Development of epicormic sprouts in Sitka spruce following thinning and pruning in south-east Alaska

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Summary

The frequency and size of epicormic sprouts in Sitka spruce (*Picea sitchensis* (Bong.) Carr.) were assessed in five 23-29 year-old mixed Sitka spruce-western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) stands that were uniformly thinned and pruned to 2.4, 3.7 and 5.2 m lift heights. Six to nine years after treatment sprouts were very common with 232 of 236 trees producing sprouts and an average of 9-11 sprouts m^{-1} of tree bole. The total numbers of sprouts were similar for the different pruning treatments but significantly more large sprouts ($P = 0.025$) were produced in the 5.2 m pruning lift. Trees that developed large sprouts were significantly smaller, shorter and had less crown length at the time of pruning than trees without large sprouts. Our results suggest that spruce responds to thinning and pruning treatments with the production of numerous epicormic sprouts. If one of the main goals of pruning is to produce clear, higher valued wood, Sitka spruce may be a poor candidate species for pruning.

Introduction

Tree pruning is an accepted silvicultural practice for improving wood quality, and pruning has been used in the management of Sitka spruce in Europe for many years (Anderson, 1937; Beach, 1939; Rowan, 1963). In south-east Alaska, pruning has rarely been used because high quality old growth timber has historically provided a dependable supply of clear wood. However, the amount of old growth forests available for timber production has declined and a larger proportion of the timber harvest is expected to come from lower quality young growth forests. Silvicultural treatments, such as thinning to reduce stocking and pruning to improve wood quality in young growth stands, could provide another source of high quality clear wood. Little is known, howeve, about the effect of these treatments on the wood quality of the major tree species in south east Alaska. Recent pruning research in this region showed that trees quickly healed and produced callous tissue over wounds caused by pruning lower branches (Petruncio, 1994). The longer term response of pruned Sitka spruce and its ability to produce clear wood are unclear. There is concern about the development and growth of epicormic sprouts on pruned spruce trees and the effect of sprouts and knots associated with these branches on wood quality. Assessing the effects of pruning and the longerterm development of epicormic branches in spruce would provide valuable information on the potential of pruning Sitka spruce for improving wood quality. The effect of precommercial thinning and pruning treatments on the development of epicormic sprouts and their potential effect on wood quality needs to be assessed before implementing such silvicultural treatments throughout the region.

Epicormic branches are shoots arising spontaneously from an adventitious or dormant hud on the stem of a woody plant (Kozlowski *et al*., 1991). Sudden exposure of trees by heavy thinning or pruning can stimulate dormant buds on stems to produce epicormic sprouts, but the effect of silvicultural practices on the production of sprouts differs widely among species. Epicormic sprouting is a common concern for some hardwood species (Hedlund, 1964; Evans, 1985; Workman, 1989; Kerr and Harmer, 2001) but with a few exceptions, the development of epicormic branches is not considered generally to be a problem for timber production in softwood species (Cosens, 1952; Hingston, 1990; O'Hara and Valappil, 2000; Collier and Turnblom, 2001). Epicormics in Sitka spruce have been reported previously along roadsides and openings in forest stands (Isaac, 1940; Ruth, 1958; Harris, 1966) but these studies have provided little information about the frequency and development of epicormic sprouts. Herman (1964) found that epicormics in Sitka spruce came from dormant buds that were exposed to increased levels of light. Petruncio (1994) reported some sprouting following wide spaced thinning and pruning treatments but he did not determine whether these sprouts developed into larger branches. The presence of epicormics does not affect the utility of spruce saw logs for structural grades of lumber, but knots associated with epicormic branches can degrade higher value clear lumber and the loss of clear wood could significantly reduce timber value (Haynes and Fight, 1992; Fight and Bolon, 1995).

A series of five pruning installations were established in 1990-1993 in mixed stands of Sitka spruce and western hemlock in south east Alaska. This paper presents epicormic sprouting data from Sitka spruce that were thinned and pruned to three different lift heights. The objectives of this study were to report the frequency and size of sprouts, determine the relationship of pruning severity and tree variables on the development of sprouts, and assess the potential of Sitka spruce to produce clear wood following pruning.

