WOODY DEBRIS AND WILDLIFE TREES IN ASPEN AND MIXED-WOOD FORESTS OF NORTHEASTERN BRITISH COLUMBIA

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SUMMARY

A study to quantify and assess the characteristics of wildlife trees and coarse woody debris in the Dawson Creek Forest District was initiated in 1993. The purpose of the study was to establish baseline data on the abundance, wildlife use, and management of wildlife trees and coarse woody debris in the mixed-wood boreal forests of northeastern British Columbia. The study established random sampling plots in aspen and mixed-wood forest stands in several successional stages ranging from mature forests to recently cut areas. Plots were also established around active woodpecker nest trees for comparative analysis with the random sampling plots. Trees within each plot were assessed for wildlife tree characteristics using standardized criteria. Characteristics and data were gathered for downed woody material.

To provide forest management recommendations for mature aspen stands, analysis was conducted on various tree characteristics among random, wildlife, and nest trees. Significant differences were found among mean dbhs for all three tree types. Significant differences were also found for height classes between random and wildlife trees, and for wildlife tree snag classes between random and nest trees. Coarse woody debris was compared across mature aspen and mixed-wood stands for differences in volume and clumping distribution. Mixed-wood stands had a considerably larger volume of coarse woody debris than mature aspen stands. Both stand types showed that coarse woody debris was not uniformly clumped at the stand level, but instead, its distribution was a mixture of both random and clumped. Although the number of coarse woody debris pieces per ha was considerably higher in mixed-wood than mature aspen stands, there was no significant difference in the level of clumping between the two areas.

Recommendations for managing wildlife trees and coarse woody debris in mature aspen and mixed-wood stands in northeastern British Columbia include establishing wildlife tree patches in cutblocks across the landscape. Wildlife tree patches should be selected on the basis of the amount and quality of wildlife trees and coarse woody debris that is present in the patch. Wildlife trees, particularly larger, live aspens with visible conks or cankers should be incorporated in wildlife tree patches to maximize wildlife benefits. Coarse woody debris should be left on site after harvesting in a way that mimics the natural distribution of coarse woody debris including randomness, connectivity, some clumping, and layering (i.e., in low-height piles). It should include a variety of piece sizes and decay classes.

Key words: coarse woody debris, management, small mammals, wildlife trees, woodpeckers

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1 INTRODUCTION

The boreal forest occupies 35% of the land mass of Canada. In British Columbia, the mixed-wood boreal forest covers the northeast corner of the province with a diverse mosaic of broadleaf and coniferous stands. Recent human encroachment into these forested areas have in some cases fragmented and changed the landscape dramatically. Disturbance factors have altered wildlife habitat and foraging areas that are important features for maintaining healthy populations of native species.

The effects of harvesting and forest management practices on forest resources such as wildlife trees (WLTs) and coarse woody debris (CWD) have not been examined in the mixed-wood forests of British Columbia. A study to determine the use and availability of WLTs and CWD in the Dawson Creek Forest District occurred between 1993-1998 and collected baseline data on these important forest resources (Darling and Farr 1994; Merkens *et al.* 1995; Booth and Merkens 1996; Merkens and Booth 1997, 1999).

In British Columbia, over 15% of the province's vertebrate fauna, some 90 different species, depend on WLTs for their subsistence (Steeger *et al.* 1996). Generally, WLTs are trees whose health is in decline due to disease, weather, insect infestation, or poor site growing conditions. These trees are characterized by broken limbs, loose bark, growth defects, and fungal attack, all of which provide import habitat and forage for many wildlife species. During the initial phases of decay, WLTs are particularly important for primary cavity nesters such as woodpeckers (Thomas *et al.* 1979; Harestad and Keisker 1989). These species are specialized at excavating the weakened tissue of WLTs to create cavities, which in turn are used by secondary cavity nesters and small- to medium-sized mammals (Machmer and Steeger 1995).

The older the age of a forest the greater the density of WLTs (Basham 1987). Large-scale harvesting in the Dawson Creek Forest District has reduced the amount of mature and old forests and, consequently, affected the number of WLTs that are present. Forestry practices such as juvenile spacing, thinning and short rotational harvest entries do not allow some forest stands to mature to the age at which pre-harvesting levels of WLTs are found.

Coarse woody debris is any downed branch, limb, or trunk of a tree or shrub that is found on the forest floor. Amphibians, reptiles, birds, and small mammals use CWD for shelter and foraging or as travel routes throughout their respective territories (Carter 1993; Lee *et al.* 1995). These species in turn are an important prey source for other forest predators higher in the food chain. Current harvesting practices of clearing and burning slash reduces the amount of CWD that is left on the forest floor. The use of heavy machinery during harvesting and site preparation disturbs and compacts pre-existing CWD and associated wildlife travel corridors and thoroughfares.

Within the last decade, harvest rates for mature aspen stands in the Dawson Creek Forest District have increased dramatically due to new techniques in aspen pulping. Research on WLTs and CWD levels in aspen stands has been particularly sparse. This report collates results from Merkens and Booth (1997), Manning and Chytyk (1997) and Merkens and Booth (1999), all based on data gathered by PAW Research Services on these forest resources in mature aspen and mixed-wood stands within the Dawson Creek Forest District. The report is focused on providing management options for maintaining naturally occurring levels of WLTs and CWD within mature aspen and mixed-wood forests across northeastern British Columbia.

2 STUDY AREA

Sampling plots were located in the mixed-wood boreal forest in the Dawson Creek Forest District of northeastern British Columbia. The forest district has an area of approximately 2.9 million ha and is characterized by gently rolling prairie near the Alberta border, foothills through the Chetwynd and Tumbler Ridge area, and the rugged terrain of the Rocky Mountains west of Chetwynd to Pine Pass. Study sites were located in the Alberta Plateau ecoregion in the Boreal White and Black Spruce Peace moist warm (BWBSmw1) and the Boreal White and Black Spruce Murray wet cool (BWBSwk1) biogeoclimatic variants. Forests consisted of a mosaic of several different stand types that varied in species composition and age class.

Mature aspen sampling plots were located in areas where trembling aspen (*Populus tremuloides*) accounted for 89% of all trees encountered (Merkens and Booth 1997). Small patches of white spruce (*Picea glauca*) were scattered throughout the study sites, while a small component of black cottonwood (*Populus balsamifera balsamifera*) was found in the main canopy, and paper birch (*Betula papyrifera*) occurred sporadically in the understory. Smaller white spruce and lodgepole pine (*Pinus contorta latifolia*) were also found intermittently below the forest canopy. Mixed-wood stands had upper canopies of evenly mixed spruce and aspen, with birch and cottonwood making up small proportions of the total canopy. Mixed-wood understories were similar to that of the mature aspen stands in structure and species composition.

The age of the mature stands ranged between 60-100 years and had uniform canopies that were 20-25 m high with dense understories that were <2 m high. The terrain was flat to gently rolling, with small low-lying areas that were generally wetter. At a landscape level, aspens were dominant and interspersed with varying patches of spruce. In boggy, wet areas, black spruce (*P. mariana*) was found, while on higher, dry sites, lodgepole pine dominated.

3 METHODS

3.1 Sampling Design

Sampling plots were established on both new and pre-existing survey transects. One series of sampling plots spaced ≥ 160 m apart was located along bird surveying transects that were established in previous studies of mature aspen and mixed-wood stands (Darling and Farr 1994; Darling 1995; Booth 1996; Booth and Merkens 1996). Another set of sampling plots in mature and regenerating aspen stands was located along different pre-existing study transects, and plots were spaced ≥ 30 m apart (Lance and Phinney 1995). A third set of random plots in mature aspen and mixed-wood stands was established in 1996 throughout the forest district. A fourth set of sampling points for assessing small mammal use of woody debris in mature and recently cut aspen and mixed-wood was established in 1997 (Merkens and Booth 1999).

3.2 Wildlife Tree Sampling

Wildlife trees were assessed in 98 random plots in mature aspen stands, 50 new-cut aspen cutblocks, 24 shrub-stage regenerating aspen stands, 16 pole-sapling-stage regenerating aspen stands, and 50 plots in mature mixed-wood stands. Wildlife trees were also described in 20 plots at natural and man-made edges in the mature aspen forest and in 20 plots in retention patches in harvested cutblocks.

Sampling plots were circular with a 5.6-m radius (100 m^2). All trees ≥ 7.5 cm diameter at breast height (dbh) that exhibited any WLT characteristics (Appendix 1) were documented and evaluated using standardized data sheets. Existing WLT classification criteria (Guy and Manning 1995) were used initially to describe WLTs in the study area. However, these classifications had to be modified to incorporate the unique stand structure and characteristics found in aspen stands. Current WLT classification for British Columbia is found in the *Field Manual for Describing Terrestrial Ecosystems* (MELP and MOF 1998).

