PROTECTING UNDERSTORY WHITE SPRUCE WHEN HARVESTING ASPEN

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ABSTRACT

This report covers the silviculture component of a joint FRDA-funded project involving NoFC (ForCan), FERIC (West), the AFS and four companies in Alberta. Nine mixedwood stands with understories were scheduled for aspen harvesting in 1988 using a variety of conventional and modified techniques. This report addresses six of these stands.

A brief background on trends in aspen utilization in mixedwood stands with understory spruce is followed by a theoretical two-stage model for tending and harvesting such stands.

Harvesting results — seen as practical tests of the model from a silvicultural perspective — are given in terms of understory damage by cause, yield implications for residuals, and recommendations based on data and experience.

INTRODUCTION

Nature and Extent of Regional Boreal Mixedwoods

The distribution of boreal mixedwoods within four regional Forest Sections (Rowe, 1972) is illustrated in Figure 1. They occupy an estimated 150 000 ha, representing about one-third of the productive forest land base in the prairie provinces. This paper focuses on the white spruce *(Picea glauca* (Moench) Voss) component of mixedwoods which occurs as an understory with aspen *(Populus tremuloides* (Michx.), balsam poplar *(Populus balsamifera* L.) and white birch *(Betula papyrifera* Marsh.). Data on the nature and extent of spruce understory stands are not available from current inventories. Recent surveys in Alberta have shown understory stands to be very significant, occupying up to 80% of stands currently inventoried H (hardwood) and HS (hardwood-softwood) (Brace and Bella, 1988, personal comm. D. D'Amico - Blueridge Lumber (1981) Ltd.)

NEED FOR UNDERSTORY SPRUCE PROTECTION

Future supplies of commercial white spruce depend in the long run upon successful establishment of new stands, which has proved to be relatively costly and ineffective to date (Drew, 1987, 1988; Peterson, 1989), even though it has been the subject of considerable regional research for many decades on mixedwood sites (Jarvis et al. 1966). In the shorter term, understory stands occurring naturally in association with hardwoods are a primary source of spruce. Until recently, these understories have developed to commercial size through natural succession under the protection of the hardwoods. However, the demand for aspen, which accounts for 80% of regional hardwoods, is rising dramatically, particularly in Alberta (Brennan 1988; Ondro 1989) where over 70% of the aspen AAC has been committed for new and proposed developments by 1993 (Table 1). Many stands inventoried as H and HS are now being scheduled for aspen harvest using conventional harvesting equipment and procedures, jeopardizing the associated spruce understory and the future softwood timber supply.

