Assessment of Forest Insect Conditions at Opax Mountain Silviculture Trial

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SITUATION OVERVIEW

Forest management in British Columbia requires that all resource values are considered along with a variety of appropriate management practices. For the past 100 years, partial-cutting practices were the method of choice when harvesting in Interior Douglas-fir (IDF) zone ecosystems. Along with a highly effective fire suppression program and minimal stand tending, these practices have created new and distinct stand structures. These range from low-density stands of uniform height to variable-density, multi-layered stands with patchy distributions of tree clumps and canopy gaps.

However, some management practices in IDF ecosystems have created ideal conditions for epidemics of insects and diseases, which are detrimental to both stand and landscape values. The Douglas-fir beetle (*Dendroctonus pseudotsugae*) is the principal bark beetle attacking mature Douglas-firs (Furniss and Carolin 1980). Timber losses attributed to the Douglas-fir mortality caused by this beetle were estimated at 2.4 million m^3 from 1956 to 1994. These losses occurred primarily in the province's Southern Interior (Humphreys 1995). Visual quality values associated with stands and landscapes can be strongly affected by the removal of the principal cover species, whether by clearcut activities or widespread tree mortality. By eliminating the mature component of Douglas-fir trees within a stand, bark beetles can ultimately affect mule deer by removing their winter cover and browse.

The risk of attack by the Douglas-fir beetle is determined by such stand attributes as age, species composition, size, and growth rate (B.C. Ministry of Forests and B.C. Environment 1995a). Epidemics of Douglas-fir beetles are generally associated with factors such as root disease, tree defoliation, and excessive amounts of logging slash and debris (Furniss and Carolin 1980; Humphreys 1995). The prevalence of all three factors is strongly influenced by forestry practices, which significantly influence all forest resources. Past practices of selective logging have increased the incidence and prevalence of root diseases such as *Armillaria ostoyae*, *Phellinus weirii*, and *Phaeolus schweinitzii* (B.C. Ministry of Forests and B.C. Environment 1995b).

Epidemics of Douglas-fir beetles have historically followed epidemics of the western spruce budworm *(Choristoneura occidentalis)*, known widely as the most destructive forest defoliator in western North America (Furniss and Carolin 1980). Seven epidemics of western spruce budworm have been recorded in British Columbia since 1909 (Harris et al. 1985; Koot and Hodge 1992b). The last epidemic involved 800 000 ha at its peak in 1987, mostly in the Southern Interior of British Columbia (Koot and Hodge 1996).

Initiation and decline of budworm outbreaks in susceptible forests are influenced primarily by weather, and therefore fluctuate in an irregular and unpredictable fashion (Thomson et al. 1984). However, the duration, intensity, and frequency of outbreaks are also influenced by host quality and availability and natural enemy complexes (Schmidt 1985). Fire suppression and minimal stand-tending practices have created an abundance of high-quality host material in the form of multilayered canopies, and dense understorey and intermediate canopies (B.C. Ministry of Forests and B.C. Environment 1995c). Selective harvesting of ponderosa pine and exclusion of pine regeneration has created a predominance of Douglas-fir forests, with little species diversity

Repeated years of Douglas-fir defoliation by the western spruce budworm resulted in scattered tree mortality over large areas. Mortality of Douglas-fir during the 1970–1974 epidemic near Pemberton, B.C. was estimated at 39% in heavily defoliated stands (Alfaro et al. 1982). As well as timber losses attributed to tree mortality, stands suffered additional volume losses because of reduced radial and height growth, and stem deformities that arose from topkill (Van Sickle 1985; VanderSar 1987). After an infestation has collapsed, defoliated trees may require several years to regain a full complement of foliage and thereby re-acquire their growth potential. For example, up to 5 years after the collapse of the infestation, reduced growth was noted in the stand near Pemberton (Alfaro et al. 1982). The incidence of topkill can also be quite high. Topkill was found in 85% of 65 stands surveyed in the Vancouver and Kamloops forest regions, and 25% of all trees had crown topkill (Alfaro 1986). Losses over a 20-year period were estimated at 6-33% of total stand volume (Alfaro and Maclauchlan 1992).

Forest health has traditionally focused on situations involving excessive numbers of a few species, generally termed "pests." However, we should also consider the absence or reduction of other species, or guilds of insects. Ecological processes are highly dependent on the activities of insects. The biodiversity guidelines of the Forest Practices Code attempt to protect such groups through the "the development of an ecosystem management approach that provides suitable habitat conditions for all native species" (B.C. Ministry of Forests and B.C. Environment, Lands and Parks 1995d). At the landscape level, biodiversity management should consider:

- seral stage distribution;
- temporal and spatial patch size distribution;
- landscape connectivity;
- stand structure; and
- species composition.

The relative benefits of various options should be supported with an understanding of the insect fauna.

A silvicultural trial was established at Opax Mountain near Kamloops, B.C. in the IDFxh2 and IDFdk1 subzones to evaluate the effects of different partial-cutting regimes on such factors as growth and yield, biodiversity, forest health, and visual quality. Six treatments were allocated to each of two areas:

1. no-treatment unit:
2. low-density patch cuts;
3. high-density patch cuts;
4. 80% uniform retention;
5. 50% uniform retention; and
6. 35% island retention.

The overall goal for this and subsequent studies is to develop integrated forest management tactics and strategies for IDF forests that use silviculture as an integral component for creating stable, healthy forested ecosystems. Four research programs were conducted in 1996 at Opax Mountain to address the following objectives:

- Assess the risk from forest insects on the viability of the demonstration trial;
- Evaluate the general diversity of forest beetles associated with the trial, and
- Determine obvious correlations between insects and silvicultural treatments.

DIVERSITY OF ARBOREAL BEETLES

Forest health depends on a diversity of ecological processes, and also on the diversity of species that participate in such processes. Site productivity is closely linked with nutrient recycling, and therefore closely linked with a diverse assemblage of insect species. The most prominent processes in forested stands involve arboreal beetles such as bark and wood boring beetles. Arboreal species of beetles greatly influence stand structure and composition, and serve as the initiators of decomposition and nutrient recycling.

Therefore, methods are required to monitor patterns of insect diversity across landscapes, preferably ones that provide linkages with other resource sectors. A major focus of the Opax Mountain silviculture trial was to promote collaboration and interaction between various research sectors. Our objectives were:

- to estimate baseline levels of beetle diversity in stands of Douglas-fir: and
- to develop a sound and comprehensive monitoring tactic for arboreal beetles.

Methods

Arboreal beetles can be monitored with baited multiple-funnel traps. On May 22–23, 1997, three replicates of three multiple-funnel traps (8-unit) per replicate were set within each of the six treatment blocks at both sites of the Opax Mountain silviculture trial, for a total of 108 traps. Each trap was suspended by rope between trees such that the trap bottle was 1.0–1.5 m above ground level. No trap was within 2 m of any tree. Each trap bottle contained a Vapona square (2 x 2 cm) to kill captured insects and prevent damage by insect predators.

Host compounds, such as ethanol and monoterpenes, attract a wide range of beetle species. Release devices containing monoterpenes and ethanol were used as attractants in the funnel traps. The following three bait treatments
a

(based on published data and personal experience) were assigned randomly among traps within each replicate:

- ethanol + a-pinene;
- myrcene + terpinolene; and
- b-pinene + 3-carene.

Ethanol was released from a 25-cm black polyethylene pouch. Each monoterpene was released separately from closed 15-mL polyethylene screw-cap bottles.

Catches were collected every 7-14 days, starting on June 7, 1997 and ending on October 10, 1997. All catches were stored in a freezer until analyses during the winter months. Baits were replaced in August. All beetles were identified to family, genus, and species when possible. A reference collection was assembled and insect identifications were verified periodically at the Pacific Forestry Centre in Victoria.

Results and Discussion

During 1996, beetles in at least 38 families and 150 species were captured in the funnel-trap program at Opax Mountain (Table 1). Additional specimens have yet to be identified. Most species were in the Cerambycidae, Elateridae, Scarabeidae, Scolytidae, and Staphylinidae families.

