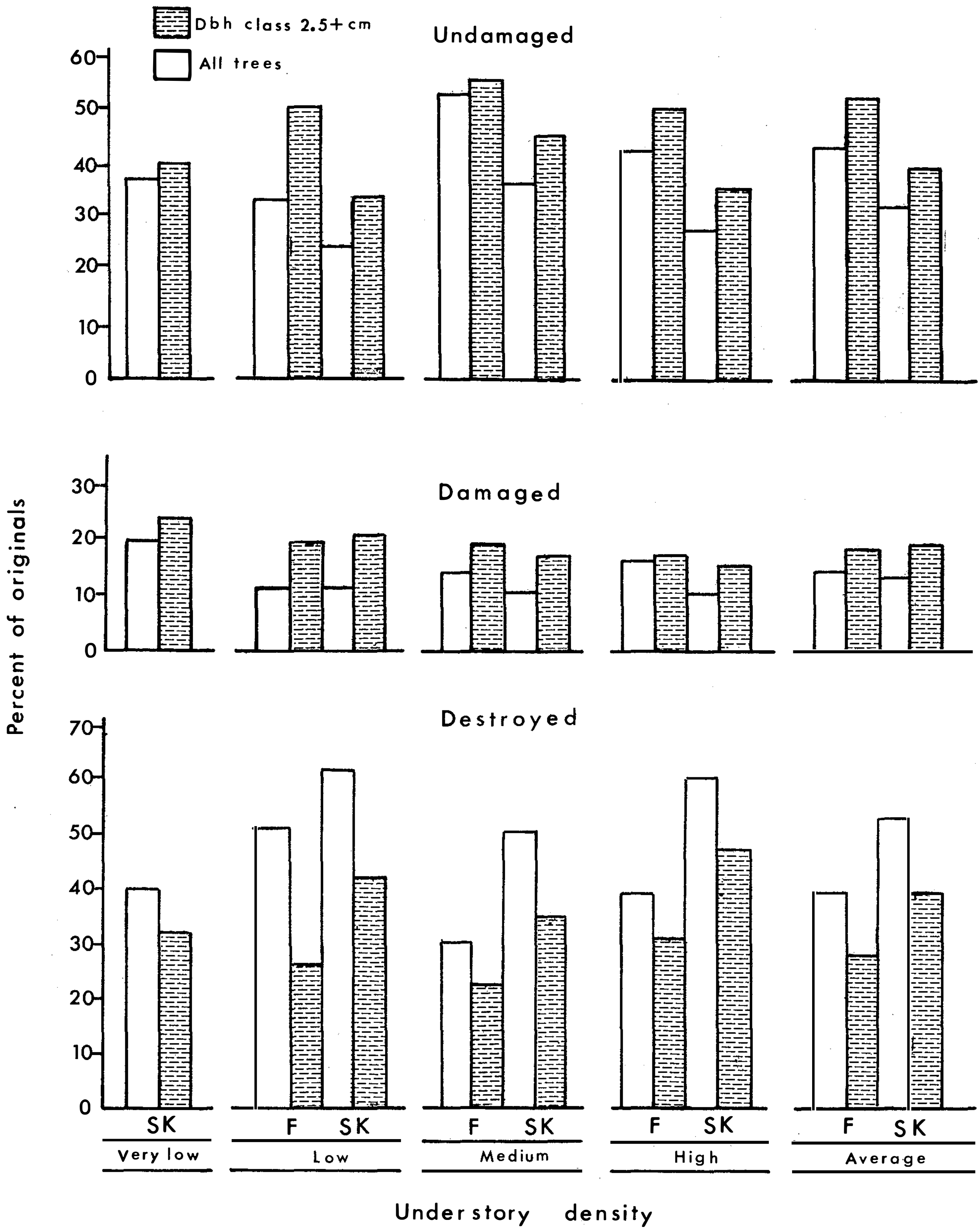

Figure 14. Studies I and II spruce understory status after felling (F) and skidding (SK) in percent of original trees.