Figure 1

Boreal mixedwood: B15, B.18a, B.19a, B.24

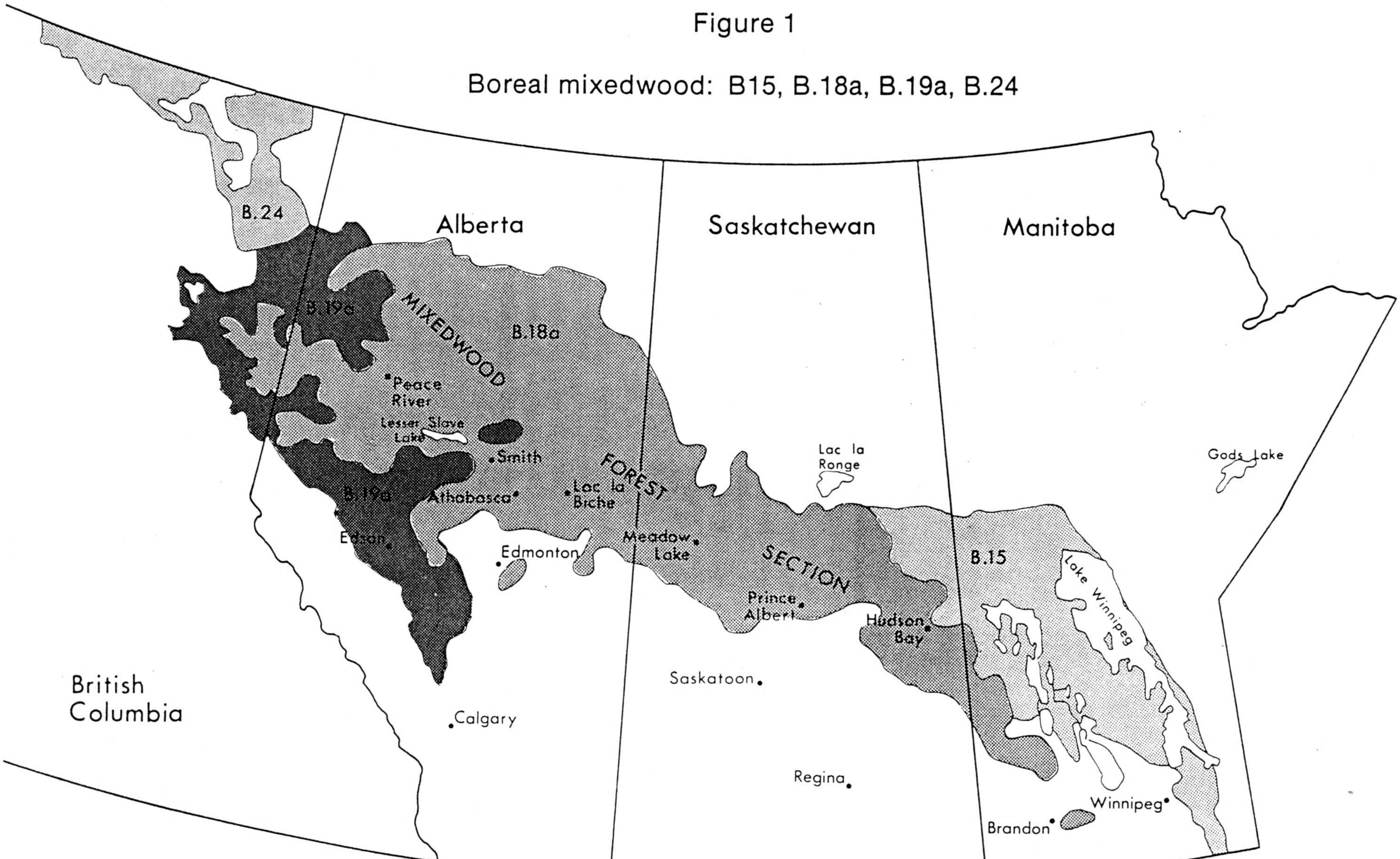


Table 1. Utilization trends and current AAC - aspen - Western Canada (million m^3)

	Utilization Trends[1]					% AAC committed 1993 (est)
	1978	1983	1988	1993 (est)	Current AAC[2]	
Manitoba	.06	.16	.14	1.03	1.8	57
Saskatchewan	.30	.37	.84	1.70	2.6	65
Alberta	.05	.17	.89	6.00	8.4	71
B.C. (Northwest)	-	-	.16	.16(+)	3.5	5
				8.89	16.3	55

[1]Summarized from information provided by provincial governments.

[2]From Woodbridge, Reed and Associates; 1989.

The need for protection of spruce as a component of boreal mixedwoods goes beyond concern for the future commercial softwood timber supply. Concerns also include fisheries and wildlife habitat, aesthetics and recreation, a general dissatisfaction with clearcutting in mixedwoods and a strong interest in mixedwood perpetuation, as expressed recently in 41 public meetings on forestry development in northern Alberta (Concord Scientific Corp., 1989). Also, at a recent forum on the environment organized by the Canadian Pulp and Paper Association (CPPA), industry leaders strongly expressed forest management concerns much beyond timber supply (Addison et al. 1989). There is clearly a need to develop new approaches to mixedwood harvesting, particularly where spruce understories need protection.

In areas with no demand for aspen and where white spruce has a priority, other scenarios for understory white spruce release not entailing problems of harvest technology and other associated risks to the understory should be considered in order to perpetuate or increase the spruce component of mixedwoods.

TWO-STAGE TENDING AND HARVESTING MODEL

Figure 2 illustrates a model which has been designed to accommodate two harvests of aspen in a 120 year cycle and to realize the yield potential of associated understory spruce. The model is described by Brace and Bella (1988). Beginning with an aspen stand aged 60 and understory spruce averaging 40 years of age, the aspen and all spruce over 25 cm dbh could be harvested, leaving a released spruce understory. Sixty years later the mature spruce and a 60-year-old aspen stand which originated from suckers at the time of initial cut could be harvested again and options for future management of the land base considered. The model does not necessarily imply a sustained yield policy for white spruce on this specific land base. The future of the land base - whether hardwood, softwood, or mixedwood - poses many silvicultural challenges, some of which are addressed by Navratil et al. (1989).