Relative abundance of arboreal beetles varied by species, treatment block, and variant. Some species, such as *Spcmdylis upiformis* (Cerambycidae), *Thanasimus undatulus* (Cleridae), *Ampedus brevis* (Elateridae), *Serropalpus substriatus* (Melandryidae), and *Dendroctonus pseudotsugae* (Scolytidae), were very abundant. Other species such as *Byrrhus kirbyi* (Byrrhidae), *Podabruspiniphilus* (Cantharidae), *Anthonomus robustulus* (Curculionidae), and *Thymalus marginicollis* (Trogossitidae) were much less abundant with only a single specimen each. Although not exhaustive, these data do provide an initial baseline estimate of the diversity of arboreal beetles in dry stands of Douglas-fir.

A funnel-trap program with ethanol and monoterpenes seemed an effective tool for comparing stands. Further work is needed to improve the trapping program and elucidate correlations between trap catches and ecological processes. The utility of this method lies in its comparative approach to the study of stand and landscape features. It is not possible or feasible to assess all species and families of insects.

BLOWDOWN AND ASSOCIATED BARK AND WOOD BORING BEETLES

Blowdown events in 1995 and 1996 led to concern about and interest in bark and wood boring beetles at Opax Mountain. Infestations of the Douglas-fir beetle, *Dendroctonus pseudotsugae,* typically start with attacks on slash and windfall material, and can result in widespread patch mortality of large-diameter Douglas-fir. Our objectives were:

- to assess the distribution and categories ofblowdown in all 12 blocks of the Opax Mountain silviculture trial; and
- to determine the use of windfall material by bark and wood boring beetles.

TABLE 1 Relative abundance of arboreal beetles captured in baited multiple-funnel traps at Opax Mountain silviculture trial from May 23 to October 10, 1997 (n = 18)

FAMILY (Species[a])	Total number of beetles					
	Control	Patch (low)	Patch (high)	Retain 80%	Retain 50%	Retain islands
ANOBIIDAE						
Microbregma emarginatum	5	5	7	5	4	3
BUPRESTIDAE						
Anthaxia aenogaster	2		1	3	1	
Buprestis langi (xh)			1			
Buprestis lyrata (xh)			1	1	7	1
Melanophila drummondi (xh)						
BYRRHIDAE						
Byrrhus sp.			1	1		
Byrrhus kirbyi (dk)				1		
CANTHARIDAE						
Podabrus piniphilus (dk)				1		
CARABIDAE						
Anisodactylus sp. (dk)			1			
Bembidion mutatum	3	5	8	1	2	
Cincindela longilabris (xh)						1
CEPHALOIDAE						
Cephaloon sp.	4	1	5	6	5	10
Cephaloon tenuicorne (dk)				1		
CERAMBYCIDAE						
Acmaeops proteus	4	3	5	3		1
Anastranglia sanguinea (xh)			1			
Anoplodera sexmaculata (xh)				1		
Cosmosalia chrysocoma (dk)		1	2	2		
Dicentrus bluthneri (xh)				1		
Leptura plagifera (dk)		1		1		
Megasemum asperum	22	28	7	2	32	5
Monochamus scutellatus				1	1	1
Neanthophylax mirificus	2	1	2	2	5	2
Neoclytus muricatulus (xh)						1
Phymatodes dimidiatus (xh)						1
Pygoleptura nigrella (dk)			1		2	
Rhagium inquisitor		2	1			
Spondylis upiformis	15	43	33	71	65	65
Strictoleptura canadensis	1	5	3	3		1
Tetropium velutinum	1			4	2	2
Trachysida aspera	1	1	7		1	2
Xestoleptura crassipes	1	1	3	1		
Xylotrechus longitarsis	3	18	9	9	3	8
CHRYSOMELIDAE						
Plateumaris pusilla (dk)						1
Syneta sp. (dk)	1	1	1			2
CLERIDAE						
Enoclerus lecontei				2		
Enoclerus sphegeus	22	7	18	29	33	10
Thanasimus undatulus	63	75	57	118	122	78
COCCINELLIDAE						
Coccinella septempunctata (xh)	1					

TABLE 1 *Continued*

FAMILY (Species[a])	Total number of beetles					
	Control	**Patch (low)**	**Patch (high)**	**Retain 80%**	**Retain 50%**	**Retain islands**
COLYDIIDAE						
Lasconotus complex (dk)	2		1			
Lasconotus vegrandis	1		1	3	1	
Oxylaemus californicus (xh)					3	
CRYPTOPHAGIDAE						
Antherophaguspallidivestis			1	1	2	
Atomaria quadricollis	1	2	1	2		
CUCUJIDAE						
Cucujus clavipes				7	6	5
Dendrophagus cygnaei			3	2	4	1
Leptophloeus alterans (dk)	3		1			1
Silvanus bidentatus (xh)	2					
CURCULIONIDAE						
Anthonomus robustulus (dk)				1		
Cossonus pacificus (dk)					1	
Magdalis gentilis (xh)	1					1
Pissodes sp.	13	13	14	22	6	6
Rhyncollis brunneus				2	2	
DERMESTIDAE						
Attagenus unicolor (xh)					1	
Megatoma sp.	25	6	5	'11	13	11
Megatoma cylindrica	13	7	10	19	18	23
DYTISCIDAE						
Agabus sp. (xh)				I		
ELATERIDAE						
Acteniceromorphus umbricola	1		2	1	1	2
Agriotella occidentalis		1	1			2
Agriotes *sparsus*	2	1		3	1	
Agriotes tardus (dk)			2			1
Ampedus brevis	18	29	26	22	30	28
Ampedus glauca (xh)		1				
Ampedus moerens	2	9	3	9	16	3
Ampedus nigricollis	4	7	7	2	10	8
Ampedus nigrinus	7	5	7	4	6	3
Ampedus occidentalis		4		2	1	
Ampedus phoenicopterus		1	4	2	2	4
Ampedus pullus	3	1	10	3	6	3
Ampedus varipillis (dk)		1				
Cteniceru bombycina (xh)						1
Ctenicera propola	6	14	19	12	18	17
Ctenicera pudica	6	4	15	4	8	16
Ctenicera resplendens	1	1	7	3	3	1
Cteniceru rupestris	1	1	3		3	
Ctenicera *silvatica* (dk)						1
Dalopius sp.	1		2	1	4	
Danosoma brevicorne	1	2	6	4	4	1
Drasterius debilis	4	2	3	3	5	4
Eanus estriatus (dk)	1	1		7		
Limonius aeger	12	5	15	14	33	34

TABLE 1 *Continued*

FAMILY (Species")	Control	Patch (low)	Patch (high)	Retain 80%	Retain 50%	Retain islands
	Total number of beetles					
ELATERIDAE (continued)						
Pseudanostirus nebraskensis	20	21	28	17	11	15
Selatosomus aeripennis (xh)		2				
Selatosomus cruciatus			1		1	2
EROTYLIDAE						
Triplax dissimulator	1			1	1	1
HISTERIDAE						
Margarinotus umbrosus (xh)			1			
Paromalus mancus	1	2	1	6	1	3
Psiloscelis subopaca (xh)						
HYDROPHILIDAE						
Sphaeridium scarabaeiodes (xh)			2			
Tropisternus sp.				1	1	
LANTHRIDIIDAE						
Aridius nodifer	10	3	7	3	15	
LEIODIDAB						
Catops egenus (dk)					1	
Catoptrichus frankenhauseri (xh)		1				
LYCIDAE						
Dictyopterus sp.	1	2	2	4	4	1
MELANDRYIDAE						
Melandryia striata (xh)		1		1		1
Phryganophilus collaris	1	1				
Serropalpus substriatus	284	159	69	50	348	128
Xylita laevigata	6	5	19	23	14	12
NITIDULIDAE						
Glischrochilus vittatus (dk)					1	
OEDEMERIDAE						
Calopus angustus (dk)	2				1	2
PYTHIDAE						
Pytho americanus (dk)			1	2		
RHIZOPHAGIDAE						
Rhizophagus sp.	4	11	2	8	6	6
SALPINGIDAE						
Rhinosimus viridiaeneus	1	1	2	4	5	6
SCAPHIDIIDAE						
Scaphisoma castaneum	4	6	5	3	4	7
SCARABEIDAE						
Aphodius sp.		2	4		1	1
Aphodius congregatus	5	6	12	6	10	8
Aphodiusfimetarius	1	8	35	3	6	7
Aphodius fossor (dk)						2
Aphodius guttatus	3		1	1		
Aphodius leopardus		6	3	7	3	
Aphodius opacus	7	7	9	3	5	12
Aphodius vittatus	1	3	2	1		2
Dialytes ulkei (xh)			1			
Dichelonyx fulgida	11	17	11	4	3	6
Diplotaxis brevicollis	1		3	1	1	
Onthophagus nuchicornis		7	3	2	1	