All non-wildlife trees within the sampling plots were tallied, identified to species, and measured for height and dbh. Data were collected over three field seasons: 1993, 1995, and 1996.

3.3 Nest Tree Sampling

Forty-eight sampling plots were established around known nest trees of Yellow-bellied Sapsucker (*Sphyrapicus varius*) and Hairy Woodpecker (*Picoides villosus*). Wildlife tree plots were centered on the nest tree; all WLTs and healthy trees were assessed according to the criteria outlined in Appendix 1. All nest trees exhibited WLT characteristics; however, for simplicity of analyses, no nest trees were defined as WLTs or included in the WLT tally.

3.4 Coarse Woody Debris Sampling

Sampling plot centres used for WLT sampling were also used for CWD sampling. Sixty-eight plots were assessed in mature aspen and 48 in mature mixed-wood stands. An equilateral triangle with sides of 30 m was centered around each plot centre (Lofroth 1992). Random compass bearings were used to align one side of the triangle from the plot centre. Data were recorded in nine 10-m segments per triangle. Coarse woody debris characteristics (Appendix 2) were recorded for all downed woody material ≥5 cm in diameter that intersected the 90-m transect. Current CWD classification for British Columbia is found in the *Field Manual for Describing Terrestrial Ecosystems* (MELP and MOF 1998).

3.4.1 Small mammal use of coarse woody debris

In the fall of 1998, a study was conducted in mature and regenerating aspen and mixed-wood stands to determine the use of woody debris by small mammals (Merkens and Booth 1999). Animals were captured in two mature aspen stands, two regenerating stands (two and four years old), two mature mixed-wood stands, and two regenerating mixed-wood stands (both four years old). Sixty-six Red-backed Voles (*Clethrinomys* *gapperi*) were selected from all captures to assess CWD use (n = 16, 17, 18 and 15 animals in the four stand types, respectively). Characteristics of CWD (piece length [m] in addition to variables in Appendix 2) in these sites were recorded on four 30-m linear transects per site and compared among site types. Six Deer Mice (*Peromyscus maniculatus*) were marked and tracked in a pilot study in mature aspen stands the previous fall (Merkens and Booth 1997).

Fluorescent pigment was used to track small mammal movements through CWD as described by Lemen and Freeman (1985) and subsequent authors (*e.g.,* Barnum *et al.* 1992; Carter 1993). Captured voles were placed in a plastic bag containing pink or green fluorescent pigment. Animals were coated with the pigment by gently shaking the bag and then released at the point of capture at dusk (20:00 hrs or later). After at least 20 minutes post-release, the fluorescent trails were followed using a portable ultraviolet light source and marked with plastic "snow flags." If necessary, notes regarding the behaviour of the vole were written on individual flags at the location where the behaviour was observed.

Release sites were revisited during subsequent days to collect data on the marked trails. Each trail was divided into segments based on whether the vole was traveling along CWD or not. The length of each segment was measured to the nearest cm and the behaviour of the vole in relation to the CWD was noted. Behaviours included: "cross over," "cross under," "follow on," "follow under," and "follow beside." Each CWD piece that was used by an animal was measured and described for standard CWD characteristics (see Appendix 2).

To examine CWD use in relation to its availability, a comparison was made between the use of CWD by each animal and the amount of CWD the animal would have encountered if it had traveled in a straight line. The linear distance between the release point and the end of the fluorescent trail was measured. If the path of the vole was not particularly linear (*e.g.,* if the animal traveled in a circle or changed direction frequently), several linear transects covering the traveled area were measured. The length of each linear transect that was intercepted by CWD was measured, and the travel behaviour of the vole that was associated with the encountered CWD was recorded for comparison with fluorescent trails.

3.5 Data Analysis

3.5.1 Wildlife tree analysis

Wildlife tree data from mature aspen plots were pooled for analysis. Three tree types – random, wildlife, and nest trees – were compared using one-way analysis of variance (ANOVA) for determining significant differences in dbh, height, and snag classes (Parker 1979). Tukey's Honestly Significant Difference (Tukey's HSD) tests were conducted for dbh analysis for the three tree types, while a non-parametric Friedman's Rank Order multiple comparison test was used to analyze height and snag classes due to their skewed distributions (Zar 1974; Siegel and Castellan 1988).

For descriptive purposes the means of stems/ha were calculated and plotted for WLT characteristics for mature aspen stands. Characteristics – including dbh, heartwood soundness, height, and snag classes – were plotted for both random and nest tree plots. Other tree characteristics such as the presence of conks, heartwood soundness, dbh, height, and snag and trunk classes were graphed for nest trees (n=48).

3.5.2 Coarse woody debris analysis

Volume of CWD in the mature aspen and mixed-wood stands was calculated for all downed woody debris with a diameter ≥5 cm. Volume of CWD in m^3/ha was calculated using the following formula (Lofroth 1992):

$$V = \frac{\pi^2 \Sigma d^2}{8L}$$

Where: V = volume of CWD in m^3/ha
d = diameter of each CWD piece in cm
L = length of CWD transect in metres

For descriptive purposes, volumes of CWD were calculated and plotted by diameter and decay class for mature aspen and mixed-wood stands. Pieces of CWD per hectare were tabulated for mature aspen and mixed-wood stands and were also plotted by diameter and decay class.

Clumping of woody debris across the forest floor was analysed by tallying the number of pieces of debris per 10-m segment of each 90-m transect, ranking the tallies, and comparing them to median values. In this report, the term clumping can be understood as "loosely arranged concentrations of CWD, as opposed to CWD pieces randomly spread across the forest floor." Samples from mature aspen stands (531 segments) and mixed-wood stands (432 segments) were assessed

Table 1. Aspen and aspen WLT densities among different tree characteristics for random vs. nest tree plots in mature aspen stands in the Dawson Creek Forest District.

	Random Plots		Nest Tree Plots	
Tree Characteristics	total aspen stems/ha	aspen WLTs stems/ha	total aspen stems/ha	aspen WLTs stems/ha
total trees	1031	537	886	438
snag class <1[a]	803	309	729	281
snag class ≥1[b]	228	228	157	157
height class >2[c]	880	406	752	342
heartwood soundness >0[d]	196	194	163	163
dbh (in cm)	20.5	18.8	24.1	22.5

[a] – live tree; [b] – dead tree; [c] – >10 m tall; [d] – advanced heartwood decay present.

within respective forest types using the non-parametric Kruskal-Wallis test (Siegal and Castellan 1988). Differences between the two forest types were tested using the Mann-Whitney U test (Zar 1974, Siegel and Castellan 1988). Concurrently, the 10-m segments were analysed by "study block" (a previously defined sampling unit in a related wildlife diversity study [Merkens and Booth 1998] and additional geographically distinct locations): for a total of 17 mature aspen study blocks and nine mixed-wood study blocks. Where more than two 90-m triangular transects had been sampled per study block, the Kruskal-Wallis test was used to assess clumping. Where only two transects were sampled per block, a non-parametric Mann-Whitney U test was used because there was only one degree of freedom.

4 RESULTS

Results of analyses of stand characteristics and composition data for recently cut and mature aspen and mixed-wood forests of the Dawson Creek Forest District are referenced in the following sections; details are found in Merkens *et al.* (1995) and Merkens and Booth (1997, 1999). Otherwise, results are from analyses conducted under the direction of the primary authors.