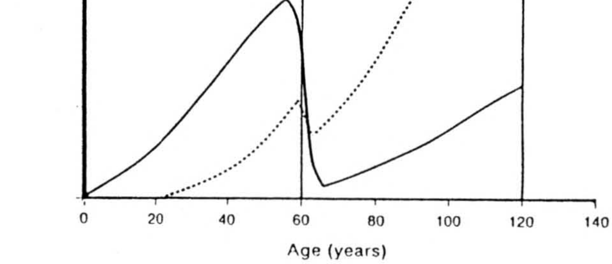
Advantages of the Model

Advantages of the model would include:

a) reduction or avoidance of the costs and risks associated with establishing and growing spruce on mixedwood cutovers,
b) improved utilization of aspen and increased spruce AAC through increased growth and shorter rotations for spruce released from the understory (tending component of model),
c) maintenance of spruce-related landscape aesthetics, wildlife habitat and recreational values, thereby addressing major shortcomings of the clearcutting

Figure 2

Generalized two-stage tending and harvesting model.



system as now practised on many mixedwood sites,

d) contribution to solving the problems created where hardwood and conifer harvesting rights are held by different companies on the same land base, and where protection of understory spruce is a priority for the softwood user.

Disadvantages of the Model

Some of the disadvantages of the model would include:

a) uncertainty about the feasibility of adapting available harvesting technology to protect the understory under a range of stand age, density and site conditions,
b) potential for windthrow of released spruce, particularly on moist sites, as well as the risk of leader-weevilling in released spruce,
c) problems with estimating the growth and yield of mixed-species stands of released spruce and new aspen suckers.

GROWTH AND YIELD AND OTHER MIXEDWOOD MANAGEMENT IMPLICATIONS

Brace and Bella (1988) developed growth and yield estimates for spruce released at age 40 and harvested at age 100 in the previous model, for one specific site. Results indicated that if 600 viable 40-year-old spruce residuals survive to age 100 they could yield 550 to 590 m³/ha. Yields would be 10% lower for 400 trees and 30% lower for 200 trees. It is assumed that aspen suckers will occupy any available space in the stand, either as pure clumps or in mixture with spruce, and will supplement softwood yield as spruce stocking declines, up to the yield potential of the site.

After harvesting aspen to release spruce it is not uncommon for a stand to develop separate clumps of aspen suckers and spruce residuals, as well as areas where the species intermix. Because of the variety of conditions possible in such mixedwoods with respect to the density and distribution of species components, growth and yield prediction for spruce and associated hardwoods is difficult, and reliable techniques are not yet available. Such variety, seen as an impediment to growth and yield prediction, is often desirable from other perspectives, for example to provide habitat for particular wildlife species and for landscape aesthetics.

Increases in hardwood utilization, coupled with public demand to maintain mixedwoods for a variety of non-timber purposes are challenging traditional softwood bias in mixedwood management, requiring management objectives beyond softwood silviculture and growth and yield and creating the need for an effective multi-disciplinary approach to both management planning and operations.

FIELD TEST OF THE TWO-STAGE MODEL

Project and Participants

A cooperative mixedwood harvesting project which serves as a field test for the two stage tending and harvesting model was initiated recently under the Canada-Alberta Forest Resource Development Agreement (FRDA). Co-operators include the Northern Forestry Centre of Forestry Canada, the Forest Engineering Research Institute (FERIC-west) the Alberta Forest Service (AFS), Pelican Spruce Mills (now Weyerhaeuser Canada Ltd. (Alberta)), Weldwood of Canada Ltd., Blueridge Lumber (1981) Ltd., and Millar-Western Industries Ltd. There are a total of nine study stands, 3 in each of the areas shown in Figure 3. This report addresses the stands harvested in the Drayton Valley area (identified in the report as DC (control), D1 and D2) and in the Hinton area (HC (control) H1 and H2). All nine stands should be completed by April 1990. The final two stands will be harvested during winter to determine the effects of cold weather operation on understory damage. This is particularly important since many sites in the region are only accessible for winter operations.