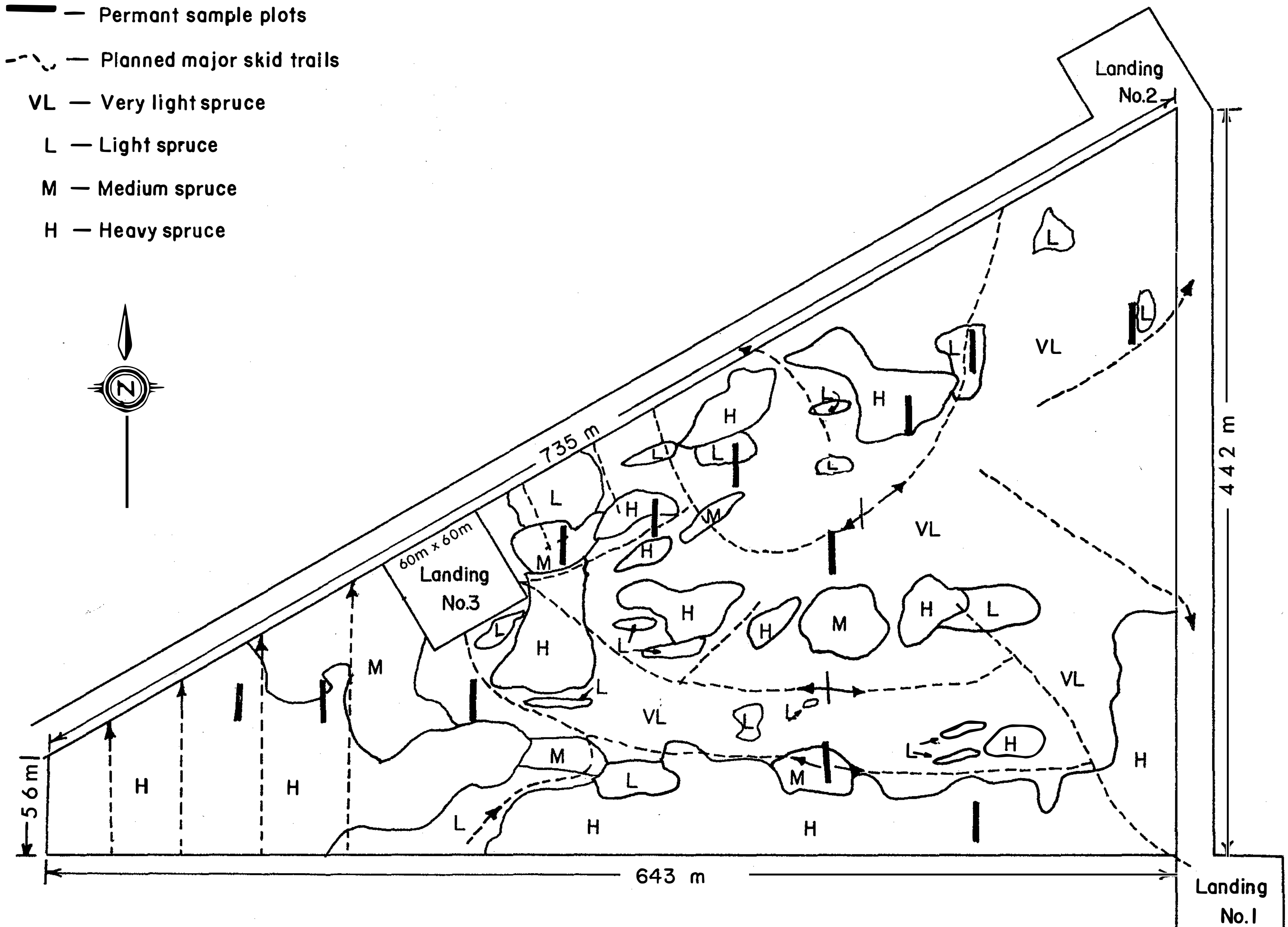

Figure 15. Sketch of Study III trial area indicating spruce understory density.

Two logging haul roads and three landings along two sides of this triangle (Fig. 16) had been constructed the year before logging. Inventory maps showed the stand to be HD3[2] on level terrain. The site itself was imperfectly drained, with a high proportion (30%) of balsam poplar in the merchantable (17.8+ cm) hardwood class. The 60-year-old hardwoods showed signs of early maturity in the form of stained heartwood and some butt rot.

Cruising provided prelogging stand information and allowed mapping of the spruce understory (Fig. 15), which in turn served in plotting main skid trails.

The cruise-compass lines spaced 50 m apart, with 5 × 25 m plots located at 50-m intervals (4.4% cruise), showed an irregular pattern of the spruce and even distribution of the aspen and balsam poplar stems.

Nearly 90% of the spruce understory was less than 10 cm dbh and ranged in height from an average of 1.2 m for the 1.5-cm and under dbh class to 7.3 m for the 10-cm dbh class. Larger spruce were usually located in the denser clumps, while smaller spruce occurred singly (Fig. 17) and under frequently intense competition from shrubs. Stem counts are shown in Figure 18. The 5-cm dbh spruce were about 25 years old, and the 10-cm dbh spruce were on the average 39 years old at stump height.