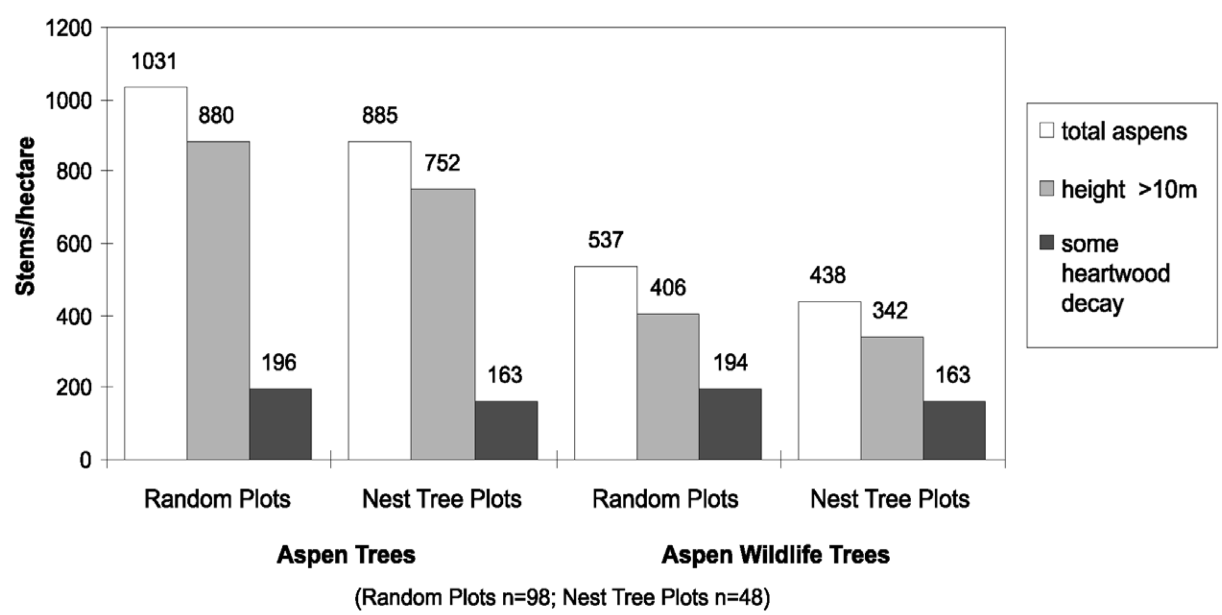

Figure 1. Height class and heartwood soundness of aspen trees and aspen wildlife trees in random and nest tree plots in mature aspen stands in the Dawson Creek Forest District.

4.1 Aspen Wildlife Trees – Mature Aspen Stands

4.1.1 Stand characteristics in random vs. nest tree plots

Nest tree plots were generally more open and had larger-diameter aspen trees than random plots. Density of aspens in nest plots was lower, at 885 stem/ha, than in random plots, with 1031 stems/ha (Table 1, Figure 1). The mean dbh for aspen was greater in nest plots at 24.1 cm than in random plots at 20.5 cm (Figure 2). Tree height was evenly distributed, with 85% of all aspens being >10 m (height class >2) in both random and nest plots (Figure 1).

In both plot types the majority of aspens were live trees (snag class <1): 78% in random plots and 82% in nest plots (Figure 3). Aspens that showed progressed signs of decay that could provide good forage for primary cavity nesters (snag class >3) were found evenly throughout random and nest plots, at 11% and 8% respectively. Dead aspens accounted for 228 stems/ha in random plots and 157 stems/ha in nest plots. Eighty-six percent of the dead aspens showed signs of advanced heartwood decay (heartwood soundness >0) in the random plots, while in the nest plots 100% had advanced heartwood decay.

4.1.2 Aspen WLT characteristics in random vs. nest tree plots

Generally, nest plots had larger-diameter WLTs than random aspen forest plots, but overall proportions of WLTs were equal among the two different plots. Nest plots had larger-diameter aspen WLTs (mean of 22.5 cm dbh) than random plots (mean of 18.8 cm dbh) (Figure 2). Wildlife trees that were >10 m (height class >2) appeared to be equal among random and nest plots accounting for 76% and 78% respectively of all aspen WLTs.

Approximately 52% of all randomly sampled aspens, or 537 stems/ha, exhibited WLT characteristics; nest plots were similar at 49%, or 438 stems/ha (Table 1, Figure 1). Merkens and Booth (1997) reported that although < 1% of aspen stems in mature aspen stands had visible external signs of heartwood decay *(i.e., Phellinus tremulae* conks), 20% of the stems on random plots and 25% of stems in nest tree plots had some level of heartwood decay. The density of stems exhibiting conks in mature aspen stands was significantly greater than in the pole sapling stage of regeneration ($t = -2.68$, 112 df, $P < 0.05$; Merkens and Booth 1997).[1] Aspen trees in the mixed-wood forest exhibited substantially lower levels of bird feeding

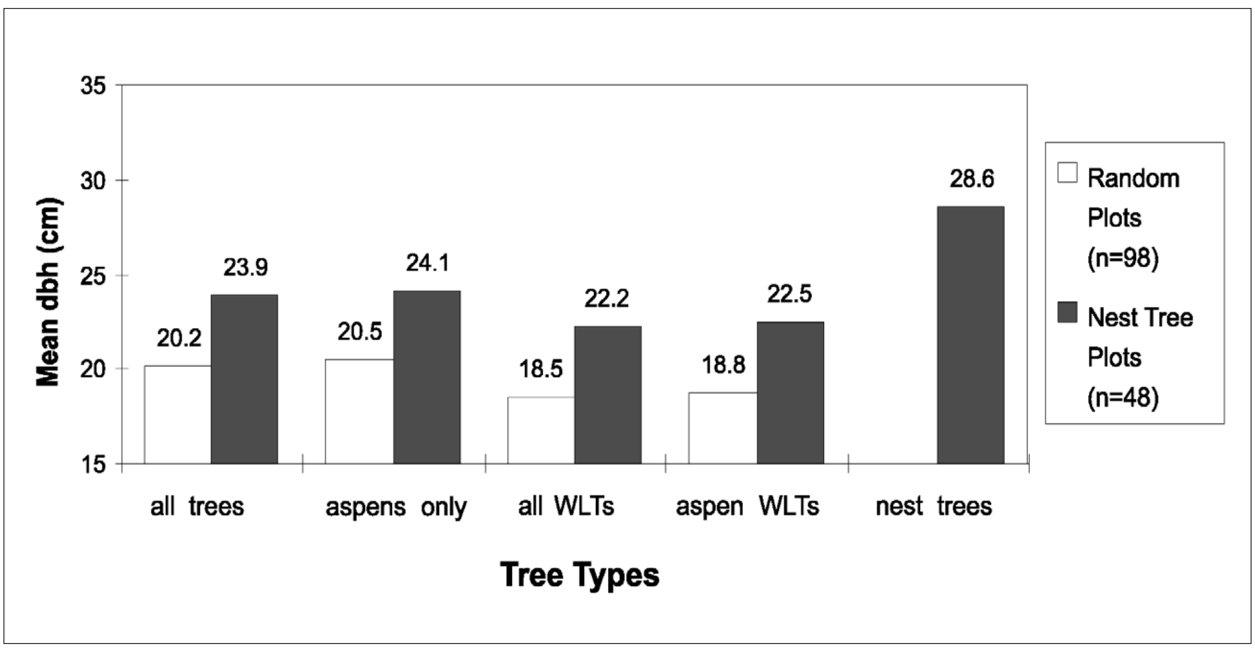

Figure 2. Mean dbh of aspen trees and aspen wildlife trees in random and nest tree plots in mature aspen stands in the Dawson Creek Forest District.

[1] Merkens and Booth (1997) found that the density of trees exhibiting conks and wounds was significantly affected by edge class. The density of aspen exhibiting *P. tremulae* conks was higher at old man-made edges than at new edges and mature forest, but was no higher than at natural edges (ANOVA $F = 4.92$, df = 3, 76; $P < 0.01$ and Tukey's HSD).

Table 2. Principal tree characteristics (dbh, height and snag class) of random, wildlife and nest trees in mature aspen stands in the Dawson Creek Forest District.

Tree Characteristics	n	Min	Max	Median	Mean	SE	sig. diff. with*
dbh (cm)							
Random Trees	1031	7	53	20	20.5	7.5	wildlife, nest
Wildlife Trees	537	7.5	51	18	18.8	7.5	random, nest
Nest Trees	48	18.5	43	28	28.7	4.7	random, wildlife
Height Class (classes 1-4)							
Random Trees	1031	1	4	3	2.8	0.5	wildlife
Wildlife Trees	537	1	4	3	2.8	0.6	random
Nest Trees	48	1	4	3	3.0	0.4	none
Snag Class (classes 0-6)							
Random Trees	1031	0	6	0	0.7	1.6	wildlife
Wildlife Trees	537	0	6	0	1.4	2	random, nest
Nest Trees	48	0	5	0	0.2	0.9	wildlife

* see Tables 3-5 for *P*-values measuring significant differences (sig. diff.) α=.05

sign and insect infestation that characterized coniferous WLTs (Merkens and Booth 1997).

Merkens and Booth (1997) reported that in aspen forests the number of stems exhibiting wounds (from mechanical damage such as falling trees or machinery) and bark scraping by wildlife was significantly greater in the random plots than in nest tree plots (wounds t = -2.98, df = 143, $P < 0.01$; scraping t = -2.86, df = 143, $P < 0.01$). They also found that the density of stems with cavities (other than the nest tree cavity) was greater in nest tree plots than in random plots (t = 5.45, df = 143, $P < 0.01$).