Objectives

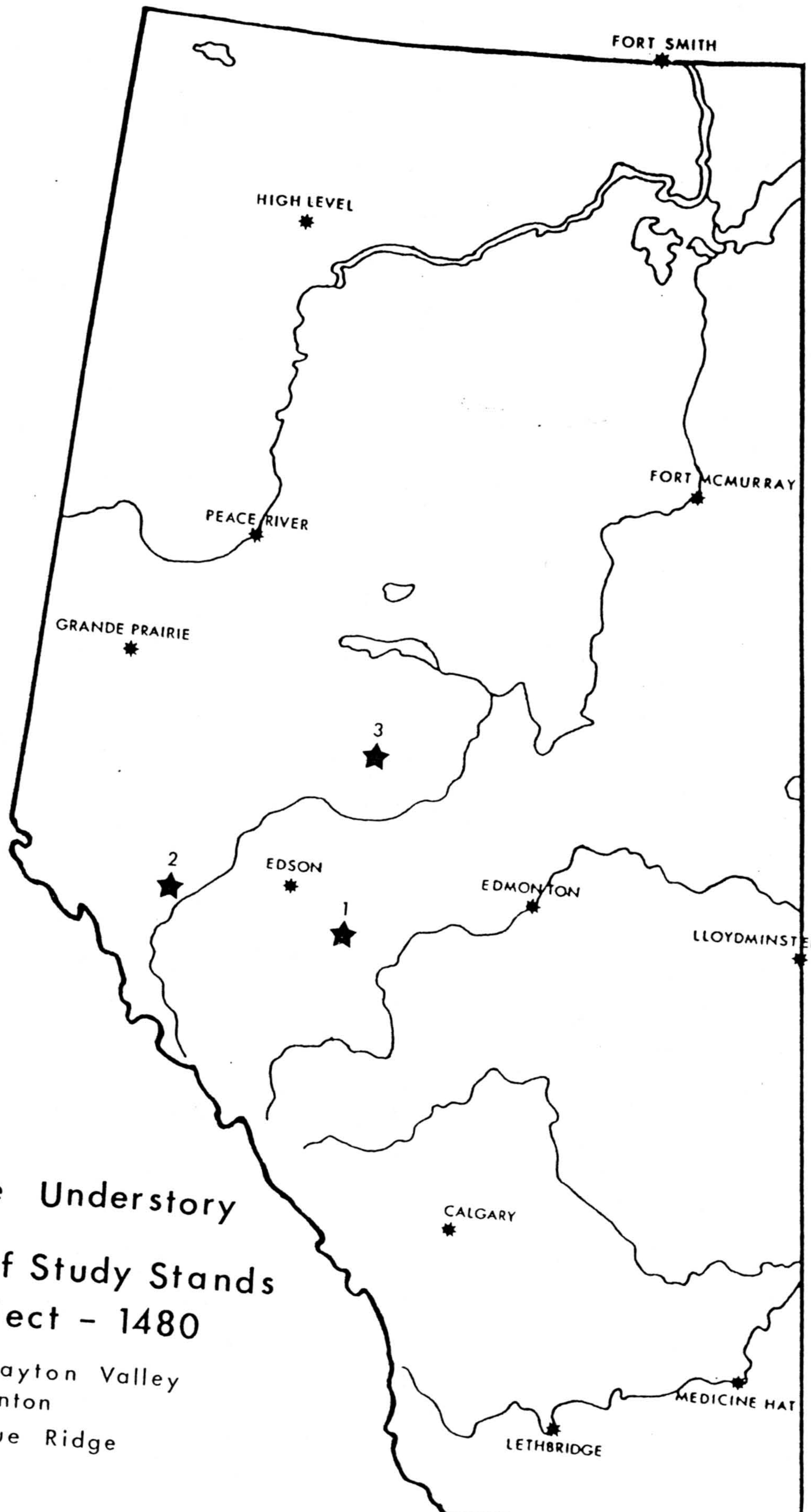
The primary silvicultural objectives of this project were:

a) assess damage to residual spruce trees released during harvesting of the aspen overstory; and
b) monitor subsequent development of the residual spruce (growth, windthrow and weevil risk) and of new aspen suckers (density, growth), and the utility of the approach for addressing non-timber mixedwood management issues.

This report addresses objective (a), emphasizing the residual spruce crop between 2.5 and 14 m high which are the trees most likely to survive and grow to maturity, because they are tall enough to compete with new aspen suckers (Johnson, 1986) and should be reasonably windfirm on upland sites.

Harvesting costs, equipment productivity and details of operational procedures for each stand harvested in the project have been reported by Sauder and Sinclair (1989).

Figure 3



White Spruce Understory

Location of Study Stands
Project - 1480

1 Drayton Valley
2 Hinton
3 Blue Ridge

Procedures and Pre-Harvest Status of Stands

Table 2 describes the harvesting methods and procedures (treatments) applied in each stand. Feller-buncher/ grapple skidder harvesting equipment was used in all cases except treatment 2 in Hinton (H2) which used a Swedish shortwood (Rottne) processor and forwarder combination.