Methods

Pruning study sites were located in five 23-29 year old mixed species stands in south-east Alaska (Figure 1). Stands naturally regenerated following clearcutting and were predominantly composed of Sitka spruce and western hemlock with a minor component of western red cedar (*Thuja plicata* Donn ex D. Don) (Table 1). All sites were densely stocked (>10 000 trees ha^{-1}), high site index stands (26-30 m, 50-year) with uniform topography and slope. Stands were operationally thinned at age 15 years to ~1000-1200 trees ha^{-1} and were uniformly rethinned during the summers of 1990-1993 to an average of 420 trees ha^{-1} (Table 1) leaving the largest diameter trees as crop trees. A randomized complete block design with four pruning treatments and five replications was used for the experiment. At each site during the same year, four 0.22 ha treatment plots were installed. Each treatment plot included a 0.08-ha measurement plot with a 9.1 m buffer on all sides. All trees in each treatment plot were either left unpruned or were pruned to 2.4, 3.7 or 5.2 to pruning lifts. The unpruned treatment was not used in this study to assess sprouting due to difficulty in determining if branches came from new sprouts or preexisting branches. This eliminated the possibility of determining if observed effects were related to thinning or pruning. Prior to treatment, all trees were measured for tree height, d.b.h. (diameter at 1.3 m height), and live crown height, and remeasured again in 1999 (Table 1). In the summer of 1999 (6-9 years after pruning treatment) the number and size of epicormic sprouts were assessed. Sprouts were tallied on each 0.6 m tree section for each of the four cardinal directions of the tree bole from the