The majority of aspen WLTs in aspen forests were live trees (snag class =0): 58% in random plots and 64% in nest plots (Figure 3). Aspen WLTs that showed progressed signs of decay (snag class >3) were more abundant in random plots (42%) than in nest plots (36%). Advanced signs of heartwood decay (heartwood soundness >0) in aspen WLTs were present in 194 stems/ha in random plots and 163 stems/ha in nest plots (Table 1, Figure 1).

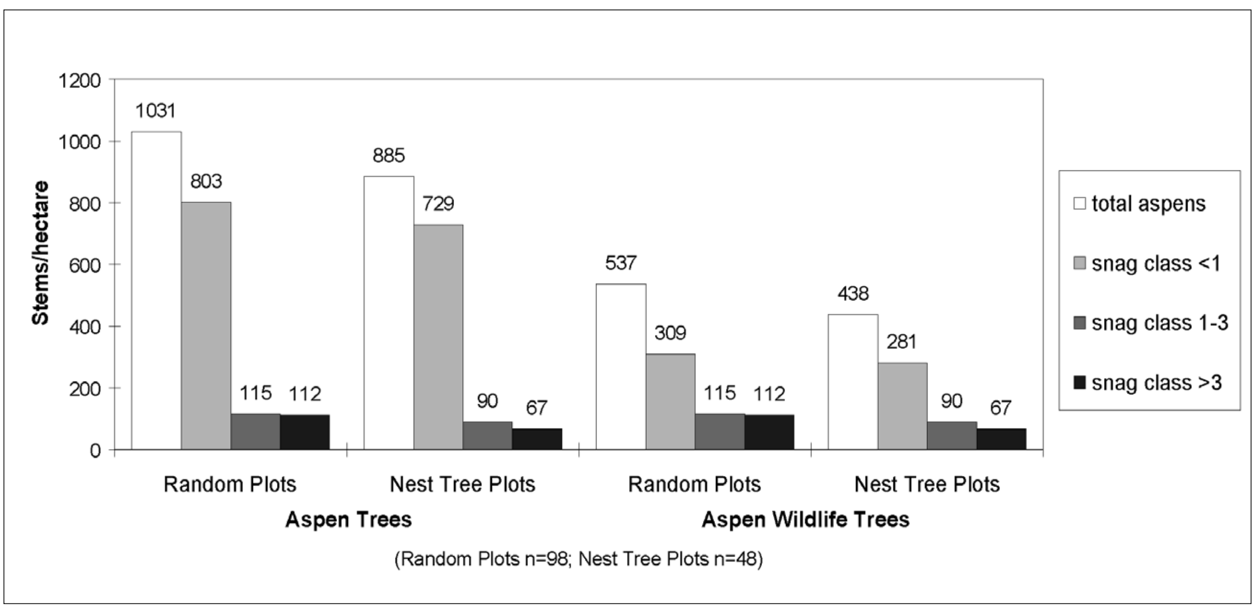

Figure 3. Snag classes of aspen trees and aspen wildlife trees in random and nest tree plots in mature aspen stands in the Dawson Creek Forest District.

Table 3. ANOVA table for dbh, height, and snag classes in random, wildlife, and nest trees in mature aspen stands in the Dawson Creek Forest District.

Tree Characteristics	tree type MSS	error MSS	F	df	*P*
dbh	2291.3	55.08	41.60	2,1613	<0.01
Height Class	2.30	0.29	7.97	2,1613	<0.01
Snag Class	82.21	2.90	30.74	2,1613	<0.01

Table 4. Tukey's HSD table for dbh comparison among random, wildlife, and nest trees in mature aspen stands in the Dawson Creek Forest District.

dbh Comparison	difference of means	SE	Q critical*	Q	df	*P*
Random vs. Wildlife	-1.7	0.28	5.21	6.07	120	<0.01
Random vs. Nest	8.2	0.78	5.21	10.51	120	<0.01
Wildlife vs. Nest	9.9	0.79	5.21	12.53	120	<0.01

*α=.05

4.1.3 Nest tree characteristics

Forty-eight active woodpecker nest trees were located in the study area: 43 Yellow-bellied Sapsucker, three Hairy Woodpecker and two Downy Woodpecker. All nests were in aspen trees except for one Downy Woodpecker nest in a Cottonwood tree.

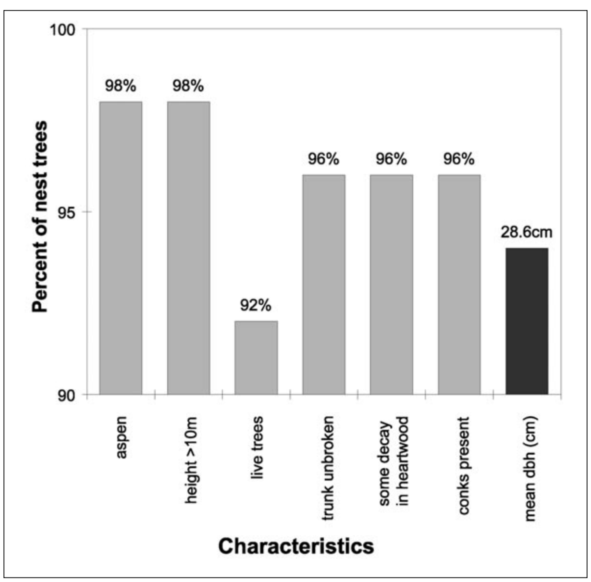

Figure 4. Nest tree characteristics of 48 active woodpecker nest trees in mature aspen stands in the Dawson Creek Forest District.

Nest trees were generally larger, live aspens. Ninety-eight percent of the nest trees were aspens that had a height class >2 (>10 m tall)(Figure 4). Nest trees had a significantly larger (t=7.65, 1164df, P<0.05) mean dbh (28.6 cm) than random aspen trees (20.5 cm) (see Figure 2; and Merkens and Booth 1997). Nests were built in live trees; 92% of nest trees had a snag class =0 (live, green cambium tree). Ninety-six percent of all nest trees had fungal conks present and some level of heartwood decay (heartwood soundness >0). Broken tops (trunk class >1) were an uncommon characteristic of nest trees, with only 4% exhibiting this feature.

4.1.4 Characteristics of random vs. wildlife vs. nest trees

Three principal tree characteristics (dbh, height, and snag class) were analyzed for three tree types: random, wildlife, and nest trees.

1) dbh

Mean dbh values varied considerably between the three tree types, ranging from 18.8 cm for WLTs to 28.7 cm for nest trees (Table 2). ANOVA showed that mean dbh values were significantly different (F=41.6, 2,1613df, P<0.01) among the three tree types (Table 3). Further analysis using Tukey's HSD test showed that there were significant differences (Q=6.07, 3,120df, P< 0.01) between each tree type (Table 4).

Table 5. Friedman's Rank Order table of height and snag classes among random, wildlife, and nest trees in mature aspen stands in the Dawson Creek Forest District.

	Difference of Means			
Tree Characteristics	value	critical*	n	*P*
Height Class (classes 1-4)				
Random vs. Wildlife	58.8	58.52	1568	0.05
Random vs. Nest	98.6	159.4	1079	0.42
Wildlife vs. Nest	157.4	166.3	585	0.07
Snag Class (classes 0-6)				
Random vs. Wildlife	153.9	58.52	1568	<0.01
Random vs. Nest	103.6	159.4	1079	0.36
Wildlife vs. Nest	257.5	166.3	585	<0.01

*α=.05

Table 6. Volume, pieces/ha and species composition (by pieces/ha) of CWD for mature aspen and mixed-wood stands in the Dawson Creek Forest District.

Stand Type	volume (m^3/ha)	pieces/ha	% aspen	% spruce	% other sp.
Mature Aspen	40.9	2484	81%	3%	16%
Mixed-wood	139.6	3150	34%	61%	5%
Average	**90.3**	**2817**	**58%**	**32%**	**10%**

2) Height Class

Height classes were measured using discrete values, and therefore statistical analysis was not as sensitive in determining differences as with dbh analysis. Mean height classes ranged between 2.8 and 3.0; ANOVA showed there were significant differences (F=7.97, 2,1613df, *P*<0.01) among the three tree types (Table 3). A non-parametric Friedman's Rank Order test determined there was a significant difference (difference of means=58.8, n=1568, *P*=0.05) between random and WLTs (Table 5).

3) Snag Class

Snag classes were also measured using discrete values, and therefore a less sensitive non-parametric test was used in the analysis. ANOVA showed that there were significant differences (F=30.7, 2,1613df, *P*<0.01) among the three tree types (Table 3). Friedman's Rank Order test demonstrated that there were significant differences between random trees and WLTs (difference of means=153.9, n=1568, *P*<0.01) and between wildlife and nest trees (difference of means=257.5, n=585, *P*<0.01) (Table 5).