Table 3 presents pre-harvest statistics for each stand treated. There were substantial differences between stands in terms of hardwood and softwood overstory composition, volume and quality, average stem size and softwood understory density and distribution. This, combined with the variety of equipment and procedures (Table 2) makes detailed comparisons between stands inappropriate and requires a case study approach based on data and observation.

RESULTS AND DISCUSSION

Controls

Felling and forwarding in stands DC and HC (Table 4) were carried out using conventional equipment, according to prevailing operational ground rules in Alberta, clearcutting the aspen with no concern about understory damage or mortality. No restrictions were placed on the felling sequence or on travel routes for forwarders (skidders). There was apparently a psychological effect of the protection philosophy being applied to other stands, as operators made unusual attempts to preserve some understory spruce clumps. Some spruce were also protected within clumps of non-merchantable hardwood. Control stands are therefore predominantly clearcut, with a few dense understory spruce clumps and scattered individuals and should regenerate primarily to aspen suckers. Control stands primarily used to provide comparative cost and productivity data for the FERIC component of the project.

Felling Mortality and Damage

In general felling caused less mortality but more damage than forwarding in treatments D1, D2, H1 and H2 (Table 4). Felling mortality was minor, varying from 1 to 5%. Felling damage varied from 11 to 19% for feller-bunchers (D1, D2, H1) but was 40% for the Swedish Shortwood Treatment (H2), primarily because the shortwood processor had much less directional felling control than the feller-bunchers. The relatively high initial stand density (1994 trees/ha) may also have been a factor.

Felling damage was recorded mainly as broken tops and branches, bark scrapes on stems, and leaning trees. The Swedish shortwood processor caused a relatively large proportion of bark scrapes and leaning trees. Much of the processor-related damage was minor and would be considered acceptable on residual crop trees.

Large individual spruce, characteristic of many mixedwood stands containing understories, caused considerable damage when hand-felled in treatments D1 and H1. This poses a dilemma in such stands because their high timber value has to be balanced with understory protection priority, blowdown hazard, and need for seed trees when setting treatment objectives.

Equipment-related factors affecting understory damage include size and type of carrier and boom and size and type of felling head. Multiple entries for felling and forwarding also increase damage. These sources of damage can be minimized by matching equipment and harvesting pattern to stand conditions (personal comm. E.A. Sauder, FERIC west). The feller-buncher used in stands D1 and D2 had no boom, so had to approach each tree before felling, increasing understory damage, but it was also relatively narrow, which compensated to some extent for the lack of a boom. The feller-buncher used in H1 had a 3-4 m boom so could reach for trees, but it had a large counterweight which caused damage when turning and a relatively large felling head which caused damage when being positioned for a cut. Both types of feller-buncher carried the trees upright after cutting and bunched them on skid trails, which reduced subsequent forwarding damage and mortality. The relatively good performance of the feller-buncher in H1 was noteworthy, considering the initial understory density (Table 4), reflecting effective planning as well as operator experience and attitude.

The Swedish shortwood processor had a 10 m boom but was unable to take full advantage of it due to the large average size of the aspen being felled (mean dbh 22.1 cm., Table 3) making it necessary to move toward many trees to fell them, resulting in a zig-zagging pattern in the stand rather than maintaining a relatively straight course and reaching for the trees. In addition, it had little directional felling capability and it also caused damage as it shifted felled trees back and forth in a horizontal plane while delimbing and bucking. It had an advantage over the feller-bunchers in being able to swing the felling head above the understory when reaching for aspen, and the smaller felling head caused less damage when being positioned for a cut. This machine would cause much less felling damage if it were operated in a stand where the trees being cut were small enough to allow it to maintain alignment in the stand and take full advantage of the 10 m boom and the smaller crowns of younger aspen would compensate to some extent for the lack of directional felling capability. A large single-grip machine should function more productively