TABLE 1 *Concluded*

FAMILY (Species[a])	Total number of beetles					
	Control	Patch (low)	Patch (high)	Retain 80%	Retain 50%	Retain islands
SCIRTIDAE						
Cyphon variabilis (dk)						3
SCOLYTIDAE						
Dendroctonus ponderosae			2	5	2	1
Dendroctonus pseudo tsugae	172	131	311	234	185	234
Dendroctonus valens		5	4	13	3	1
Dryocoetes affaber	4		3	6	9	9
Dryocoetes autographus		1	3	2	4	4
Gnathotrichus retusus			5	9	3	3
Hylastes longicollis	81	281	111	211	39	104
Hylastes nigrinus	5	13	49	22	16	16
Hylastes ruber	2	9	9	8	19	11
Hylurgops **porosus**	64	129	195	253	197	101
Hylurgops rugipennis	11	13	12	16	22	10
Ips emarginatus (xh)						1
Ips la tidens		1	4	2	5	1
Ips mexicanus (dk)			2	1		
Ips pini (dk)	1	1	6	3	9	
Pityogenes knechteli	1	1	12	7	6	1
Pityokteines minutus	2					
Pityophthorus sp.					3	5
Polygraphus rufipennis	1				1	3
Pseudohylesinus nebulosus				4	1	1
Scierus annectans	12	24	14	33	19	25
Scolytus monticolae	1	2	1	3		5
Trypodendron lineatum	249	9	322	25	32	23
SPHINDIDAE						
Odontosphindus denticollis (xh)				1		
STAPHYLINIDAE						
Lordithion sp.	6	5	3		6	3
Mycetoporus sp.	15	21	25	21	22	19
Oxyporus occipitalis (xh)		1	1			
Quedius sp.	17	21	40	40	35	17
Quedius giffinae (xh)			1			
Staphylinus pleuralis (dk)		1				
Stenus sp. (xh)			1	1		
Xenodusa *reflexa* (dk)		1				
TENEBRIONIDAE						
Corticeus sp. (dk)				1		
Corticeus strublei	9	9	15	14	12	7
TETRATOMIDAE						
Tetratoma concolor (dk)	1		1			
TROGOSITIDAE						
Calitys scabra		2	5	3	1	
Ostoma ferruginea			2	1		4
Temnochila chlorodia	1				1	
Thymalus marginicollis (xh)				1		

a Species found at both sites unless otherwise noted.

Methods

In 1996, a two-person crew conducted surveys of windfall material from August 12 to 15 and 19 to 21. All forested areas within patch-cut treatment blocks (C, E, J, and K) were assessed. The remaining blocks were assessed by a 10% (by area) sampling scheme. Parallel transect lines were spaced 100–150 m apart. Each transect was 10 m wide and 150–250 m long. We measured the length and diameter of all windfall material in blocks C, E, J, and K, and of all material encountered within 10-m transects in the remaining blocks. Only trees with stumps lying within the 10-m transect were included in density calculations for blocks A, B, D, F, G, H, I, and L. Leaning trees (> 30° from vertical) were distinguished from broken tops, high stumps, and uprooted trees.

The occurrence and prevalence of bark and wood boring beetles attacks were assessed for the stem or bole portion of each piece of windfall. Prevalence was estimated as a proportion of bark surface with frass piles and feeding galleries. Galleries were periodically examined for species identification. Round- and flatheaded wood borers (Buprestidae and Cerambycidae, respectively) were distinguished by coarse frass (fecal and cutting material), which consisted of white and reddish brown fragments. Ambrosia beetles (Scolytidae) were distinguished by fine white frass, while other scolytids produced fine to coarse reddish-brown frass. Species of *Dendroctonus* produced coarser frass than smaller beetles. Voucher specimens of bark beetles were collected for species verification.

Results and Discussion

The density of downed trees was low at the IDFxh2 site (Figure 1), with most of the area averaging 0–10 trees per hectare. The highest density of windfall at this site was found in the northern section of block F. Douglas-fir was the most abundant tree species in blowdown, accounting for 87% of 89 downed trees that were examined. Trembling aspen, paper birch, spruce, and lodgepole pine accounted for the remainder.

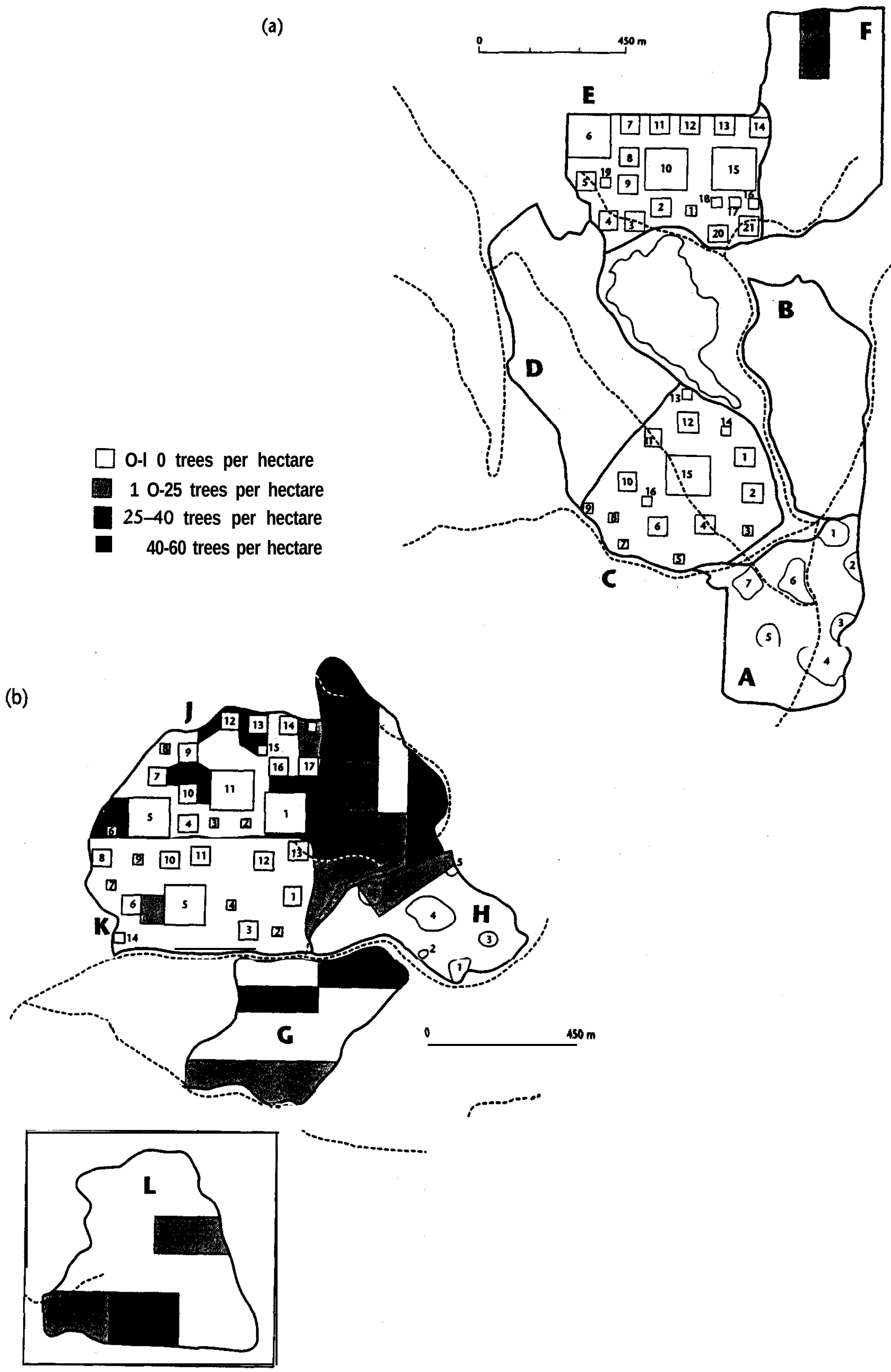

FIGURE 1 *Distribution of downed trees* at *(a) IDFxh2 (A–F) and (b) IDFdk1 (G–L) at the Opax Mountain silviculture trial: (A, H) 35% island retention; (B, G) 50% uniform retention; (C, K) low-density patch cuts;* **(D, I) no-treatment unit; (E, J) high-density patch cuts;** *and (F, L) 80% uniform retention.*