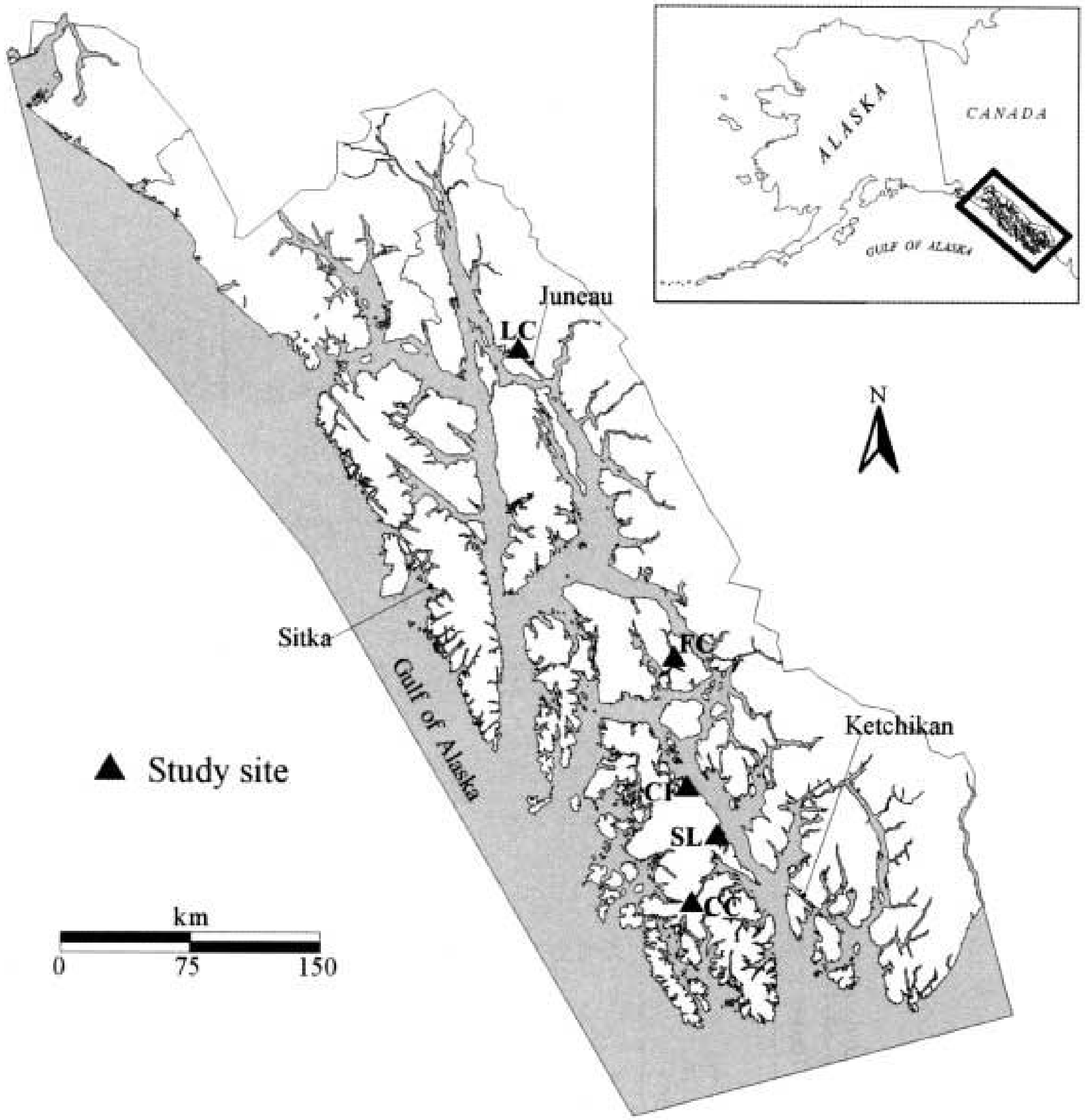

Figure 1. The location of five research study areas in south-east Alaska. Site location codes are defined in Figure 5.

ground to top of pruning lift. Sprouts were separated into live or dead categories and were tallied by two diameter size classes: small (SM-sprouts) <3 mm (Figure 2), and large (LG-sprouts) 3 mm or larger in diameter (Figure 3). The 3 mm diameter was used because this size was identified as an important threshold knot size class for lumber grade (Tom Hannaman, personal communication, Western Wood Products Association, USA).

To determine the effect of pruning intensity on epicormic sprouting we blocked plots by site and used analysis of variance to test for differences in the frequency, size and direction of sprouts. To assess potential differences in trees with and without LG-sprouts, we analysed tree d.b.h.,

Table 1: Thinning and pruning treatments and current stand structure 6–9 years after treatment

Site	Treatment				Current stand structure					
					Tree density					
	Thinning density (trees ha^{-1})	Pruning lift ht (m)	Age at treatment (years)	Post-treatment (years)	Spruce (trees ha^{-1})	Hemlock (trees ha^{-1})	Cedar (trees ha^{-1})	Basal area (m^2 ha^{-1})	Mean height (m)	Mean d.b.h. (cm)
Cave Creek	420	2.4	25	9	138	275	12	29.5	15.1	28
	420	3.7	25	9	138	212	0	28.0	14.5	30
	420	5.2	25	9	163	200	0	21.7	14.3	26
Coffman Cove	420	2.4	25	7	100	312	0	31.5	16.4	30
	420	3.7	25	7	125	225	50	25.3	13.9	27
	420	5.2	25	7	288	125	12	39.4	15.9	33
Falls Creek	420	2.4	26	6	212	100	0	14.7	14.3	24
	420	3.7	26	6	275	200	0	17.6	14.9	22
	420	5.2	26	6	163	88	0	17.2	16.2	29
Lemon Creek	420	2.4	23	9	288	100	0	23.0	14.2	27
	420	3.7	23	9	175	150	0	18.6	13.7	26
	420	5.2	23	9	250	88	0	19.9	14.3	27
Salamander Lake	420	2.4	29	8	225	200	0	26.2	14.7	27
	420	3.7	29	8	238	162	25	25.4	14.6	26
	420	5.2	29	8	200	225	12	23.0	14.3	25

Figure 2. A small epicormic sprout (SM-sprout) on bole of Sitka spruce 9 years after pruning.

crown length and height before treatment and tested for differences between means using *t*-tests.