Table 2. Harvesting Methods and Procedures Applied by Location and Treatment

Treatment	Function	Location: Drayton Valley (D)	Location: Hinton (H)
Control	Felling	Feller-buncher on tracked loader with shear head	Feller-bunchers on tracks, with shear head
	Forwarding	Grapple skidders - full tree	Grapple skidders - full tree
	Procedures	Conventional clearcut. All species topped, delimbed and bucked on the landing by hand	Conventional clearcut. Stroke delimber and slasher on landing
Treatment 1	Felling	Same as control	Same as control
	Forwarding	Same as control - full tree	Same equipment as control, but tree length instead of full tree and rub-stumps used along trails
	Procedures	Main stand trails located before harvesting and Feller-buncher operator chose other trails. Conifer hand-felled after aspen and skidded separately. All species topped, delimbed and bucked on landing by hand	Main skid trails prelocated and secondary trails flagged before harvesting. Conifer and aspen felled and bunched at same time and limbed and topped before skidding. Oversize spruce hand felled. Stroke delimber and slasher on landing.
Treatment 2	Felling	Same as control	Rottne double grip processor (fell, limb and buck)
	Forwarding	Same as control (full tree)	Rottne forwarder
	Procedures	Trail designation as in treatment 1. Conifer and aspen machine - felled and thatched down on skid trails by feller - buncher. All species topped, delimbed and bucked on landing by hand.	Highly skilled operators selected trails and controlled operation

Table 3. Pre-harvest Stand Statistics by Treatment

Standard treatment	Area (ha)	Species group	Aspen age (yrs)	Total Stand: Stems/ha	Total Stand: Mean Dbh (cm)	Total Stand: Total vol. (m^3/ha)	Total Stand: Vol./tree (m^3)	No. understory spruce/ha by Ht class (m): 2.5-7.5	7.6-14	2.5-14
Drayton	20	Aspen	110+	140	31.0	114	.81			
Valley		Poplar		395	17.4	70	.18			
Control		Birch		136	25.4	58	.43			
(DC)		Spruce		868	9.8	46	.05	412	138	550
		Total				288				
Drayton	20	Aspen	110+	243	29.5	170	.70			
Valley		Poplar		216	18.8	47	.22			
Treatment		Birch		14	20.6	4	.29			
1 (D1)		Spruce		691	9.4	31	.04	268	123	391
		Total				252				
Drayton	15	Aspen	110+	284	26.3	148	.52			
Valley		Poplar		143	21.3	35	.24			
Treatment		Birch		559	5.5	-	-			
2 (D2)		Spruce		464	9.0	11	.02	249	74	323
		Total				194				
Hinton	18	Aspen	70+	853	18.9	170	.20			
Control		Poplar		222	17.6	30	.14			
(HC)		Birch		-	-	-	-			
		Spruce		4125	5.7	47	.01	1371	373	1744
		Total				247				
Hinton	14	Aspen	70+	1085	19.1	222	.20			
Treatment		Poplar		253	13.1	18	.07			
1 (H1)		Birch		-	-	-	-			
		Spruce		1218	6.3	5	.01	533	207	740
		Total				245				
Hinton	18	Aspen	70+	470	22.1	135	.29			
Treatment		Poplar		315	15.8	29	.09			
2 (H2)		Birch		-	-	-	-			
		Spruce		3951	5.9	45	.01	1607	387	1994
		Total				209				

Table 4. Percent Damage to Understory Spruce Trees 2.5 to 14 m During Aspen Harvesting

Treatment	Initial Nt/ha	Undamaged	Felling		Forwarding		Harvested	Other	Total
			Damage	Mortality	Damage	Mortality			
DC	550	33	19	1	13	28	6	-	100
HC	1744	13	16	4	14	49	3	1	100
D1	391	44	19	-	11	24	2	-	100
D2	323	65	11	1	9	13	1	-	100
H1	740	51	18	1	10	18	1	1	100
H2[1]	1994	29	40	5	(11)	(14)	1	-	100

[1]The Swedish shortwood systems is not directly comparable to others due to the combined functions of felling, delimbing and bucking. Damage and mortality identified as forwarding was not distinguishable from skidder damage but primarily caused by the delimbing and bucking functions. Forwarding effects were minor.

with up to 20% less understory damage, than the double-grip machine used in stand H2 (personal comm. O. Hannula, Weldwood of Canada Ltd.).

Forwarding Mortality and Damage

In general, forwarding caused considerably less damage but more mortality then felling in all cases (Table 4). Damage ranged from 9 to 11% and occurred mainly as bark scrapes and leaning trees. Forwarder damage was almost entirely skidder-caused.

Damage statistics for the Swedish shortwood forwarder are misleading because they really reflect the delimbing and bucking functions of the processor as described earlier, but could not be separately identified. The shortwood forwarder itself did minor damage when loading logs - mainly upper stem scrapes - and virtually no damage during forwarding as it was the same width as the processor.