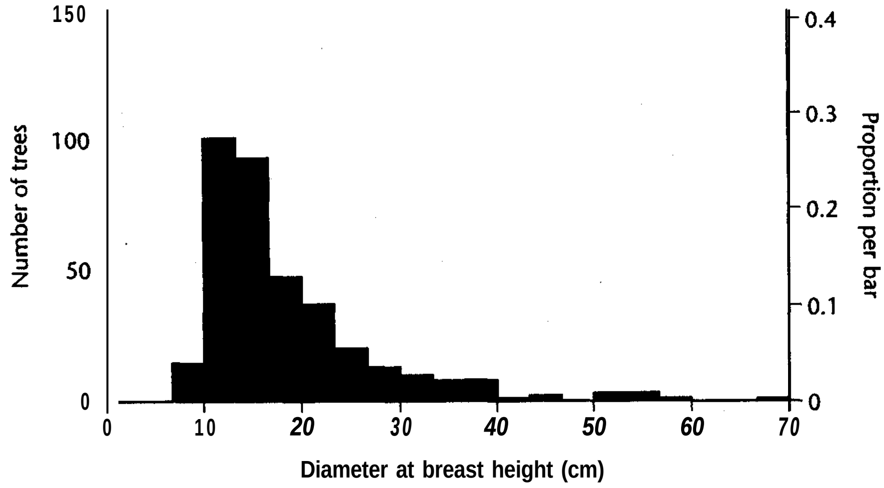

FIGURE 2 *Distribution of diameters of downed Doug/as-fir at the Opax Mountain silviculfure trial (n = 337).*

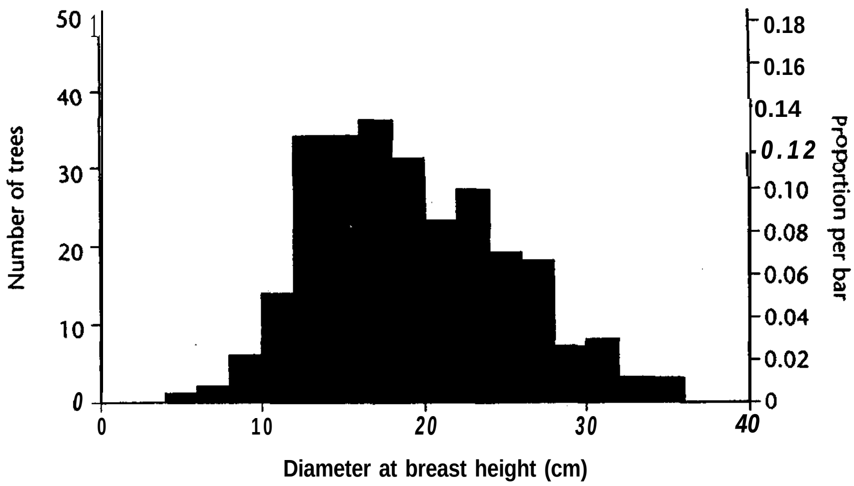

FIGURE 3 *Distribution of diameters of downed lodgepole pine at the Opax Mountain silviculture trial (n = 1 96).*

In contrast, blowdown densities were quite high at the IDFdk1 site, with most of the area averaging 10–40 trees per hectare. The highest density of windfall was in block I, followed by block J and block G. Both Douglas-fir and lodgepole pine trees were abundant in windfall material, accounting for 57% and 42% of 481 downed trees, respectively. The remaining downed material was spruce.

The diameter of downed Douglas-fir ranged from 7 to 68 cm at breast height, with a large component of small-diameter trees and few older veterans (Figure 2). In contrast, the diameters of downed lodgepole pine trees ranged from 6 to 36 cm at breast height, with considerably less variation (Figure 3). Some variation in mean diameter and height of downed Douglas-fir occurred among treatment blocks (Table 2). The largest-diameter downed trees were found in blocks C and F. Variation in tree height was less pronounced. Only trees with intact boles were used for height determination. Height and diameter of downed lodgepole pine were less affected by treatment blocks at the IDFdk1 site (Table 3).

TABLE 2 *Heights and diameters of downed Douglas-fir in each block of the Opax Mountain silviculture trial*

	Diameter (dbh)		Height	
Block	n	Mean (± SE) (cm)	*n*	Mean (± SE) (m)
A	3	15 ± 0.9	2	11 ± 3.0
B	13	19 ± 1.9	7	16 ± 2.2
C	25	23 ± 2.8	12	13 ± 1.2
D	2	15 ± 4.5	1	6 ± 0
E	17	21 ± 3.4	13	15 ± 1.8
F	15	24 ± 2.1	15	16 ± 1.4
G	33	20 ± 1.4	26	15 ± 1.1
H	12	17 ± 1.6	9	11 ± 1.4
I	33	19 ± 1.6	23	12 ± 1.1
J	107	18 ± 0.8	80	13 ± 0.6
K	62	18 ± 1.2	44	12 ± 0.5
L	15	14 ± 0.7	12	9 ± 0.6

TABLE 3 *Heights and diameters of downed lodgepole pine in each block of the Opox Mountain silviculture trial*

	Diameter (dbh)		Height	
Block	*n*	Mean (± SE) (cm)	*n*	Mean (± SE) (m)
G	28	21 ± 1.0	25	16 ± 0.8
H	4	21 ± 4.7	2	14 ± 5.5
J	104 19	21 20 ± 0.6 1.3	59 6	16 15 ± 0.7 2.3
K	28	20 ± 1.0	17	16 ± 1.0
L	10	22 ± 2.5	6	14 ± 1.6

Downed trees were classified into one of four categories: leaning, broken, uprooted, and felled. Uprooted and broken trees accounted for most of the blowdown (Figure 4). Leaners were defined as trees with root disturbance caused by wind or snowpress, with stems or boles deviating from vertical by more than 30°. Broken trees consisted of secure stumps with boles broken at heights greater than 1 m above ground level. Uprooted trees had most, if not all, of their root mass exposed, with the bole lying close to horizontal. Ten felled trees were encountered near patches 7–9 in block C. These trees had been felled by chainsaw, delimbed, and bucked into lengths of 2-3 m. Significant variation was evident in the relative proportion of the four types of blowdown across treatment blocks at both the IDFxh2 site (χ^2, df = 15, $p < 0.001$) and the IDFdk1 site (χ^2, $df = 10$, $p = 0.02$). The proportion of uprooted trees ranged from 0 to 94% (Table 4).

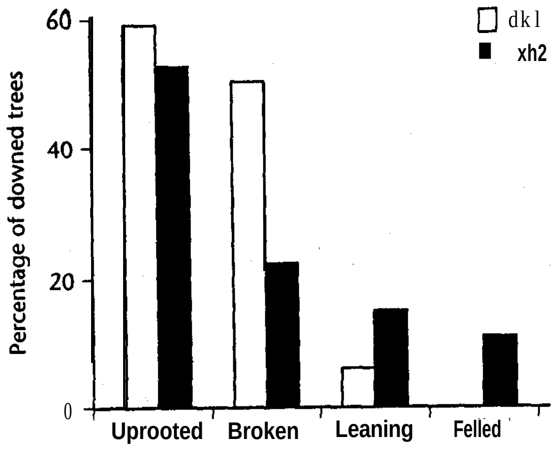

FIGURE 4 *Percentage of* **downed trees by type for** *IDFdk 1 (n = 48 1) and IDFxh2 (n = 99) sites.*

The various categories of blowdown resulted in four types of large woody debris:

- leaning trees;
- uprooted trees;
- high stumps; and
- broken tree tops.