Results

Epicormic sprouts were uniformly prevalent and very common in thinned and pruned Sitka spruce. Overall, 232 of 236 spruce trees in this study produced sprouts with an average of about 9-11 sprouts m^{-1} for all pruning treatments (Figure 4). Most sprouts were SM-sprouts; the combined live and dead SM-sprouts accounted for 86 per cent of all sprouts.

The total number of sprouts was similar for the three different pruning treatments. For bole quadrants containing sprouts, the 2.4, 3.7 and 5.2 m pruning lifts averaged 11.3-12.0 sprouts m^{-1} (Table 2). There were no significant differences among treatments in the total number of sprouts, or in the number of live SM-sprouts ($P = 0.394$ and 0.379, respectively). However, the 5.2 m lift had significantly more live LG-sprouts ($P = 0.025$) than the other pruning treatments

Figure 3. Numerous large epicormic sprouts (LG-sprouts) on bole of Sitka spruce 9 years after pruning.

with 81 per cent of all trees in the highest lift producing LG-sprouts (Figure 4; Table 2). For bole quadrants containing sprouts, the 2.4 m and 3.7 m lifts averaged 0.9 and 1.2 sprouts m^{-1}, respectively, compared with 2.7 sprouts m^{-1} in the 5.2 m lift (Table 2). Only 33-45 per cent of the trees produced LG-sprouts in 2.4 and 3.7 m lifts compared with more than 80 per cent of the trees in the 5.2 m lift. Also, the number of clear bole sections decreased with pruning lift height with an average proportion of clear directional (N, E, S and W) quadrants per tree of 18.1, 8.7 and 1.2 in the 2.4, 3.7 and 5.2 m lifts, respectively (Table 2).

The number and size of sprouts varied greatly among sites and there were significant differences in the total number of sprouts among sites ($P < 0.001$). The greatest number of sprouts occurred at Cave Creek (CC, Figure 5) and this site also had more dead SM- and LG-sprouts. The most live LG sprouts occurred at Lemon Creek (LC, Figure 5). The number of sprouts also differed substantially with bole direction. The south facing tree bole had significantly more sprouts (3.1 sprouts m^{-1}, Figure 6) than any of the other directions ($P < 0.001$).

The development of LG-sprouts was closely related to both pruning lift and size of tree at time of treatment. Trees with LG-sprouts in the 2.4 m pruning lift were shorter, smaller in diameter and had smaller crowns than trees without LG-sprouts. Tree height, crown length and d.b.h.,