Forwarder-caused mortality varied form 13 to 24% and again was almost entirely skidder-related, since the 14% shown for this Swedish forwarder is really related to delimbing and bucking functions. The good performance of the skidder operation in relatively dense understory in H1 is noteworthy, reflecting effective coordination of the skidder and feller buncher functions, and operator experience and attitude. The 24% skidder related mortality in D1, compared to 13% in D2 in a stand of comparable initial understory density, and 18% for H1 in a stand of relatively high initial understory density is largely a reflection of protection effort, not of equipment.

The Importance of Protection Effort

Table 5 summarizes pre- and post-harvest understory spruce density according to degree of protection effort, which was assigned to reflect the planning, layout, supervision and crew experience and attitude which characterized each case. Figure 4 shows that protection effort was more significant than type of equipment used, an observation which is consistent with the results of previous mixedwood harvesting studies (Brace and Stewart 1974, Froning 1980).

Growth and Yield and Other Management Implications

If growth and yield data for spruce released at age 40 and harvested at age 100 (Brace and Bella 1988) are applied to the spruce residuals in Table 5, treatment H2 is overstocked and should perform as a relatively pure spruce stand if the trees were well distributed, yielding from 550 to 590 m³/ha, whereas the lower-stocked treatments (DC, D1, D2) should yield spruce in the order of 30% less. Aspen yield would be expected to increase in proportion to spruce yield decrease. These observations are tentative as such growth predictions are currently not well refined, and even assuming they were accurate, their significance could only be judged in terms of management objectives. The lower spruce stocking and yield results would be unacceptable for softwood oriented management, but may be acceptable for mixed-species management. Even without specific objectives for wildlife habitat (e.g., hiding cover, thermal cover and browse for ungulates) or for landscape

Figure 4
Percent Residual Spruce, 2.5 to 14.0m

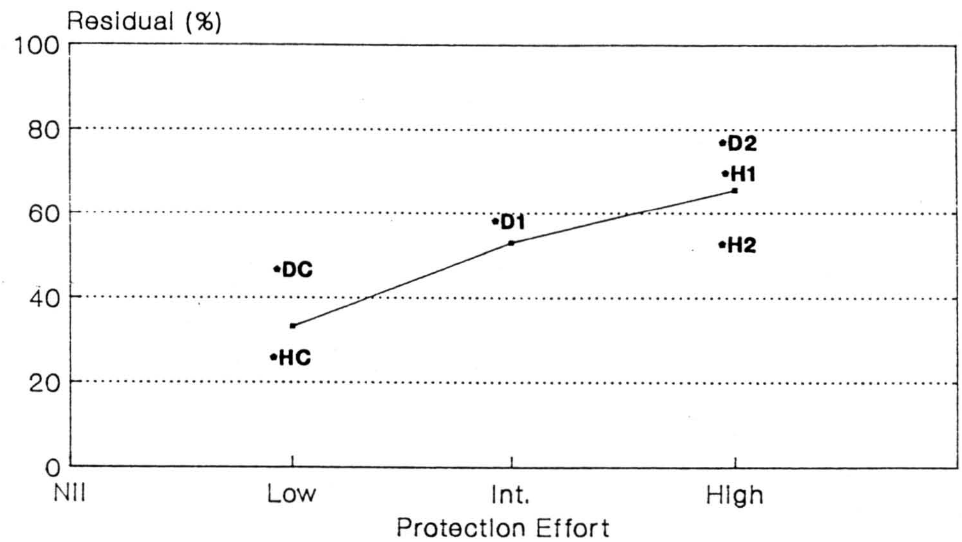


Table 5. Residual Crop by Treatment and Protection Effort (trees 2.5-14.0 m)[1]

Treatment	Stems/ha		Post-cut percent	Protection effort[2]
	Pre harvest	Post harvest		
DC	550	238	43.3	Low
HC	1744	403	23.1	Low
D1	391	209	53.4	Int.
D2	323	233	72.1	High
H1	740	485	65.5	High
H2	1994	1181	59.2	High

[1]Includes undamaged trees and trees with acceptable damage, including broken leader, broken branches, minor bark scrapes and gouges.

[2]Protection effort was subjectively assigned as low, intermediate or high depending upon the combination of planning, layout, supervision and crew experience and attitude in each case.

aesthetics, the treatment results have already been judged by project participants as superior to conventional operations. Such benefits from an understory protection approach to mixedwood management could be more effectively achieved if they were integrated into timber management planning as specific objectives at early planning stages, as recently described by Bonar (1989). Preharvest silviculture prescriptions (PHSP's) as currently required by law in BC would be an important component of this planning process.