Methods

Since three landings and two haul roads were already in place, efforts were concentrated on locating major skid trails. A sketch (Fig. 15) indicating areas of high, medium, and low spruce understory densities was used initially to locate main skid trails to ensure approximately equal skidding distances to the landings. The major skid trails were flagged in the field, with sufficient flexibility that allowed taking advantage of openings in the understory.

In the western part of the area, the spruce were somewhat clumpy and generally very dense. Here three lines parallel to one another and spaced 50 m apart marked the center lines for skid trails that were to be cleared. The objective was to clear both spruce and hardwoods prior to the feller using this line as a base from which he could operate in a herringbone pattern. Depending on stand conditions and openings, bunching was to be done in either the skid trails or the stand. Bunching in the direction of skidding was a basic requirement.

The felling of every merchantable hardwood tree was not mandatory in areas of heavy understory, and leaving trees was left to the feller's discretion. It was hoped that placing this responsibility on the feller would result in continuous evaluation and even greater awareness of and attention to the objectives.

To determine felling damage, 12 permanent 5 × 25 m sample plots representing low to very high spruce understory densities were established and tallied before felling began.

The contractor responsible for logging the area agreed to log the test area as prescribed. A subsidy of $1 per 3.6 m^3 (stacked) was paid to compensate for increased costs.

Prior to felling, the operator of the Case 1150 feller-buncher was taken on foot through the stand, and conditions, objectives, and possible techniques for reducing spruce damage and loss were discussed. The operator showed keen interest in the project.

Felling began on December 13, when about 5 cm of snow covered the ground and the temperature was well below freezing. A research technician was present whenever work was done in the test area. On numerous occasions he mounted equipment to gain better appreciation of the difficulties and offered suggestions for resolution.

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[2] H = Hardwood cover type (more than 75% hardwoods by volume).
D = Density class D (71-100% crown closure).
3 = Height class 3 (15.3 to 21.3 m).

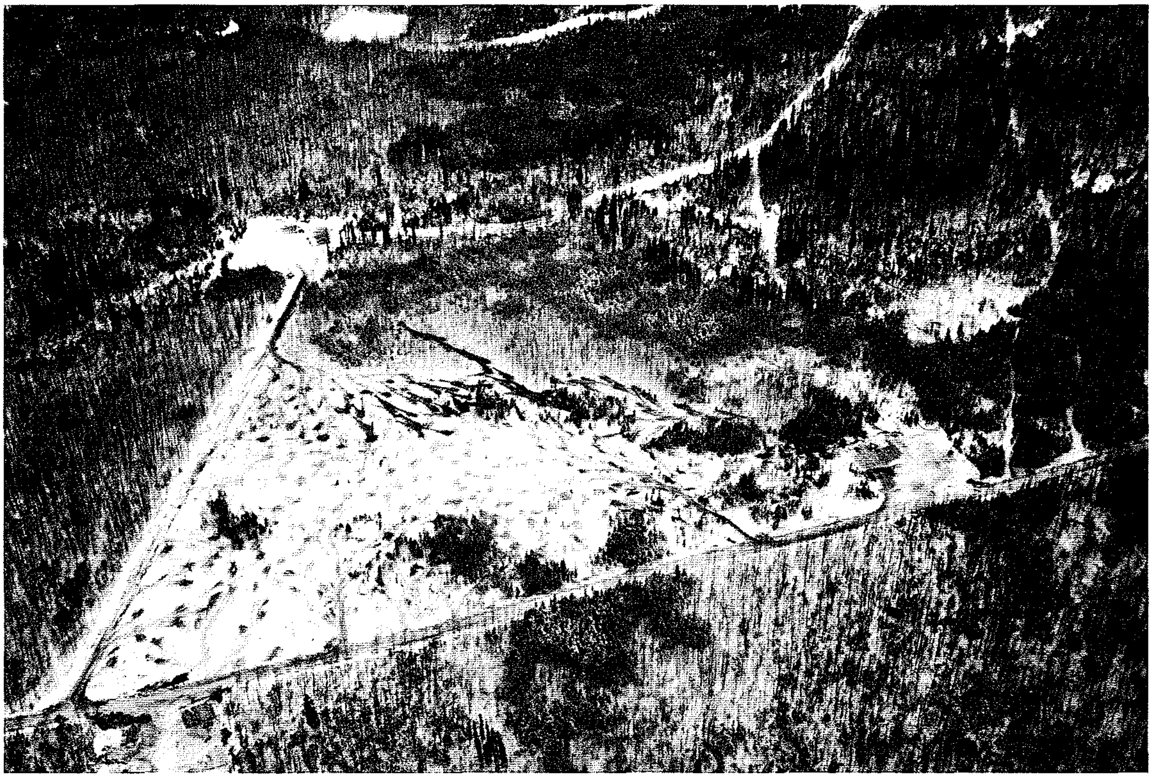

Figure 16. Study III area during logging operations. Note parallel skid trails in heavy spruce understory at right.