The latter two were derived from broken trees. Felling debris was not included because this was isolated to one area within block C. Uprooted trees, high stumps, and broken tops were the prevalent types of large woody debris for both Douglas-fir and lodgepole pine (Figure 5). Leaning trees made up only a small component of blowdown. The dimensions of each type are given

TABLE 4 *Percentage* **of the four categories of downed** *trees across all* **treatment blocks**

Block	*n*	Percentage of downed trees			
		Uprooted	Broken	Leaning	Felled
A	5	40	40	20	0
B	14	50	43	7	0
C	29	31	14	21	34
D	4	0	50	50	0
E	20	60	30	10	0
F	17	94	0	6	0
G	68	71	22	7	0
H	17	65	35	0	0
I	63	46	54	0	0
J	213	58	33	9	0
K	92	61	34	1	0
L	28	64	32	4	0
All	570	58	33	7	2

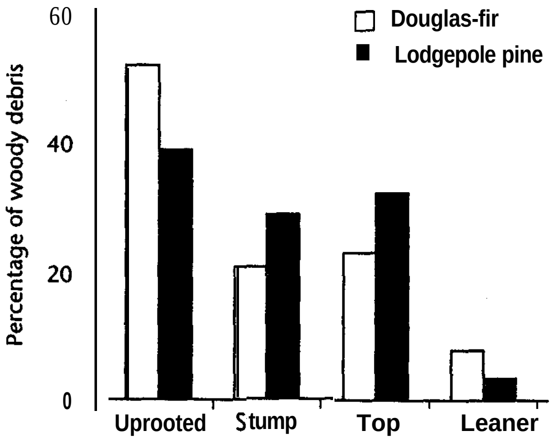

FIGURE 5 *Percentage of large woody debris by type for Douglas-fir (n = 423) and* lodgepole *pine (Pl) (n = 286).*

in Table 5. We expect that bark and wood boring beetles to vary in their use of these types of woody debris.

Bark and wood boring beetles were abundant in large woody debris, using 40% of recent windfall (*n* = 734). Fourteen species of bark and ambrosia beetles were found in windfall. ***Dendroctonus murrayanae, D. ponderosae, D. valens, Hylastes macer, Ips mexicanus, I. pini,*** and ***Pityogenes knechteli*** were common in lodgepole pine material. Douglas-fir windfall was used by ***D. pseudotsugae, Pseudohylesinus nebulosus,*** and ***Scolytus monticolae. Dendroctonus rufipennis*** was found in one downed spruce. ***Polygraphus rufipennis*** was found in both spruce and Douglas-fir material. The ambrosia beetle, ***Trypodendron lineatum,*** was found in lodgepole pine and Douglas-fir material.

Round- and flatheaded wood borers (Cerambycidae and Buprestidae, respectively) were not identified by species because there were few adults in galleries. Most of the observed larvae in phloem tissue were flatheaded wood borers. Roundheaded wood borers such as Sawyer beetles were likely present in windfall, but not easily discernible because they would have invaded the sapwood at the time when surveys were conducted.

Forty percent of windfall items at the IDFdk1 site were used by beetles (*n* = 627), while 41% of material was used at the IDFxh2 site (n = 107). At both sites, broken tree tops had the highest incidence of attack, ranging from 59 to 60% of available tops (Figure 6). The lowest attack incidences were found in leaning trees. Attack incidences was also quite low in high stumps, ranging from ii to 23%.

TABLE 5 Dimensions *of* large *woody* debris at the Opax Mountain *silviculture trial*

	Douglas-fir			Lodgepole pine		
	n	Mean (± SE) diameter (cm)	Mean (± SE) height/length (m)	*n*	Mean (± SE) diameter (cm)	Mean (± SE) height/length (m)
Uprooted	213	19.4 ± 0.64	13.4 ± 0.35	108	20.7 ± 0.62	16.0 ± 0.47
High stump	83	18.6 ± 1.04	4.5 ± 0.27	79	20.6 ± 0.59	5.5 ± 0.34
Broken top	68	15.2 ± 0.86	8.7 ± 0.35	79	16.2 ± 0.5 1	10.4 ± 0.39
Leaner	31	14.2 ± 0.91	10.2 ± 0.51	9	18.5 ± 1.74	4.85 ± 1.63

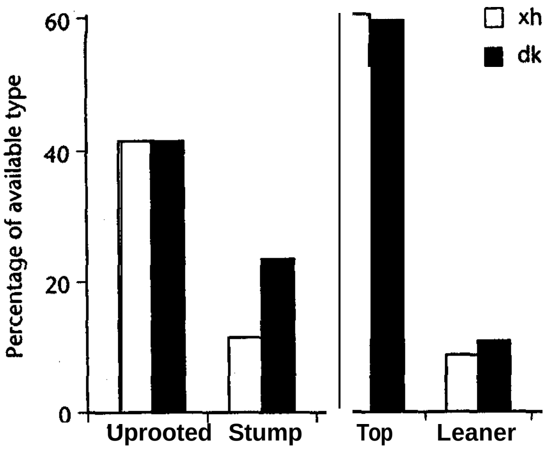

FIGURE 6 Percentage of all available woody debris attacked by bark and wood *boring beet/es at two sites at the* ***Opax*** *Mountain* ***silviculture*** *trial.*

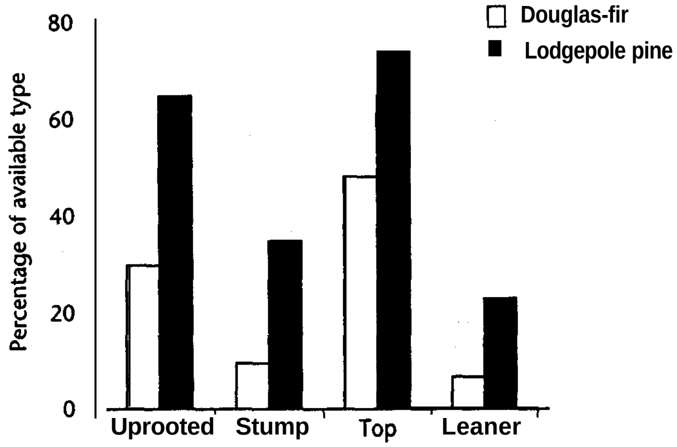

FIGURE 7 *Percentage of all available Douglas-fir and lodgepole pine woody debris attacked by bark and wood boring beetles.*

Beetles attacked much more of the available lodgepole pine windfall debris than the available Douglas-fir debris for all types of debris (Figure 7). Very low proportions of uprooted trees and stumps were used by species such as Douglas-fir beetles. The lowest use of Douglas-fir was found in stumps and leaning trees. Overall the incidence of attack was highest in lodgepole pine with 57% of woody debris infested by beetles (n = 286). By contrast, only 30% of Douglas-fir windfall was attacked by beetles (n = 433). Only 3 of 13 pieces of spruce windfall were used by beetles.

For all types of woody Douglas-fir debris, larger-diameter material was preferred by bark and wood boring beetles (Table 6). However, beetles showed little, if any, preference for larger-diameter lodgepole pine windfall, although large-diameter uprooted lodgepole pine trees showed a slight increase in use.