4.2 Coarse Woody Debris – Mature Aspen and Mixed-wood Stands

In general, volume of CWD was much higher in mixed-wood stands than in mature aspen stands. Volume in mature aspen areas averaged 40.9m^3/ha, while in mixed-wood stands the average volume was 139.6 m^3/ha (Table 6). Mean pieces of debris per hectare for mixed-wood stands was also considerably higher at 3150 pieces/ha compared to 2484 pieces/ha for mature aspen stands. Species composition of CWD was over 80% aspen in mature aspen stands, while in mixed-wood stands spruce was dominant at 61%, with aspen accounting for 34%.

4.2.1 CWD – mature aspen stands

Volume of CWD in mature aspen stands appeared to be normally distributed by decay class (Figure 5). Decay classes 2 and 3 (varying degrees of decay, but heartwood still hard) accounted for 71% of the CWD volume (Table 7). The distribution of CWD volume by diameter class was slightly skewed towards smaller-diameter classes (Figure 6); 58% of all CWD volume had a diameter ≤ 15 cm (diameter classes 1 and 2).

Table 7. Volume and percent of volume of CWD distributed by decay and diameter classes for mature aspen stands in the Dawson Creek Forest District. Class codes in Appendix 2.

	Decay Class		Diameter Class	
Class	m^3/ha	%	m^3/ha	%
1	2.16	5	10.41	26
2	14.90	37	13.22	32
3	13.88	34	8.14	20
4	5.80	14	9.14	22
5	4.17	10	N.D.*	N.D.*
Total	**40.91**	**100**	**40.91**	**100**

*No diameter class 5 data were collected in mature aspen stands.

Table 8. Pieces/ha and percent of pieces of CWD distributed by decay and diameter classes in mature aspen stands in the Dawson Creek Forest District. Class codes in Appendix 2.

	Decay Class		Diameter Class	
Class	pieces/ha	%	pieces/ha	%
1	72	3	1379	56
2	1009	40	721	29
3	869	35	284	11
4	391	16	100	4
5	143	6	N.D.*	N.D.*
Total	**2484**	**100**	**2484**	**100**

*No diameter class 5 data were collected in mature aspen stands.

The number of CWD pieces/ha in mature aspen stands appeared to be normally distributed by decay classes (Figure 7). Decay classes 2 and 3 (varying degrees of decay, but heartwood still hard) accounted for 75% of all CWD pieces (Table 8). CWD was heavily skewed towards smaller-diameter classes (Figure 8); 87% of all CWD pieces had a diameter ≤ 15 cm (diameter classes 1 and 2).

In mature aspen stands, CWD pieces/10-m segment ranged from 0 to 20 pieces/segment and had a mean of 3.31 pieces/segment (Table 9). Dispersal of CWD across the forest floor was analyzed for any clumping distribution. A non-parametric Kruskal-Wallis test showed there was significant CWD clumping (KW=193.7, 58df, $P<0.01$) when segments were pooled across the entire study area (Table 10). However, when the data were analysed at the level of 17 geographically distinct mature aspen blocks, only five blocks showed significant clumping ($P<0.01$; various Kruskal-Wallis and Mann-Whitney U tests – see Appendix 3).

4.2.2 CWD – mature mixed-wood stands

Volume of CWD in mixed-wood stands appeared to be normally distributed by decay class, except for a large volume of CWD in decay class 5 (mushy, pulp CWD) which was mainly spruce (Figure 9). Diameter class distribution for CWD volume was heavily skewed towards the larger-diameter classes (Figure 10), represented mostly by spruce CWD. Sixty percent of all CWD volume in mixed-wood stands was found in diameter class 4 (20-50 cm) and was mainly spruce (Table 11).

The number of CWD pieces/ha in mixed-wood stands appeared to be normally distributed by decay classes, with a greater number of large pieces than small

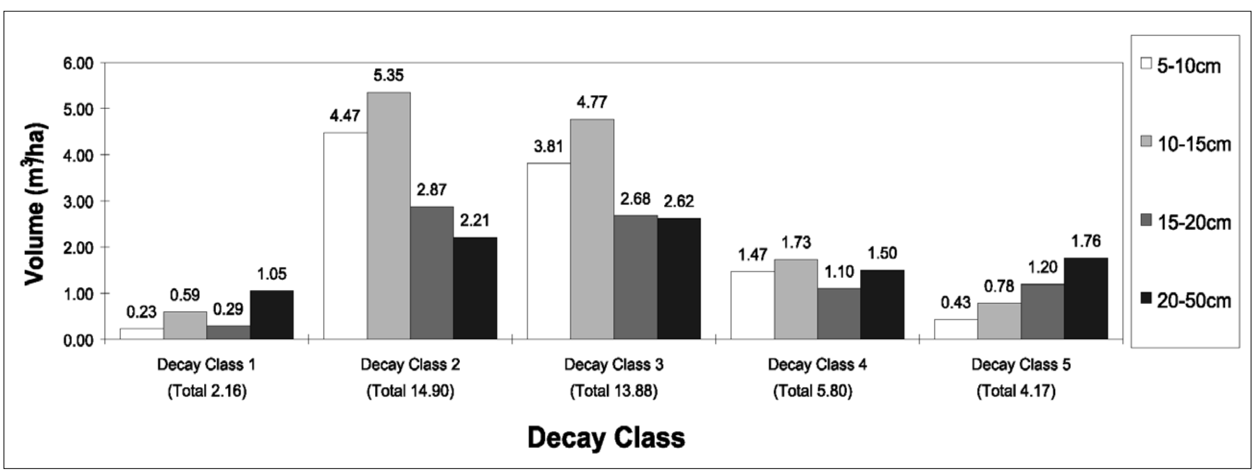

Figure 5. CWD volume by decay class in mature aspen stands in the Dawson Creek Forest District.

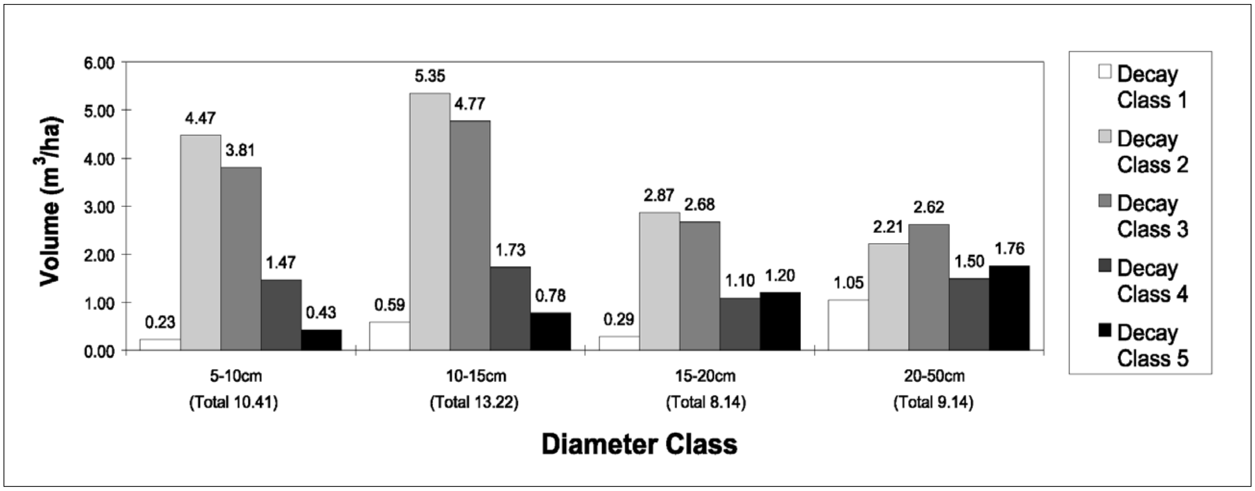

Figure 6. CWD volume by diameter class in mature aspen stands in the Dawson Creek Forest District.