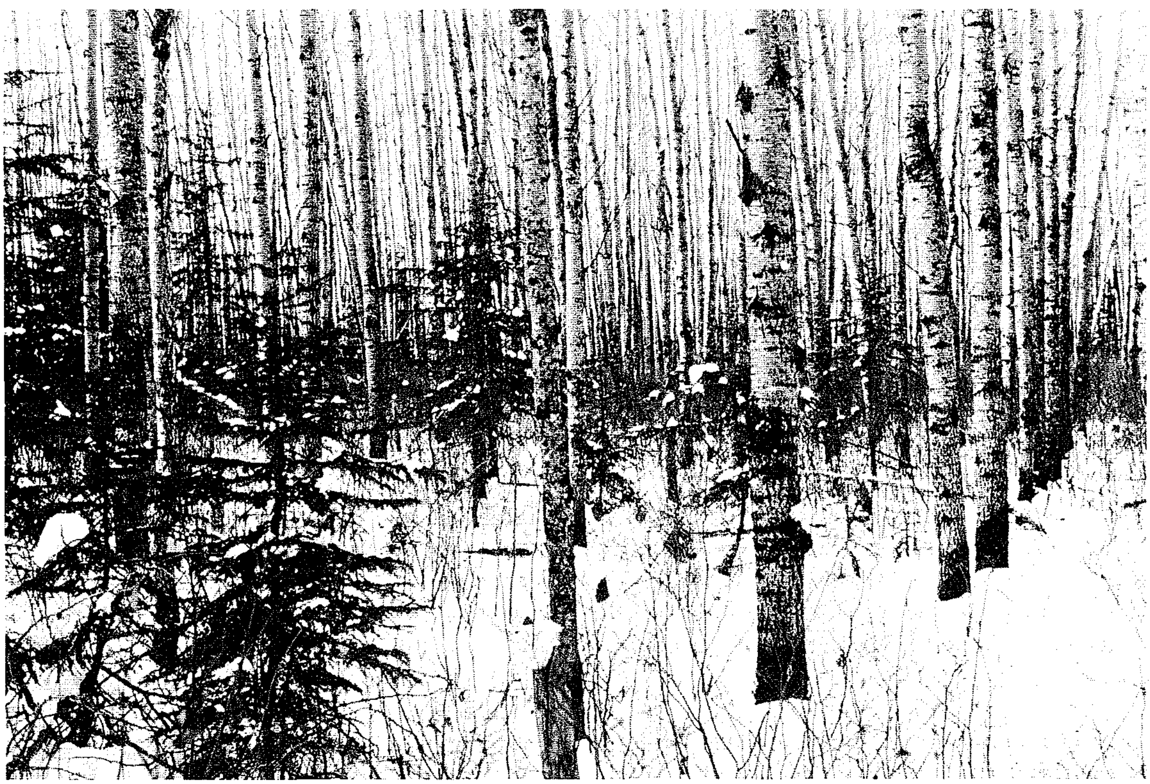

Figure 17. Prelogging stand conditions in Study III area showing light spruce understory density.

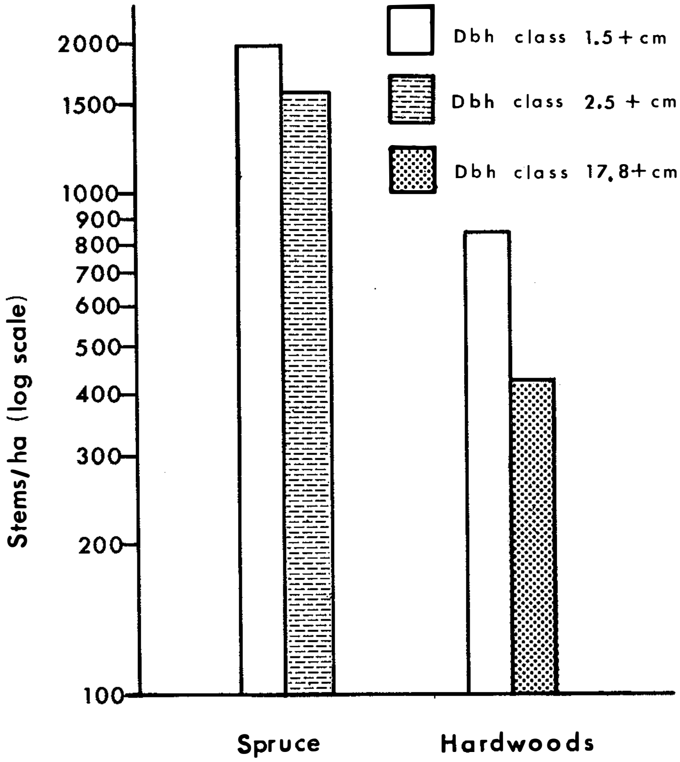

Figure 18. Study III stand composition prior to logging.