The most common species of bark beetle in infested downed Douglas-fir material was *Scolytus monticolae*, which favoured uprooted trees and broken tops (Figure 8). The Douglas-fir beetle, *Dendroctonus pseudotsugae*, was present in approximately 40% of windfall items infested with beetles,

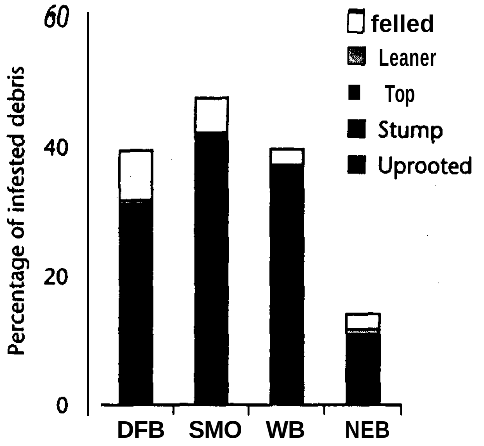

FIGURE 8 *Percentage of infested Douglas-fir blowdown by beetle species:* **Dendroctonus pseudotsugae** *(DFB),* **Scolytus monticolae** *(SMO), flatheaded wood borers (WE), and* **Pseudohylesinus nebulosus** *(NEB).*

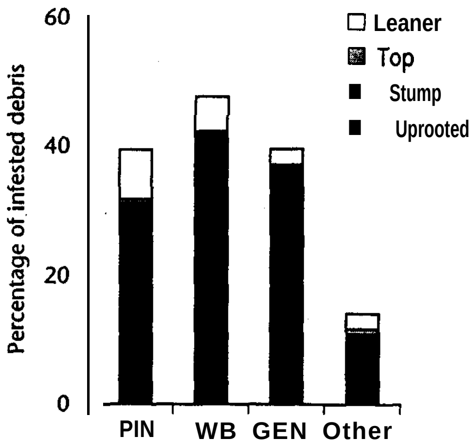

FIGURE 9 *Percentage of infested lodgepole pine blowdown by beetle species:* **Ips pini** *(PIN), flatheaded wood* **borers** *(WB),* **Pityogenes knechteli** *(GEN), and the combination of* **Dendroctonus valens, D. murrayanae, Ips mexicanus, and Trypodendron lineatum** *(Other).*

particularly in uprooted trees. Flatheaded wood borers were common in infested uprooted trees and tree tops.

Well over 50% of infested lodgepole pine debris contained the pine engraver, *Ips pini* (Figure 9), which favoured uprooted trees and broken tops. These same types of woody debris were favoured by flatheaded wood borers and the bark beetle, *Pityogenes knechteli.* Stumps were also used by the pine engraver, as well as other bark beetle species, such as *Dendroctonus valens, D. murrayanae,* and *I. mexicanus.*

Infested pieces of spruce windfall were used by four species of bark beetles: Dendroctonus *rufipennis, Ips tridens, Dryocoetes affaber,* and *Polygraphus rufipennis.* However, only three pieces were attacked.

The exploitation of available bark surface on infested blowdown varied considerably between types of debris (Figure 10). The phloem tissue in most

TABLE 6 *Diameters of used windfall pieces*

		Mean (± SE) diameter at base (cm)[a]			
Host	Type	*n*	Used	*n*	Not used
Douglas-fir	Uprooted trees	63	27 ± 1.4 a	150	16 ± 0.5 b
	High stumps	8	29 ± 7.5 a	75	18 ± 0.8 b
	Broken tops	39	17 ± 1.3 a	29	13 ± 0.9 b
	Leaners	2	24 ± 13.9 a	29	14 ± 0.4 b
Lodgepole pine	Uprooted trees	70	22 ± 0.7 a	38	17 ± 1.1 b
	High stumps	27	22 ± 1.1 a	52	20 ± 0.7 a
	Broken tops	59	16 ± 0.5 a	20	17 ± 1.3 a
	Leaners	2	17 ± 3.3 a	7	19 ± 2.1 a

a Means followed by the same letter within the same row are not significantly different at $p = 0.05$ (two-sided t-test, pooled variances).

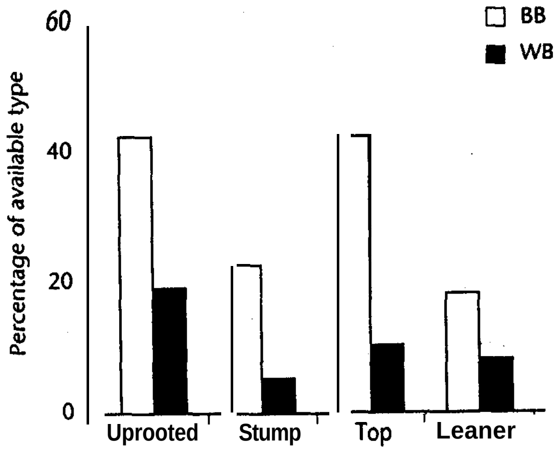

FIGURE 10 ***Percentage of bark surface area of infested blowdown exploited by bark (BB) and wood boring beetles (WB) at the Opax Mountain silviculture trial.***

pieces was rarely exploited fully by beetles. Less than half of the bark surface in infested uprooted trees and broken tops was used by bark beetles; wood borers used 10–20% of the available area. Stumps were only lightly used by wood borers. Generally, beetles preferred to concentrate attacks at the butt end of trees and stumps rather than being loosely dispersed over the entire item. One significant difference existed between sites: mean (± SE) exploitation of bark surface of infested uprooted trees was 43.8 ± 3.1% at the IDFdk1 site, but only 29.7 ± 6.9% at the IDFxh2 site. Values for other types of downed material were similar.

The exploitation of bark area in infested Douglas-fir and lodgepole pine windfall material was relatively the same (Table 7). Bark beetles generally used less than 50% of the available phloem; wood borers generally used less than 20%. The only difference was in the use of lodgepole pine stumps where use by both bark beetles and wood borers was lower than in Douglas-fir stumps.

The Douglas-fir beetle, *Dendroctonus pseudotsugae,* used 50% of the available bark surface area of infested Douglas-fir windfall (Table 8). Pieces attacked by *D. pseudotsugae* were usually of large diameter and of long length compared to pieces attacked by other species. The pine engraver, *Ips phi,* used 55% of available area of infested lodgepole pine windfall. All species of beetles in pine seemed to use pieces of windfall with the same characteristics.

TABLE 7 ***Exploitation of bark surface area by beetles in infested Douglas-fir and lodgepole pine***

		Mean (± SE) percentage of available bark exploited		
Host	Type	n	Bark beetles	Wood borers
Douglas-fir	Uprooted trees	63	40 ± 4.1	18 ± 3.1
	High stumps	8	41 ± 14.7	16 ± 12.8
	Broken tops	45	39 ± 4.1	10 ± 2.5
Lodgepole pine	Uprooted trees	70	43 ± 4.3	18 ± 2.8
	High stumps	27	16 ± 4.2	8 ± 5.1
	Broken tops	65	44 ± 4.6	10 ± 2.4

TABLE 8 *Exploitation of available bark surface by various species of beetles for Douglas-fir and lodgepole pine windfall*

Host	Beetle	Mean (± SE) % of surface area used by beetles	Mean (± SE) diameter of infested material (cm)	Mean (± SE) height/length of infested material (m)
Douglas-fir	*D. pseudotsugae*	49 ± 3.9	33 ± 1.9	18 ± 1.0
	S. monticolae	37 ± 2.9	19 ± 1.0	13 ± 0.8
	I? nebulosus	40 ± 5.6	24 ± 2.6	14 ± 1.1
	Flatheaded borers	33 ± 3.0	25 ± 1.3	1.5 ± 0.8
Lodgepole pine	*I. pini*	55 ± 3.3	20 ± 0.5	13 ± 0.6
	P. knechteli	37 ± 4.4	18 ± 1.2	12 ± 1.0
	Flatheaded borers	32 ± 2.9	19 ± 0.7	14 ± 0.6

Fresh woody material varied considerably at the Opax Mountain trial sites. Some sites had very little windfall, while others, such as blocks I and J, had large numbers of downed trees. Some trees were totally uprooted, while others had snapped at mid-bole, which resulted in an abundance of high stumps still firmly planted in the ground. Less than one-half of the pieces of woody debris were used by beetles. Of those, less than one-half of the available bark surface area was attacked. Phloem and sapwood resources were still available for beetles in 1997. In particular, high stumps and leaning trees may not be infested for several years.