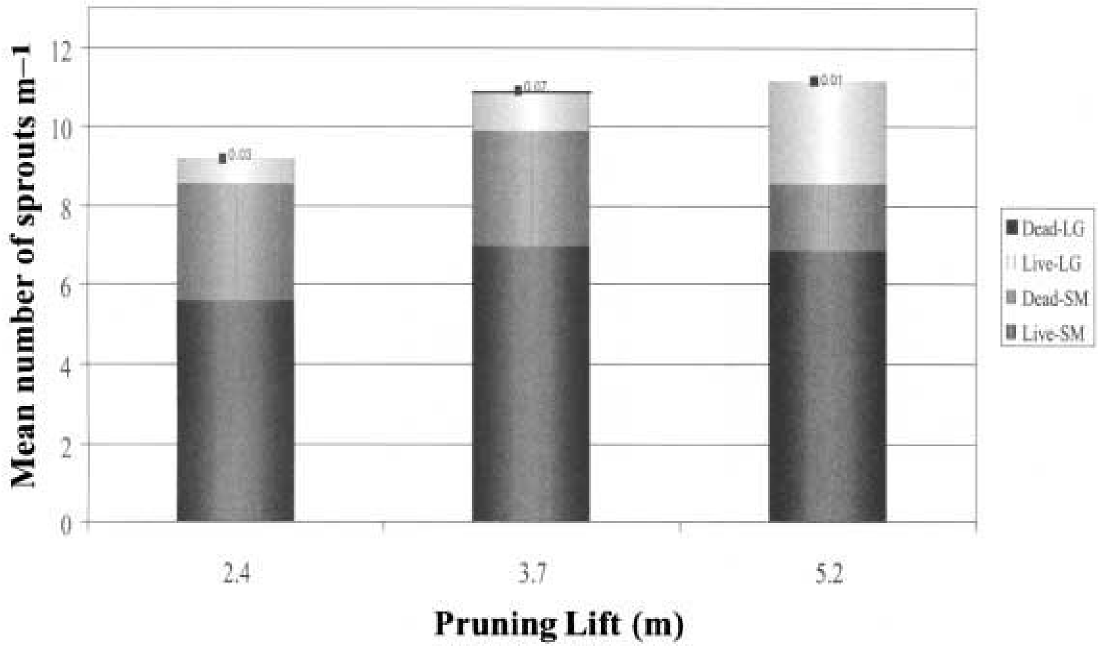

Figure 4. The mean number of sprouts m^{-1} by sprout status (live or dead) and size class (SM or LG) for three pruning lift heights. SM-sprouts are <3 mm in diameter, LG-sprouts are 3 mm or larger in diameter.

Table 2: The effect of pruning lift height on the proportion of clear bole quadrants for each tree, the average number of epicormic sprouts m^{-1}, and the proportion of trees with sprouts

Pruning lift (m)	*n*	Clear stems (% of quadrants)	All sprouts		Large sprouts	
			Sprouts m^{-1}	% of trees	Sprouts m^{-1}	% of trees
2.4	76	18.1	11.3	97	0.9	33
3.7	75	8.7	12.0	97	1.2	45
5.2	85	1.2	11.3	100	2.7	81

Clear stems are the directional quadrants (N, E, S, W) of a tree bole without sprouts.
The average numbers of sprouts are only for the quadrants that contain sprouts.
Large sprouts are epicormic sprouts 3 mm or larger in diameter.

were significantly less ($P < 0.005$) for trees that developed LG-sprouts (Table 3). The only significant factors related to the development of LG-sprouts for the 3.7 m lift were tree height and tree crown length ($P = 0.049$ and 0.033, respectively, Table 3). Trees that developed LG-sprouts in the 5.2 m lift were also significantly smaller, shorter and had less crown length than trees that did not develop sprouts (Table 3).

Discussion

One of the main objectives of pruning is to produce clear wood that is free of knots. In this study we found that numerous epicormic sprouts were produced on spruce trees following thinning and pruning of young growth stands. Overall, 98 per cent of all trees produced epicormic sprouts and these sprouts commonly developed