Felling progressed in strips from the center toward the outside, with continuous attention being paid to skidding opportunities and spruce understory trees. Tree-length skidding began on December 22 after felling had been carried out for 55 hours and the two-man topping crew was well advanced. Three different skidders—Clark Ranger 662, Case 825, and Clark Ranger 667 grapple (Fig. 19)—were used at various times, but all skidder operators were instructed to operate carefully with respect to the understory spruce. They were advised to follow main skid trails or trails already broken by the feller-buncher. They also were asked to back up, where practical, rather than to drive up to log bunches and turn around, which causes additional damage to spruce. Since the feller had aligned bunches in the direction of skidding, emphasis was placed on straight skidding and smooth turns.

Permanent sample plots were retallied between felling and skidding, but the postlogging surveys were deferred until spring.

Results

A total of 3867 m^3 (stacked) of aspen was felled on the 16.5-ha test area (234 m^3/ha). The felling appeared incomplete, as nearly 30% of the hardwood stems in the 17.8+ cm class remained uncut on the permanent sample plots. A postlogging cruise of the entire block showed, however, that only 15% of the hardwoods in the merchantable-size classes remained after logging (Fig. 20). Most of the unharvested stems were in areas of dense spruce, and some of the hardwood trees were showing signs of decay. Even under normal operational conditions, many of the trees would have remained because it would have been considered uneconomic to break through dense spruce for these relatively low volumes.

With respect to spruce damage and destruction, the extra efforts in this study appeared to have paid off. Only 12% of the spruce showed damage, and 7% were found destroyed after felling (Fig. 21). Interviews

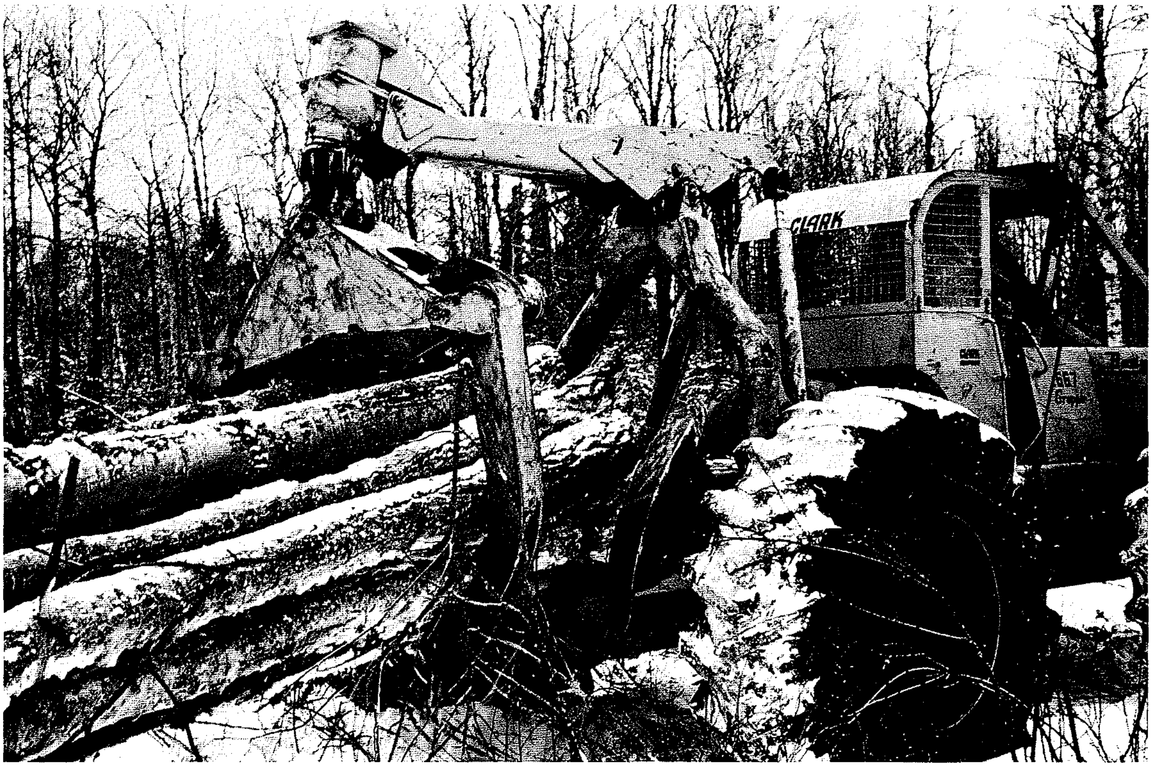

Figure 19. Tree-length skidding by grapple skidder.