STANDING DOUGLAS-FIR TREES INFESTED WITH DOUGLAS-FIR BEETLE

The Douglas-fir beetle, *Dendroctonus pseudotsugae,* is a significant factor in stands of Douglas-fir, affecting stand structure, nutrient cycling, and biodiversity. Spot infestations scattered over landscapes are common at endemic population levels (Furniss and Carolin 1980). Typically, groups of trees are attacked by beetles, generally in association with slash or windfall, root diseased trees, or trees defoliated by either the western spruce budworm or the Douglas-fir tussock moth, *Orgyia pseudotsugae.* The objective of the assessment was to determine the distribution of Douglas-fir recently attacked by the Douglas-fir beetle.

Methods

Assessments were conducted from August 12 to November 11, when sites were surveyed for blowdown and topkill. At that time, transects were run throughout all blocks. Patch-cut blocks were again surveyed on November 11–12, specifically to find infested trees. Each attacked tree was examined for brood production.

Results and Discussion

A total of 16 mature Douglas-fir were attacked by the Douglas-fir beetle in 1996 at the Opax Mountain trial site, mostly in blocks A and C. One spot infestation was found within island 6 of block A and consisted of two dead trees (dbh = 43 and 52 cm, respectively) as well as six trees with current brood (mean dbh ± SE = 45 ± 3.8 cm). Douglas-fir beetles had emerged from the dead trees, although associated beetles such as flat- and roundheaded wood borers were still present. Attacks on three of the attacked trees seemed to be partial. These trees will likely survive to 1997, but will probably be re-attacked'by emerging Douglas-fir beetles in the spring.

A second spot infestation was found along the eastern edge of patch 15 in block C. The spot consisted of five trees with current brood (mean dbh ± SE = 51 ± 6.2 cm), two trees previously infested with beetles (dbh 31 and 80 cm, respectively), and two trees unsuccessfully attacked by Dougflas-fir beetles (dbh 27 and 32 cm, respectively). Several trees appeared to have been used in successive years for brood production. Single infested trees were found at the following locations:

- between patches 10 and 11 in block C (dbh 41 cm);
- along the southern margin of patch 14 in block C (dbh 43 cm);
- at the southwest corner of patch 6 in block E;
- in the northwest sector of block F; and
- along the northern margin of patch 12 in block J.

One additional Douglas-fir was killed in 1996 along the southern margin of patch 12 in block J (dbh 15 cm). The tree had been infested by two secondary types of bark beetles, *Scolytus monticolae* (= S. *tsugae*) and *Pseudohylesinus nebulosus*, presumably after the tree was weakened or killed by other factors. These species do not attack and kill vigorous, healthy trees.

It is very likely that additional tree mortality will occur in 1997. The combination of weakened trees, beetle populations arising from infested trees, and beetle populations arising from infested blowdown will result in risk of additional attacks on healthy trees in some areas, such as along the eastern margin of patch 15 in block C, within retention island 6 in block A, and in blocks J and K. Forty windthrown Douglas-fir were attacked by Douglas-fir beetles in 1996, mostly in blocks C, G, J, and K. The diameter of 16 trees was greater than 35 cm; eight were greater than 45 cm. This material will contribute a large number of beetles to the area. Large amounts of blowdown were not used by beetles. Standing stumps (4-6 m in height) and wind-weakened trees will be favourable for attacks by Douglas-fir beetles. With sufficient beetle numbers, attacks on adjacent trees will also occur, resulting in spot infestations.

However, endemic levels of Douglas-fir beetles are generally quite high, since they breed in small amounts of blowdown and in trees attacked previously. Widely scattered spot infestations are a normal landscape feature for endemic populations of Douglas-fir beetles (Furniss and Carolin 1980). Several infested trees appear to have been attacked in successive years, which has resulted in lower populations than if the trees were used within only one year. Moreover, the beetles are spread over a large area (> 120 ha at each site). Tree mortality should be assessed again in 1997.

DEFOLIATORS AND TOPKILL OF DOUGLAS-FIRS

Opax Mountain is located in a region with a high risk of severe Douglas-fir defoliation by western spruce budworm and Douglas-fir tussock moth (B.C. Ministry of Forests and B.C. Environment 1995c). However, little significant defoliation of Douglas-fir by either species occurred at Opax Mountain in 1996. Evidence of past epidemics was clearly discernible by the numerous trees with topkill spires.

The last infestation of western spruce budworm at Opax Mountain began in 1984. This outbreak resulted from widespread infestations that had originated near Lillooet and Cache Creek and had spread eastward throughout the Kamloops Forest Region (Erickson and Loranger 1987, 1988; Koot and Loranger 1989, 1990; Koot and Hodge 1991, 1992a, 1992b, 1993, 1994). Defoliation occurred over a 9-year period until the infestation collapsed in 1993. The intensity of defoliation was heavy in some years, although it was minimal in 1989 and 1990. An infestation of Douglas-fir tussock moth occurred during 1990–1992 (Koot and Hodge 1993, 1994).

The objective was to assess the prevalence and characteristics of Douglas-fir with topkill at the IDFxh2 site. Little, if any, topkill was evident at the IDFdk1 site. Infestations of the Douglas-fir tussock are more typical in IDFxh sites than IDFdk ones (Erickson 1995).

Methods

Trees in blocks A-F were assessed for topkill October 25–27 and November 10–11, 1996. In each block, 50–75 trees were randomly selected at preset intervals ranging from 25 to 35 m, depending on predicted lengths of transect lines. Transect lines in blocks C and E were placed throughout the residual forested corridors. In the remaining blocks, parallel transect lines were spaced 100–150 m apart with orientations similar to those used in the slash survey.

The height of live and dead stem was determined for each tree, as well as the percentage of live stem occupied by live crown. Stem biomass (SBM) volumes were calculated by the following equation:

$$\text{SBM} = \frac{\pi h_t d_t^2}{12},$$

where: ht = height of tree, and
dt = diameter of tree at breast height.

Volumes of spires were subtracted from stem biomass estimates for topkilled trees using the following estimate for basal diameter:

$$d_s = d_t \left(\frac{h_s}{h_t}\right),$$

where: ds = basal diameter of spire, and
hs = height of spire.

Results and Discussion

Douglas-fir was the predominant tree species in blocks A-F, accounting for 98% of all trees sampled (n = 325). The percentage (±SE) of live stem occupied by live crown (crown/stem) averaged 59 ± 0.9% over all blocks (Table 9). Crown/stem percentages were highest in blocks D-F and lowest in blocks A and B. Spruce, lodgepole pine, trembling aspen, and paper birch accounted for the remainder and were not considered in subsequent analyses.

The mean height of Douglas-fir throughout blocks A-F was 16.5 ± 0.38 m. However, the distribution of heights was quite broad, reflecting a multi-layered stand (Figure 11). One obvious explanation for such a distribution was the prevalence of topkill in the stand. Almost 50% of the Douglas-fir had topkill spires, with the lowest incidence in blocks E and F (Table 9).

The height of trees without topkill spires averaged 20.2 ± 0.46 m across all blocks, with the tallest trees in blocks C-E (Table 10). In contrast, the height of trees with topkill spires averaged 12.5 ± 0.43 m across treatment blocks,

TABLE 9 *Crown/stem percentages and topkill incidences for Douglas-fir at the IDFxh2 site of the Opax Mountain silviculture trial*

Block	n	Mean percent live crown[a]	Topkilled trees (%)
A	50	53 ± 2.7 ab	52
B	50	52 ± 2.2 a	50
C	74	57 ± 1.9 abc	50
D	48	64 ± 2.0 c	52
E	59	62 ± 2.0 bc	44
F	44	65 ± 2.9 c	39
All	325	59 ± 0.9	48

a Means followed by the same letter within a column are not significantly different at $p = 0.05$ (Tukey's Multiple Comparison Test).

significantly less than that for trees without spires (t-test, pooled $df = 323$, $p < 0.001$). Differences in tree heights are only partially explained by heights of spires, which averaged 2.9 ± 0.14 m. Fifteen percent of all spires had broken off and fallen to the ground.

The mean diameter of topkilled trees was significantly less than the mean diameter of trees without topkill (t-test, pooled $df = 323$, $p < 0.001$) (Table 11). As with tree heights, the diameters of trees without topkill spires were largest for trees in block D and smallest for trees in block B. No significant difference existed in diameters of trees with topkill spires.