SUMMARY AND CONCLUSIONS

1. Mixedwoods are an important regional source of both timber and non-timber resources. There is growing public interest in multiple-use management and increasing criticism of the suitability of current clearcut harvesting practices for that purpose.
2. Stands with white spruce understories are an important component of the mixedwood mosaic, especially in stands inventories H and HS, and current harvesting practices do not provide adequate understory protection.
3. Recent dramatic increases in aspen utilization are resulting in the allocation of large volumes of aspen in stands inventoried H and HS, jeopardizing a significant amount of spruce understory.
4. This report presents a two-stage tending and harvesting model which should facilitate the release of spruce understories during the aspen harvest and promote the subsequent growth of a new aspen sucker stand while the released spruce are maturing. The model should also reduce or avoid the risks and costs of regenerating spruce on mixedwood cutovers, increase the short-term softwood timber supply, and address some of the inadequacies of clearcut harvesting with respect to integrating non-timber objectives into timber management plans and practices.
5. A recent cooperative field project initiated to test the feasibility of adapting available harvesting technology to protecting understory spruce while harvesting aspen has yielded the following preliminary results:
   a) major improvements in the protection of understory white spruce during aspen harvesting are possible using conventional logging equipment like feller-bunchers and grapple skidders in stands up to 1200 understory spruce per ha (exemplified in treatment H1), and using equipment like Swedish shortwood systems in understory densities of 2000/ha or more (exemplified in treatment H2).
   b) the key to success is *protection effort*, regardless of equipment. It includes:
      i) management objectives set for all relevant resource interests at the stand level, including pre-harvest silvicultural prescriptions (PHSP's), supported by an adequate stand inventory which includes the amount and distribution of spruce understory.
      ii) selecting equipment and harvesting patterns to match stand and site conditions, thereby minimizing multiple stand entries for felling and forwarding, which are a significant cause of understory damage.
      iii) pre-planning and pre-locating skid trails, landings and protective features like rub stumps in relation to understory density and distribution.
      iv) adequate crew training and supervision, coordination of operators performing different functions, and the attitude and motivation of operators are critical elements in protection, as well as production.
   c) In feller-buncher/grapple-skidder treatments, mortality was most prominent and was mainly skidder-related. Damage was secondary to mortality and was somewhat greater during felling.
   d) Equipment with directional felling capability and the ability to accumulate trees and place then on skid trails is able to substantially reduce both felling and subsequent skidding damage.
   e) In the Swedish shortwood system, *damage* was most prominent, and occurred mainly during the felling function. Delimbing and bucking functions caused less damage but more mortality than the felling function. The forwarder itself caused minor damage and mortality.
   f) Specialized equipment like the Swedish shortwood processor which work reasonably well in stands with a high density understory should be even better if used in lower density understory stands or in stands where trees to be harvested are of a size which will allow the machine to fell all material in one pass to function without deviating from a relatively straight path - i.e., using full boom capability - and where small crown sizes will help reduce felling damage and mortality. A large single-grip machine would probably function with less damage then the double-grip machine used in this project, under similar stand conditions.
   g) Scattered large spruce are a potential major source of felling and skidding damage in these stands. If they cannot be directionally felled, limbed and

topped and skidded log-length consideration should be given to leaving them to provide additional seed for the next spruce crop if they are windfirm.

h) Acceptable spruce residuals must be defined in management objectives, and equipment, planning, training and supervision adapted accordingly. Many aesthetics and wildlife habitat objectives may be met at considerable lower residual densities (i.e., 200 to 400 per ha) than optimum future spruce yield objectives which require 600 or more trees per hectare at age 40.

i) Harvesting costs, equipment productivity and details of operational procedures for this project have been reported by Sauder and Sinclair (1989) and Brace (1990).

j) There is a need for special operating ground rules with respect to utilization in harvesting operations involving the first entry into previously unmanaged stands. It may be best in the long run to leave individual large-crowned trees and to leave merchantable individual trees uncut in clumps of high-value understory in order to prevent severe damage to the residual stand. There is also a need to accommodate selected high stumps (rub stumps) left for purposes of protection along skid trails, and to reassess slash rules as they may relate to equipment such as shortwood processors.

k) Results of this project will be updated over the next 5 years to show the effects of factors such as blowdown and weevil damage, and to monitor actual growth response of both spruce residuals and aspen suckers.

l) The jury on the feasibility of retaining viable spruce residuals when harvesting overstory hardwood is still out - *but* - there is plenty of evidence in this and other trials that a favorable ruling is possible if both government and industry are *committed* to such work.

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