Figure 20. Study III area after felling.

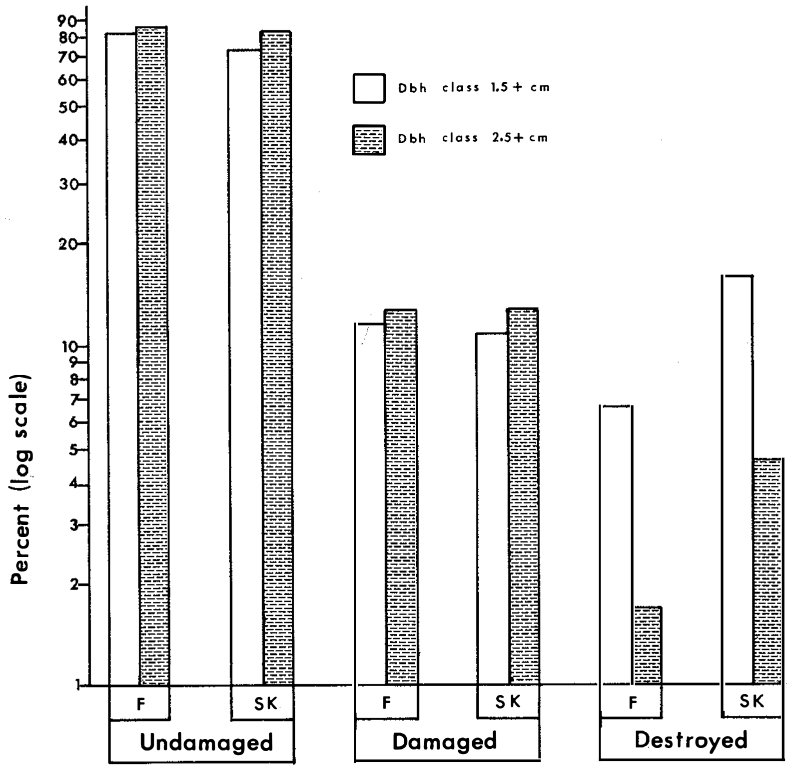

Figure 21. Study III spruce understory status after felling (F) and skidding (SK), in percent of original trees.

with the skidder operators indicated that skidding efficiency did not suffer because of the extra precautions and efforts requested. Time that may have been lost was apparently compensated for by good alignment of log bunches, nearly equal skidding distances to landings, and suitably located major skid trails on which travel was fast.

Although grapple skidding appeared more efficient, it requires more precautions because of its greater width. In narrow trails under dense understory conditions it is likely to result in greater damage.

As was observed in studies I and II, the number of damaged spruce had actually decreased after skidding because of destruction of some of these trees and despite new damage that skidding caused. Damage and destruction from skidding is best observed from the standpoint of remaining healthy spruce trees. Skidding contributed to an 8% reduction in undamaged trees on the sample plots. Destroyed trees after skidding increased by 9%, but many of them had already been damaged during felling.

Aspen harvesting could have been more complete if the skid trails in dense understory had been located every 25-30 m instead of every 50 m. The parallel skid trails in the dense understory appeared comparable to row thinning, and crown closure is likely in a few years.

Discussion

As the percentages of undamaged spruce after skidding indicate (Fig. 21), at least 70% of the merchantable hardwoods in similar stands could be logged in a manner that leaves at least 70% of the spruce undamaged. Because about half of the damaged trees will also recover, at least 75% of the original spruce understory trees could be considered saved.

The small size of this study's hardwoods (with short stems and small crowns) may have resulted in fewer losses and less damage than would occur with larger trees; however, logging of smaller trees means more trees per log bunch and so more maneuvering by the feller. Also, because of sometimes excessive feller movement, log bunches were frequently of less than optimal size, necessitating more bunches and skidding turns. Having a larger number of smaller trees per bunch led to fanning-out of crowns to facilitate adequate topping.

The good logging performance in this study in terms of understory preservation is seen as the result of improvements in cutblock layout and design, discriminatory tree removal, continuous supervision, and above all the operator's willingness to cooperate. From the logger's point of view, the subsidy of nearly $0.30 per m^3 (stacked) did not quite compensate for extra costs, but he conceded that this was largely because of the smaller hardwood timber.

In this study, the herringbone pattern of hardwood felling in dense spruce understory left an adequate stocking of spruce (Fig. 22). For more-complete logging, however, skid trails should be 30 m apart or closer. Where spruce understory is dense, harvesting of hardwoods can actually benefit the spruce through release and improved spacing. To fully capitalize on this, emphasis should be placed on adequacy of stocking with healthy spruce after logging rather than on damage and destruction percentages.