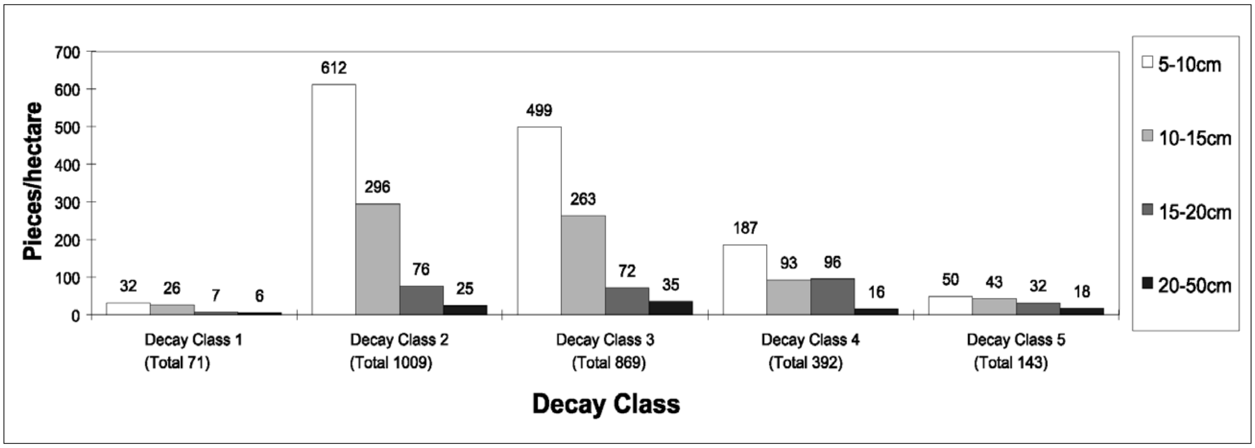

Figure 7. CWD pieces/hectare by decay class in mature aspen stands in the Dawson Creek Forest District.

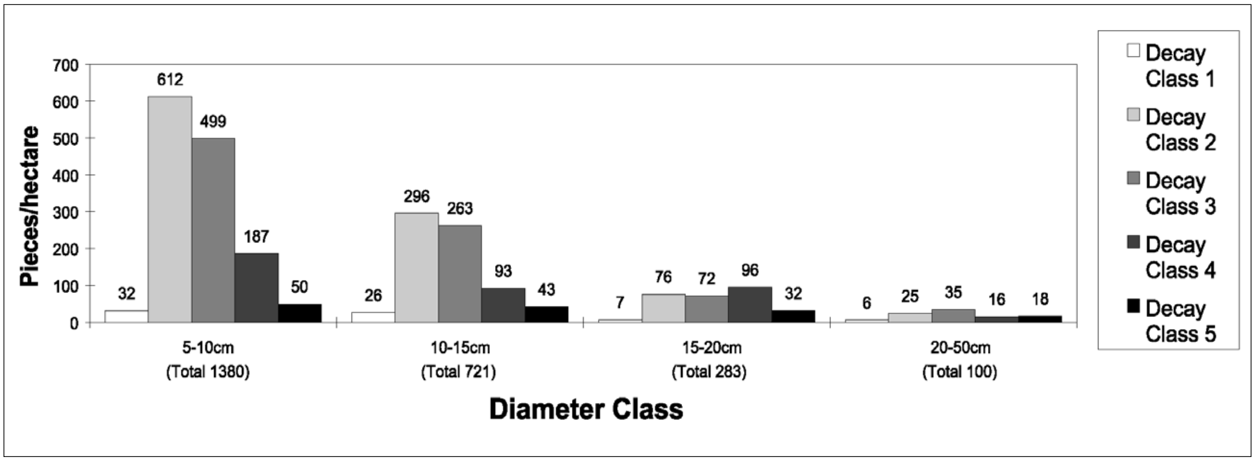

Figure 8. CWD pieces/hectare by diameter class in mature aspen stands in the Dawson Creek Forest District.

Table 9. CWD pieces/10-m segment in mature aspen and mixed-wood stands in the Dawson Creek Forest District.

CWD pieces/ 10-m segment	n[a]	Min	Max	Median	Mean	SE	pieces/100 m
Mature aspen	531	0	20	3	3.31	0.11	33
Mixed-woo d	432	0	15	3	3.61	0.13	36

[a] number of 10-m segments

Table 10. Kruskal-Wallis table for the presence of CWD clumping in mature aspen and mixed-wood stands in the Dawson Creek Forest District.

CWD clumping	n[a]	KW_{value}	Chi Square critical[b]	df	*P*
mature aspen	531	193.7	83.3	58	<0.01
mixed-wood	432	195.7	71.4	47	<0.01

[a] number of 10-m segments; [b] α=.05

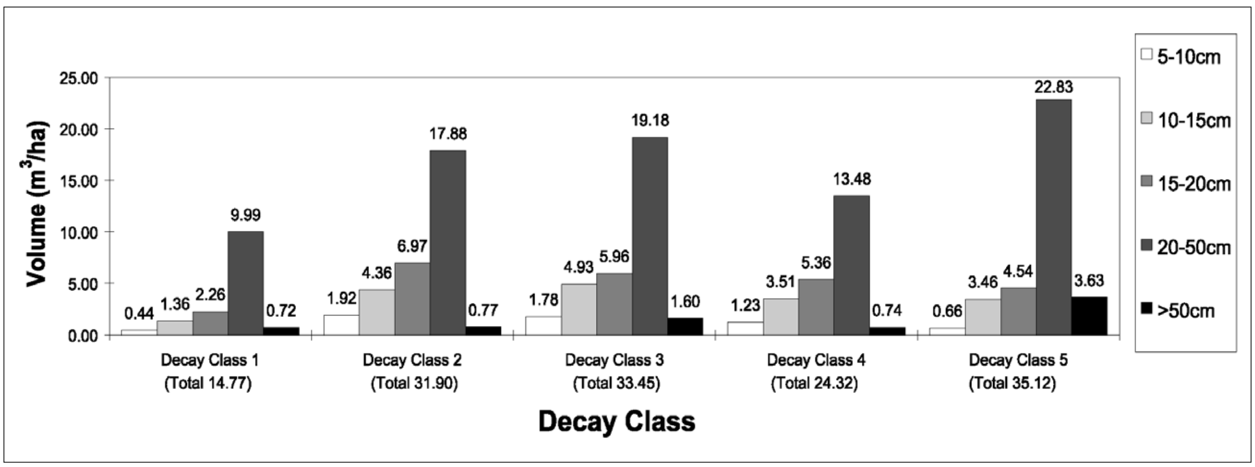

Figure 9. CWD volume by decay class in mature mixed-wood stands in the Dawson Creek Forest District.

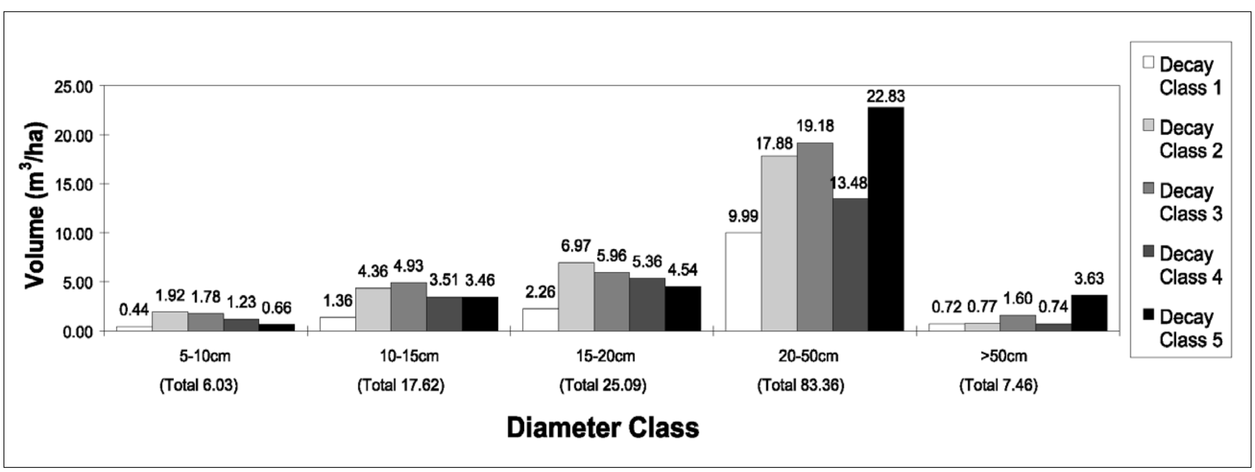

Figure 10. CWD volume by diameter class in mature mixed-wood stands in the Dawson Creek Forest District.

Table 11. Volume and percent of volume of CWD distributed by decay and diameter classes in mature mixed-wood stands in the Dawson Creek Forest District. Class codes in Appendix 2.

	Decay Class		Diameter Class	
Class	m^3/ha	%	m^3/ha	%
1	14.77	11	6.03	4
2	31.90	23	17.62	13
3	33.45	24	25.09	18
4	24.32	17	83.36	60
5	35.12	25	7.46	5
Total	**139.56**	**100**	**139.56**	**100**

Table 12. Pieces/ha and percent of pieces of CWD distributed by decay and diameter classes in mature mixed-wood stands in the Dawson Creek Forest District.