The mean stem biomass of topkilled trees was 54% less than the mean biomass of trees with no topkill (t-test, pooled df = 323, $p < 0.001$) (Table 12). The lowest volumes of stem biomass with no topkill were found in trees in blocks A, B, and F, while the highest were in trees in blocks C and D. No significant difference existed in stem biomass of trees with topkill among the treatment blocks. Volumes within spires accounted for 1% of the difference in stem biomass between trees with topkill compared to those without topkill.

Risk of defoliation by either western spruce budworm or Douglas-fir tussock moth is currently low because little, or no, defoliation occurred in 1996. However, the silvicultural system site is in a high-risk region and will likely

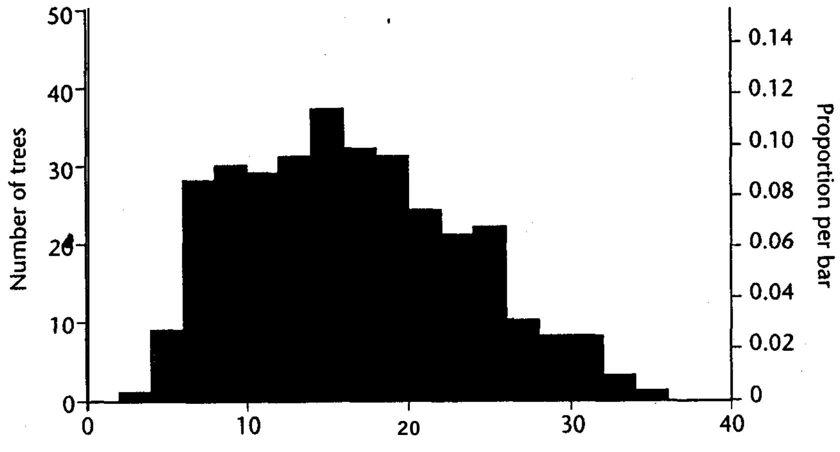

FIGURE 11 *frequency distribution of heights of live stems of Douglas-fir at the Opax Mountain silviculture trial (n = 325).*

TABLE 10 *Height of trees with and without topkill spires at the IDFxh2 site of the Opax Mountain silviculture trial*

Block	Without topkill spires		With topkill spires		
	n	Mean (± SE) height of live stem (m)[a]	*n*	Mean (± SE) height of live stem (m)[a]	Mean (± SE) height of topkill spire (m)[a]
A	24	18.0 ± 0.99 a	26	10.2 ± 0.70 a	3.2 ± 0.49 a
B	25	18.5 ± 0.74 a	25	12.5 ± 0.91 a	2.4 ± 0.29 a
C	37	21.7 ± 1.06 ab	37	13.6 ± 1.07 a	2.7 ± 0.25 a
D	23	23.6 ± 1.35 b	25	12.1 ± 1.13 a	3.5 ± 0.35 a
E	33	20.8 ± 0.93 ab	26	13.1 ± 0.96 a	2.7 ± 0.30 a
F	27	17.8 ± 1.21 a	17	13.1 ± 1.36 a	3.2 ± 0.46 a
All	169	20.2 ± 0.46	156	12.5 ± 0.43	2.9 ± 0.14

a Means followed by the same letter within a column are not significantly different at $p = 0.05$ (Tukey's Multiple Comparison Test).

TABLE 11 *Diameter at breast height (dbh) of trees with and without topkill spires at the IDFxh2 site of the Opax Mountain silviculture trial*

Block	Without topkill spires		With topkill spires	
	n	Mean (± SE) dbh (cm)[a]	*n*	Mean (± SE) dbh (cm)[a]
A	24	27.2 ± 2.28 ab	26	19.5 ± 1.12 a
B	25	25.4 ± 1.27 a	25	21.3 ± 1.33 a
C	37	34.1 ± 2.43 ab	37	23.9 ± 1.82 a
D	23	37.2 ± 2.69 b	25	23.5 ± 2.30 a
E	33	31.8 ± 2.54 ab	26	23.3 ± 1.84 a
F	27	25.9 ± 2.02 a	17	25.5 ± 3.18 a
All	169	30.5 4 1.00	156	22.8 ± 0.79

a Means followed by the same letter within a column are not significantly different at $p = 0.05$ (Tukey's Multiple Comparison Test).

TABLE 12 *Stem biomass (sbm) of trees with and without topkill spires at the IDFxh2 site of the Opax Mountain silviculture trial*

Block	Without topkill spires		With topkill spires	
	n	Mean (± SE) sbm (m3)[a]	*n*	Mean (± SE) sbm (m3)[a]
A	24	0.46 ± 0.085 ab	26	0.15 ± 0.025 a
B	25	0.36 ± 0.043 a	25	0.22 ± 0.039 a
C	37	0.94 ± 0.155 bc	37	0.39 ± 0.104 a
D	23	1.10 ± 0.171 c	25	0.37 ± 0.115 a
E	33	0.78 ± 0.159 abc	26	0.33 ± 0.098 a
F	27	0.44 ± 0.086 ab	17	0.46 ± 0.201 a
All	169	0.70 ± 0.058	156	0.32 ± 0.042

a Means followed by the same letter within a column are not significantly different at $p = 0.05$ (Tukey's Multiple Comparison Test).

experience an intense epidemic in the near future. The multi-layered conditions of the stands at the Opax Mountain trial site, combined with patches of high-density, closed-canopy stands will provide an ideal environment for a protracted infestation of western spruce budworm, likely resulting in severe levels of defoliation.

Past infestations have created heterogeneity in stand structure, with almost 50% of trees with topkill. These stagheads provide perching and nesting opportunities for birds, as well as sheltered areas for canopy insects. Over time, the spires fall to the ground, providing additional small, woody debris to the forest floor.

Topkilled trees were dramatically different in height, diameter, and stem biomass volume compared to trees with no topkill. The spires account for only a small portion of these differences. The rest can be ascribed to growth losses attributed to defoliation by the western spruce budworm and the Douglas-fir tussock moth and/or feeding preferences of defoliators on smaller, sub-dominant trees.

SUMMARY AND RECOMMENDATIONS FOR 1997

The lack of buffer zones and replication at the Opax Mountain trial site severely restricts conclusive interpretation of the silvicultural treatments on beetle fauna. Arboreal beetles are highly vagile, dispersing over large areas, and often flying distances greater than 0.5–1.0 km. The distribution of beetles within a stand is often patchy such as spot infestations of Douglas-fir beetle. Replication over a broad range of site characteristics is required for objective evaluations of stand treatments on forest health.

However, the Opax Mountain Silvicultural Systems Project does provide an invaluable opportunity to gain baseline information on the diversity of arboreal beetles, as well as to develop sampling methods geared to a broad range of resource objectives. The combined research endeavours at Opax Mountain have provided considerable insight into measures of interest to other researchers, such as the distribution of woody debris and the associated beetles that initiate decomposition.

Work conducted in 1996 has resulted in the compilation of a large reference collection, which consists of over 40 families of Coleoptera. This collection will be invaluable in the training of technicians for further replicated studies, as well as a reference source for the University College of the Cariboo and other public facilities and organizations.

The funnel-trap method is well suited to studies of forest health and biodiversity. The site offers an excellent opportunity to assess the relative benefits of various combinations of trap position, lures, and preservatives. Evaluation of the following could significantly improve this method:

1. trap height (crown, mid/upper bole, and breast height);
2. preservative (Vapona, ethylene glycol, and propylene glycol);
3. lures (monoterpene, ethanol, and pheromone blends);
4. inter-trap distance (10, 25, 50, and 100 m);
5. visual stimulus (baited and nonbaited); and
6. sample size (one, three, and five traps per site).

In conclusion, the survival of the trial is not currently at risk from forest pests. However, the presence of Douglas-fir beetles in slash and standing trees (albeit at low levels) combined with an abundance of tall, standing stumps may result in a significant increase in the abundance of Douglas-fir beetle and subsequent mortality of standing Douglas-fir. In contrast to uprooted trees and broken tops, standing stumps with intact root systems will be favourable to attack by beetles because of the minimal degradation of the phloem resource. The level of attacks to stumps, new slash material, and standing trees should be monitored.

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