Optimum spruce stocking with undamaged and released advance growth is desirable in this region, and logging plans and performance evaluation should be based on understory stocking. For example, where a stand shows 60% understory stocking by 10-m^2 quadrats and is judged worthy of hardwood logging, a logger might be allowed a certain percentage of destruction that, if not exceeded, would leave acceptable spruce stocking and would satisfy all objectives. Prelogging stocking surveys could also be used to map out stand conditions for planning the layout of subsequent operations.

Stocking checks would be carried out after logging, and bonuses or penalties could be given according to performance. Because such operations will be more costly, reduction of stumpage may offer the necessary incentive. Considering the potential gain in spruce growth and elimination of the need for costly artificial spruce regeneration, such a course of action could well be justified.

Consideration should be given to the use of more-suitable felling equipment. The Case 1150 feller with its 2-m-wide and 3-m-long tracks and overall length of 5.2 m showed good mobility, but may be outmaneuvered by an articulated wheeled carrier with extending cutting head. Although such equipment could leave more spruce regeneration, the size and weight of hardwoods to be harvested might dictate the type of equipment to be used.

Bark damage—mostly at stump height or slightly above—was caused mainly by skidding. High stumping in critical situations and along skid trails may save many spruce from almost certain destruction or damage (Fig. 23). High stumps would guide log bunches around spruce trees that from a stocking standpoint might be in key locations. Likewise, tight bunching of trees (Fig. 24) could help prevent losses, although it does increase the topper's work load. Tight bunching also requires greater skill. Good supervision is required to overcome the operator's tendency to fan treetops (Fig. 25).

Observations of currently logged spruce stands that were selectively logged several decades ago reveal that former basal scars lead to butt rot, which sometimes extends beyond the first 2-m log.

Root damage to spruce regeneration in winter operations is not important. Judging from observations in other and older cuts where spruce was in excess of 8-10 m in height at logging, vulnerability to windthrow is great; hence stand conditions must be evaluated prior to logging. Leaving some hardwood trees on the logged area will likely reduce wind damage to otherwise critically exposed spruce trees. The residual hardwoods would

Figure 22. Careful logging in Study III preserved the bulk of the existing spruce understory.

Figure 23. High stumping along skid trail protects spruce.

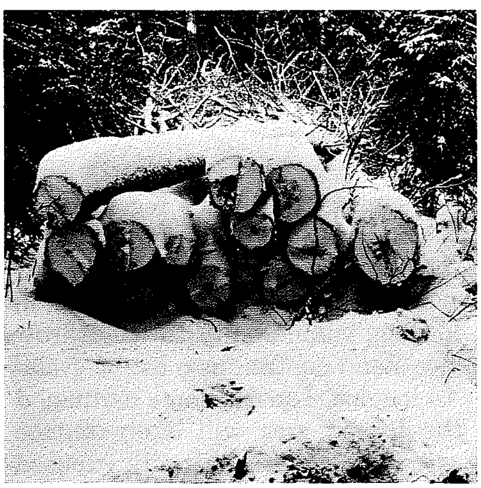

Figure 24. Tight bunching saves many spruce from damage or destruction.

Figure 25. Fanning of trees in log bunches leads to needless loss and damage.

also be subject to blowdown and might negatively influence aspen suckering.

COMPARISON OF THE CASE STUDIES

The initial stand and understory composition of the study areas is summarized in Table 1. Differences in hardwood overstory were most notable in terms of the basal area of trees 17.8+ cm dbh. In Study III, the basal area per hectare for merchantable hardwoods was only 43% that of the average for the earlier studies, but the number of merchantable trees was only 23% lower.

While studies I and II defined understory damage and loss under current operational conditions, Study III suggested that a substantial reduction in damage and loss can be achieved through modifications of the logging system. In Study II the range of undamaged spruce after felling was 35% to 54% (Fig. 26). With the modified logging system in Study III, over 80% of the spruce remained undamaged after felling.

Figure 26 shows the percentage of undamaged spruce after skidding for all three studies. Skidding reduced the average number of undamaged spruce by 14% in Study II and by only about 8% in Study III. Considering the greatly reduced maneuverability in about twice the density of undamaged spruce after felling in Study III, this must be interpreted as a definite performance improvement.

Tree damage was less varied and after felling averaged about 16% in Study II and 12% in Study III. Skidding in Study II reduced the percentage of damaged trees by an average of about 4%, mainly by destroying trees already damaged at felling. In Study III there was no appreciable change (1%) in the number of damaged trees after skidding.