	Decay Class		Diameter Class	
Class	pieces/ha	%	pieces/ha	%
1	283	9	742	24
2	846	27	892	28
3	833	26	635	20
4	602	19	863	27
5	585	19	19	1
Total	**3150**	**100**	**3150**	**100**

(Figure 11). Decay classes 2 and 3 (varying degrees of decay, but heartwood still hard) accounted for 53% of all CWD pieces (Table 12). Coarse woody debris pieces by diameter class were evenly distributed across all classes except for class 5 (diameter >50 cm) (Figure 12).

In mixed-wood stands, CWD pieces/10 m sample segment ranged from 0 to 15 pieces/segment and had a mean of 3.61 pieces/segment (Table 9). Dispersal of CWD across the forest floor was analyzed for any clumping distribution. A non-parametric Kruskal-Wallis test showed there was significant CWD clumping (KW=195.7, 47df, P<0.01) when sample segments were pooled across the entire study area (Table 10). However, when the data were analysed at the level of nine geographically distinct mature mixed-wood blocks, only four blocks showed significant clumping (P<0.01; various Kruskal-Wallis and Mann-Whitney U tests – see Appendix 3).

Generally, mixed-wood stands had more pieces and greater volume of CWD than did mature aspen stands. However, when data was pooled across both study areas a non-parametric Mann-Whitney U test showed that there was no significant difference (Chi^2=3.84, 1df, P=0.12) between the amount of CWD clumping in mature aspen and mixed-wood stands (Table 13).

4.2.3 CWD – mature vs. regenerating stands

Merkens and Booth (1999) described woody debris at sites where small mammals were marked with fluorescent powder. They found that volumes of debris in recently cut sites were up to three times greater in mixed-wood sites than in aspen sites. Average piece lengths of CWD in recently cut aspen and mixed-wood sites were significantly shorter than in mature aspen and mixed-wood sites. Recently cut aspen and mixed-wood sites also had a smaller diversity of piece lengths (where over 50% and 38%, respectively, were ≤1 m in length) compared to mature aspen and mixed-wood stands (15% and 2%, respectively, were ≤1 m in length). Average diameter of CWD pieces was not significantly different between cut (11.0 cm) and mature (10.4 cm) aspen sites; however, there was a significant difference between diameter in cut (14.0 cm) and mature (15.7 cm) mixed-wood sites. In general, most CWD pieces in mature and cut aspen and mixed-wood sites were relatively small in diameter (<20 cm). Average decay class did not differ between cut and mature aspen or mixed-wood sites. Layering of CWD pieces was more prevalent in mature sites than in recently cut sites.

Amount and characteristics of CWD were compared among mature, recently cut, shrub, and pole sapling stages of regenerating aspen (Merkens and Booth 1997). The volume of CWD varied significantly among the stand ages, with an increase following harvest and substantial decreases by the pole sapling stage. Diameter, decay class, height off the ground, amount of layering, and bark remaining were similar among the stand ages.

4.2.4 Small mammal use of CWD

Merkens and Booth (1997, 1999) examined the use of woody debris by small mammals. They found that Red-backed Voles and Deer Mice selected travel routes that were in close association with CWD. In mature and cut aspen and mixed-wood sites, 47.1% ±

Table 13. Mann-Whitney U table comparing the amount of CWD clumping between mature aspen and mixed-wood stands in the Dawson Creek Forest District.

amount of CWD clumping	rank-sum approximations			Chi Square			
	aspen	mixed	U-value	n[a]	critical[b]	value	*P*
mature aspen vs. mixed-wood	249315	214851	108069	963	2.45	3.84	0.12

[a] – number of 10-m segments; [b] – α=.05

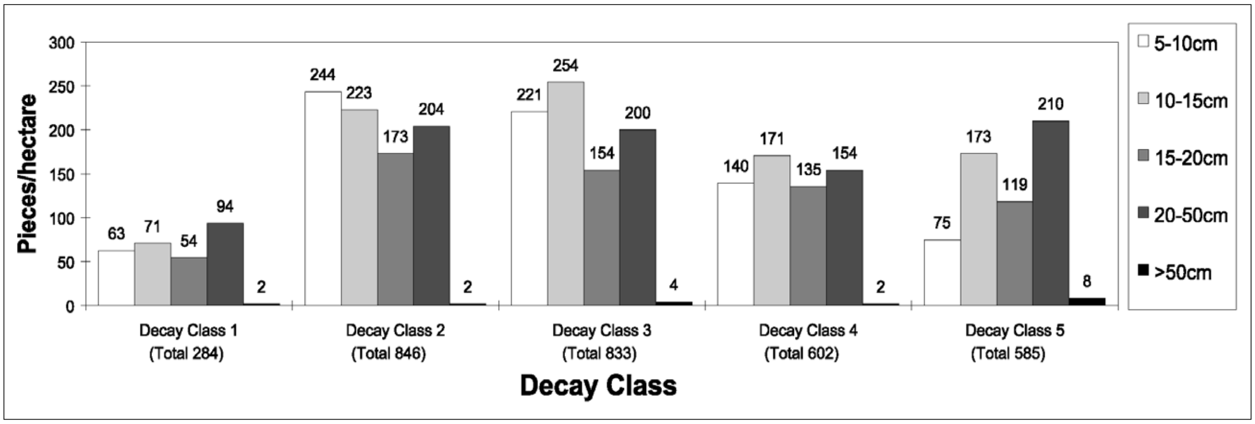

Figure 11. CWD pieces/hectare by decay class in mature mixed-wood stands in the Dawson Creek Forest District.

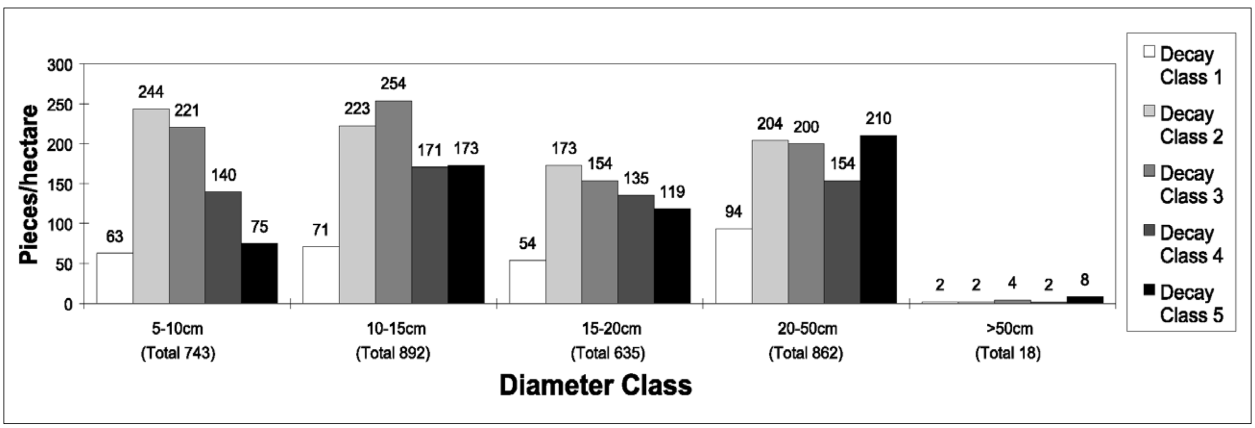

Figure 12. Comparison of CWD pieces/hectare by diameter class in mature mixed-wood stands in the Dawson Creek Forest District.

3.5% of the distance traveled by voles was associated with CWD. The distance traveled along CWD by voles was 7.3 ± 1.4 times higher than would be expected relative to its availability in all habitat types. Voles followed CWD pieces more often than they crossed them and, generally, traveled on or under the CWD piece rather than beside it. Voles preferred to travel on top of smaller diameter CWD pieces (≤10 cm); no consistent travel preference was detected for other diameter classes. Mice traveled exclusively on the top of debris and tended to cross over rather than under it; even small pieces (< 5 cm diameter) were used as travel routes. Voles also typically traveled on the top of CWD pieces that were on the ground. The higher the CWD piece was off the ground, the more often voles would travel on or under the debris piece rather than beside it. Red-backed Voles preferred to transfer or move to another piece of CWD rather than travel along the ground. When debris was layered in an area, voles did not transfer from CWD to the ground, but instead, transferred from one piece of debris to another. Voles did not select for any particular CWD characteristic along travel routes; instead CWD pieces that were traveled on appeared to be selected for their adjacency and closeness to the previous piece of debris. Deer Mice appeared to select routes along larger-diameter pieces and greater wood volume. Layering of debris and long debris lengths provided continuous debris routes. (For further discussion see Merkens and Booth 1999).