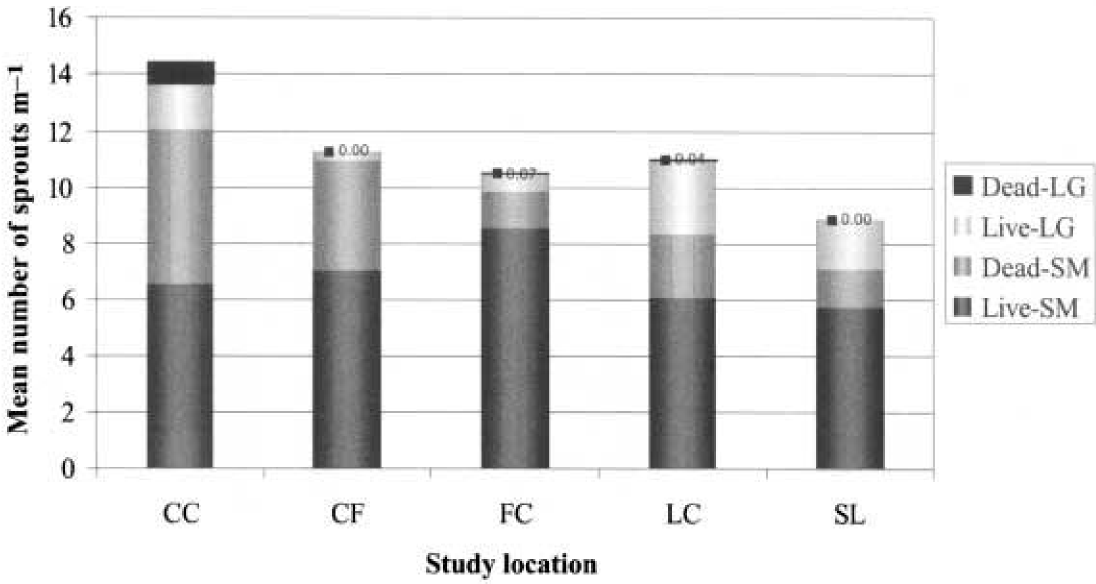

Figure 5. The mean number of sprouts m^{-1} by sprout status (live or dead) and size class (SM or LG) for each study site. Site codes: CC = Cave Cove; CF = Coffman Cove; FC = Falls Creek; LC = Lemon Creek; SL = Salamander Lake. SM-sprouts are <3 mm in diameter, LG-sprouts are 3 mm or larger in diameter.

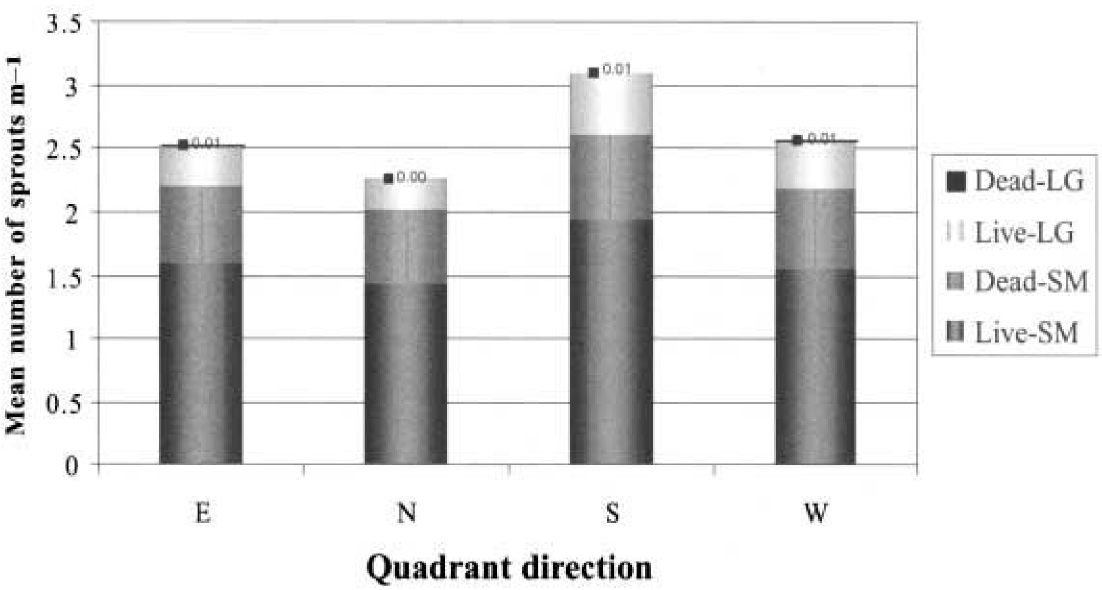

Figure 6. The mean number of sprouts m^{-1} by sprout status (live or dead) and size class (SM or LG) for each quadrant direction of tree bole (N = north; S = south; E = east; W = west). SM-sprouts are <3 mm in diameter, LG-sprouts are 3 mm or larger in diameter.

Table 3: The average tree characteristics at time of initial pruning treatment for trees with and without larger (LG) epicormic sprouts for each pruning lift

Measurement	Pruning lift (m)	Trees with LG sprouts	Trees without LG sprouts	*P* value
d.b.h. (cm)	2.4	16.0 (27)	20.8 (49)	0.004
Crown length (m)	2.4	7.8 (27)	9.6 (49)	0.004
Height (m)	2.4	10.4 (27)	12.2 (49)	0.003
BA growth (cm^2 a^{-1})	2.4	41.3 (27)	54.8 (48)	0.027
d.b.h. (cm)	3.7	19.3 (35)	20.8 (40)	0.305
Crown length (m)	3.7	7.8 (35)	8.8 (40)	0.033
Height (m)	3.7	12.4 (35)	13.3 (40)	0.049
BA growth (cm^2 a^{-1})	3.7	46.5 (35)	47.7 (40)	0.857
d.b.h. (cm)	5.2	20.6 (69)	27.2 (16)	0.002
Crown length (m)	5.2	6.6 (69)	9.4 (16)	<0.001
Height (m)	5.2	12.0 (69)	14.5 (16)	<0.001
BA growth (cm^2 a^{-1})	5.2	49.7 (69)	69.7 (16)	0.003