Destroyed trees make up the balance of unaccounted spruce trees. Tree destruction from felling in the three density classes of Study II varied between 30% and 53%, averaging about 40%. Percentage destruction was greatest in the low-density (up to 1400/ha) class, lowest in the medium-density (1400-

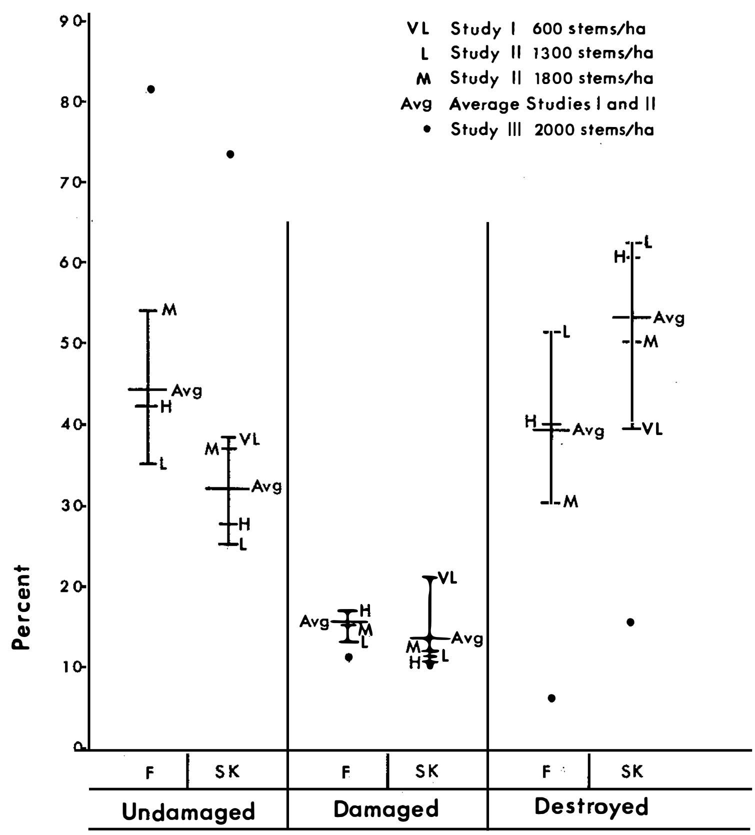

Figure 26. Range of spruce understory conditions after felling and after skidding for all studies.

Table 1. Stand statistics before logging

	Spruce density											
	Study I		Study II								Study III	
	Very low		Low		Medium		High		Average		Medium-high	
	Stems/ha	%	Stems/ha	%	Stems/ha	%	Stems/ha	%	Stems/ha	%	Stems/ha	%
Number of spruce stems	599	100	1302	100	1803	100	2440	100	1848	100	2000	100
Spruce dbh 2.5+ cm	424	71	353	27	711	40	1625	67	896	48	1593	80
Aspen dbh 17.8+ cm	492		580		702		535		606		413	
Balsam poplar dbh 17.8+ cm	42		0		0		15		4		40	
Hardwood total dbh 17.8+ cm	534		580		702		550		610		453	
Hardwood modal dbh (cm)	24.1		26.6		24.1		26.6		25.4		19.1	
Hardwood basal area (m^2/ha) for trees 17.8+ cm dbh	27.4		33.9		34.7		37.6		35.4		15.2	

2000/ha) class, and about average in the high-density (2000+/ha) class. In Study III, destruction from felling was kept a low 7%. There was, however, a considerable increase in destruction (nearly 11%) as a result of skidding, namely, 19% in Study II and 9% in Study III. Furthermore, there was no obvious trend in the numbers of undamaged and destroyed trees as the prelogging understory density increased.

CONCLUSIONS AND RECOMMENDATIONS

On the basis of these three case studies, the following conclusions were drawn and recommendations are proposed.

1. Careful logging of hardwoods can preserve a high proportion of the spruce understory.

2. Guidelines for logging of hardwoods in stands with spruce understory should be based on the percentage softwood stocking for trees less than 10 m in height.

3. Reduction in stocking should be used as a measure of logging performance.

4. Rewards or penalties should be used to encourage preserving spruce during logging.

5. Some contractors should be encouraged to specialize in logging of hardwoods in problem stands, and their crews should be specially trained and supervised.

6. The selection and use of more-suitable equipment for felling could further reduce damage to the spruce understory.

7. In major areas of dense understory, skid trails should be parallel and spaced 25-30 m apart, and the feller should use these trails as base lines from which he should operate in a herringbone pattern.

8. Hardwood logging in problem stands at very low temperatures causes increased damage and destruction of spruce and should be avoided.

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