LG sprouts are epicormic sprouts 3 mm or larger in diameter.
Average annual basal area growth is from initial treatment date until plot remeasurement in 1999.
Values in parentheses are sample sizes.
P values are for *t* tests between means.

into small branches throughout the pruned bole of the tree. The majority of tree bole sections for each directional quadrant produced sprouts. Prior to this study, the strong tendency for Sitka spruce to produce sprouts was not well documented, and information on epicormic sprouting and branch development was mostly anecdotal. In Europe, several pruning studies of Sitka spruce have been reported (Beach, 1939; Bauger and Orlund, 1962; Henman, 1963; Rowan, 1963; Waters, 1967; Gallagher, 1975) but little information is available on the development of epicormic sprouts. In North America, Isaac (1940) reported that spruce had a tendency to produce 'water sprouts' following exposure to light from roadsides, and Ruth (1958) mentioned that 'spruce is one of the few conifers that develops epicormic branches along the bole'. Herman (1964) studied the response of Sitka spruce to light thinning and reported that 50 of 57 sampled trees developed epicormic branches 10 years after thinning. Our research documents the abundance of epicormic sprouting in Sitka spruce and our results suggest that spruce responds to thinning and pruning treatments with the production of numerous epicormic branches. If one of the main goals of pruning is to produce clear, higher-valued wood, then Sitka spruce may be a poor candidate species for pruning.

Epicormic sprouts are believed to be the result of dormant buds being stimulated to grow by an increase in sunlight or heat exposure on the bole (Herman, 1964; Kozlowski *et al*., 1991). The large production of sprouts reported in this study is probably associated with both thinning and pruning treatments. Sites were rethinned to 420 trees ha^{-1} 6-9 years before remeasurement and all pruning lifts (2.4, 3.7 and 5.2 m) produced 9-11 sprouts m^{-1}. We found no significant difference among the different pruning intensities in the total number of sprouts produced (Figure 4). Other researchers (O'Hara and Valappil, 2000) have reported increased epicormic sprouting with increased pruning severity in western larch. Collier and Turnblom (2001) reported an increase of epicormic branches with increasing pruning severity for Douglas fir but they also reported a significant increase in sprouting when stocking was <500 stems ha^{-1}. Researchers using anecdotal studies in Sitka spruce have speculated that opening up stands would lead to the production of epicormic sprouts (Isaac, 1940; Herman, 1964). Our results show that numerous epicormic sprouts on Sitka spruce are produced following pruning but the frequency of sprouts may be more closely related to thinning intensity than pruning intensity. In other thinning studies in south east Alaska

(DeMars, 2000) we have observed epicormic sprouts in the different thinning intensity treatments but the number and size of epicormics was not reported. We also observed numerous small branches in our thinned and unpruned treatment but we were not able to determine if these branches came from new epicormic sprouts or pre existing branches. The effect of pruning trees in highly dense (unthinned) stands would help to separate thinning vs. pruning effects on the production of epicormic sprouts. The interaction of thinning and pruning and their associated effects on the production of sprouts needs further investigation.

Pruning should improve wood quality by removing the large lower branches on pruned tree boles. The lower crown of Sitka spruce often contains coarse, large diameter, persistent branches that produce large knots and consequently lower lumber grade (Harris, 1966; Petruncio, 1994). Also, wide space thinning in young growth stands further promotes large branches and knots that reduce wood quality (M.H. McClellan, unpublished data on file with Forest Sciences Laboratory, 2770 Sherwood Lane, Suite 2A, Juneau, AK 99801, USA). However, another concern with high pruning lifts is the development of large epicormic branches. Several of these branches 6-9 years after pruning were >1.5 m long and >15 mm in diameter (Figure 3). Many LG-sprouts appeared to be growing well and may develop into larger branches. These LG-sprouts were significantly more numerous in the highest pruning lift than in the lower lifts. The higher lift also contained fewer dead sprouts (Figure 4). Apparently, more of the SM-sprouts survived and developed into LG-sprouts in the highest lift (5.2 m) treatment. O'Hara and Valappil (2000) also reported more dead sprouts m lower pruning lifts and they speculated that these sprouts died because they were not receiving sufficient sunlight. The long term prognosis for these smaller sprouts is unknown and it is possible that these sprouts may eventually die, resulting in more clear wood production. Assessment of pretreatment tree condition showed that more LG-sprouts occur in trees that were initially shorter and smaller at the time of treatment (Table 3). O'Hara and Valappil (2000) also found similar results for western larch. Other researchers have reported that smaller or overtopped trees in hardwood species tend to produce more sprouts (Smith, 1966; Trimble and Seegrist, 1973). The development of sprouts into larger branches on the lower bole of these smaller trees may be a tree's response to develop greater photosynthetic capacity to compensate for smaller crowns. We also found a significant increase in the number of large and small sprouts in the south quadrant (Figure 6) that further supports the idea that light plays a large role in the development of epicormic sprouts. Overall, there may be some improvement in lumber grade from tree pruning but the persistence and development of sprouts into larger branches is a serious concern that further reduces the value of pruning as a silvicultural treatment to improve wood quality.

Pruning costs for a stand will vary substantially depending on the number of trees pruned per area, the lift height, size of tree and other sitespecific factors. Pruning is an expensive silvicultural treatment and recent pruning costs in south east Alaska have averaged about \$5 per tree (R. Jennings, personal communication, USDA Forest Service R10). If all trees were pruned in a typical precommercial thinning operation (e.g. 420 trees ha^{-1}), pruning costs would exceed \$2000 ha^{-1} or two to three times the cost of thinning the stand. Tree growth since pruning (6-9 years) has been substantial with an average diameter growth of 10 cm but estimated added value of wood produced with pruning was only \$1-3 per tree, which is less than pruning costs. Unfortunately, our results show that pruning Sitka spruce is unlikely to produce much clear wood. If we divided the tree up into 0.6 m bole sections for each directional quadrant of the tree, we found that less than half of all bole sections were free of sprouts and could produce clear wood free of knots. It appears that thinning and pruning of young growth spruce stands does not produce clear wood and the value of pruning needs to be reconciled with the pruning costs.

Pruning may be used to enhance forest resources other than timber and wood quality. Pruning can remove a large portion of the tree crown and could provide different and much more open stand conditions than dense unthinned stands or fully crowned trees in thinned stands. These open stand conditions will provide much more light for the forest floor and could be used to enhance forest understorey vegetation for wildlife forage or habitat. There are a number of thinning and pruning options that could provide a range of stand densities and vertical structures in forest stands. For instance, thinning to a higher stocking (lighter thinning intensity) would reduce light levels and could reduce epicormic sprouting. Also, pruning only every 2nd or 3rd tree in a stand would reduce the amount of light that reaches the tree holes and could potentially reduce the number and size of epicormic sprouts. Reducing the number of pruned trees would also alleviate some of the costs of pruning. It is unknown what the cumulative effects of different thinning and pruning intensities would have on forest overstorey and understorev interactions but clearly these treatments would change the amount of light reaching the forest floor and surrounding trees. Pruning may have different effects on other tree species. It is important to note that western hemlock trees in this study did not develop any epicormic sprouts. If the goal is to produce clear wood then hemlock may be an excellent candidate for pruning and the effects of pruning on hemlock need to be further investigated. In summary, considerably more work is needed to assess some of the potential benefits of silvicultural treatments such as thinning and pruning on a variety of forest resources. Thinning and pruning of Sitka spruce, however, results in the production of numerous epicormic sprouts, and these pruned spruce trees may not provide much clear, highervalued wood.

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