5 DISCUSSION

5.1 Aspen Wildlife Trees

In mature aspen stands in the Dawson Creek Forest District, over 50% of all aspen trees were classified as WLTs. This proportion was similar between random and nest plots. However, in nest tree plots the density of WLTs, and all trees in general, were considerably lower than in random plots. Wildlife trees tended to be shorter than random trees; 76% of WLTs and 85% of random trees had a height class >2 (>10 m tall). Random WLTs had mean dbhs that were 1.7 cm smaller than random aspen. In nest plots, mean dbhs of WLTs and aspen were almost 4 cm larger than in random areas.

The lower tree density and larger mean diameters found in nest plots in the Dawson Creek Forest District were probably due to micro-site differences such as higher moisture levels, greater soil fertility, or hardier aspen clones. No analysis was completed on the distribution of WLTs in the Dawson Creek Forest District. However, in central Montana, WLTs had a random and clumped distribution (Lutes 2001). At the stand level, WLTs in Montana had a clumped spatial distribution in 37% of the study plots, a random distribution in 62% of the plots, and a uniform distribution in 1% of the plots.

Initial data seems to show that woodpeckers build their nests in patches of older trees within a forest stand. In the southern Okanagan, 73% of sapsucker nests (n=11) were located in or near old forest patches (Manning and Cooper 1996). Older stands may provide a greater source of insects that are typically found in the decaying wood of WLTs. The lower density of tree stems in older stands may also be important for providing greater visibility and faster detection of predators.

Older tree patches may also provide woodpeckers with a greater selection of suitable nest trees. Primary cavity nesters seem to prefer larger, live trees infected with heart rot (McCallum 1984; Steeger *et al.* 1996) that tend to be more commonly found in older stands. In northeastern British Columbia, nest tree plots had significantly more trees infected with conks, the fruiting body of the pathogen *Phellinus tremulae*, than random plots (Merkens and Booth 1997). Heart rot fungi are important agents in breaking down stem wood to produce suitable nesting substrate for primary cavity nesters (Miller *et al.* 1979; Thomas *et al.* 1979). Consequently, the presence of conks may be a strong indicator of important nesting habitat for woodpecker species.

5.2 Nest Trees Characteristics

In the Dawson Creek Forest District, over 95% of all active woodpecker nests were in aspen trees. In the Okanagan, Manning and Cooper (1996) found that large-diameter aspen were also important as nest trees. In the southern interior of British Columbia, 94% (n=90) of Red-naped Sapsucker (*S. nuchalis*) nests were found in aspens that had a mean dbh of 30.4 cm (Steeger *et al.* 1996). Nest trees in the Dawson Creek Forest District had a mean dbh of 28.6 cm, which was 8 cm larger than and significantly different from random trees in the same area.

In Montane Spruce (MS) and Engelmann Spruce-Subalpine Fir (ESSF) biogeoclimatic zones in southern British Columbia, WLT use by woodpeckers differed according to the size of the tree (Gyug 2000). Four percent of large WLTs (>30 cm dbh) contained nests holes, while only 0.08% of small WLTs (10-29 cm dbh) contained nest holes. Woodpeckers foraged on twice as many large WLTs as small WLTs. In general, larger WLTs tend to stay standing for a longer period than smaller WLTs (Raphael and Morrison 1987; Gyug 2000). In the Sierra Nevada in California, WLTs that were >38 cm dbh declined by 36% during a six-year period, while WLTs ≤38 cm dbh declined by 63% during the same period (Raphael and Morrison 1987).

Ninety-eight percent of nest trees in the Dawson Creek Forest District had a height class >2 (>10 m tall); while 85% of random trees had a height class >2. In the southern interior of British Columbia, sapsuckers chose taller nest trees, with mean heights ranging from 16.9 m (n=30) in one study area to 22.8 m (n=114) for two other study areas (Steeger *et al.* 1996). Nest trees in the Dawson Creek Forest District were generally whole; only 4% had broken tops. All nest trees exhibited WLT characteristics; however, nest trees were generally taller, live trees, while most other WLTs were shorter and dead.

Nest trees tended to be live aspens; 96% of all nest trees had a decay class between 1 and 2 (live, and live with defects). In the southern interior of British Columbia, aspen nest trees were generally decay class 2 (Steeger *et al.* 1996). In the Dawson Creek Forest District, 96% of nest trees had visible external conks of *P. tremulae*. However, in the southern interior, 13% of sapsucker nest trees exhibited visible conks, yet subsequent core sampling determined that 97% of these trees were infected with heart rot (Steeger *et al.* 1996).

Heart rot caused by *P. tremulae* was found only in mature stands (60-100 years) within the Dawson Creek Forest District (Merkens and Booth 1997). Other studies have indicated that aspen <40 years old are rarely infected with heart rot (summarized in Basham 1987). The presence of *P. tremulae* and other heart rot fungi may be one of the main reasons why woodpeckers are selecting older tree patches for nesting. All woodpecker nest trees in the Dawson Creek Forest District had visible external conks. The preference of primary cavity nesters for selecting nest trees infected with *P. tremulae* has been reported in similar studies across North America (Conner *et al.* 1976; Miller *et al.* 1979; Harestad and Keisker 1989).

5.3 Coarse Woody Debris – Mature Aspen Stands

In the Dawson Creek Forest District study area, over 70% of the volume of CWD in mature aspen stands was in decay classes 2 and 3 (varying degrees of decay, but heartwood still hard). The small amount of CWD found in more advanced decay classes suggests the rapid decay rate of aspen. Although the mean diameter of standing trees in the mature aspen stands was 20.2 cm, over 85% of all CWD pieces were <15 cm in diameter, indicating that few trees were falling as intact boles in mature aspen stands. Consequently, few large-diameter pieces were found on the forest floor in these stands.

Coarse woody debris distribution on the forest floor in mature aspen stands was clumped (*i.e.,* found in loosely arranged concentrations as opposed to randomly spread pieces) when data was pooled across the entire study area. However, when considered in geographically distinct blocks, only five of the 17 blocks showed significant CWD clumping. This suggests that CWD was not found in uniformly distributed clumps or concentrations spread across the entire forest stand, but instead, its distribution was a mixture of random pieces and random clumped concentrations on the forest floor.

Coarse woody debris volumes were significantly lower in aspen stands compared to mixed-wood stands. Volumes measured in mature and regenerating aspen stands suggested an increase in volumes after harvesting through the new cut and shrub stages, followed by a drastic decrease in the pole sapling stage. Piece length was shorter in recently cut sites and more than one-half of the pieces were < 1 m long. A large proportion of pieces in cut sites were < 20 cm in diameter.

5.4 Coarse Woody Debris – Mixed-wood Stands

The frequency of CWD was evenly distributed between diameter classes 1-4 in mixed-wood stands. However, the majority of larger-diameter pieces were spruce, which tend to decay more slowly than aspen, as indicated by the disproportionately large volume of spruce CWD in later decay classes 4 and 5. The substantial amount of larger-diameter CWD pieces suggests that toppled conifers were commonplace in the mixed-wood stands. The mixed-wood study area has been subject to significant fall-over due to an endemic root rot infestation (Merkens and Booth 1997).

As in the mature aspen stands, CWD was not uniformly distributed in clumps on the forest floor in the mixed-wood stands, but had a mixed distribution of random-piece arrangements and clumped piles. Even with the larger volume of CWD found in mixed-wood stands, these areas did not have significantly more clumping than mature aspen stands. This may have been due to the large variation in the number of CWD pieces per segment in both aspen and mixed-wood study areas. In central Montana, CWD was also found to have a random-piece distribution and clump-like concentrations (Lutes 2001). In the Montana study, CWD had a clumped spatial distribution in 23% of the study plots and a random distribution in 77% of the plots. In eight of 13 statistical tests, CWD showed evidence of directional orientation in the study plots.

Debris volume was higher in mixed-wood stands than aspen stands. There were more large-diameter pieces, longer pieces, and pieces in advanced stages of decay; these differences reflect the significant contribution of spruce to the woody debris in mixed-wood stands. Mature mixed-wood stands had few short pieces of debris, and the pieces in mature stands were significantly larger than in recently cut sites.

5.5 Small Mammal Use of Coarse Woody Debris

Coarse woody debris satisfies various habitat needs for small mammals, including nesting sites, foraging substrates, travel routes, security, and thermal cover (Carter 1993; Bowman *et al.* 2000; Carey and Harrington 2000). The greater the CWD clumping, the more thoroughfares there are for small mammal species to travel. Voles and mice in the Dawson Creek Forest District study area preferred travel routes that were associated with higher levels of CWD than would be expected relative to its availability. As a result, higher populations of small mammals could be expected on sites with higher levels of clumped CWD (see Merkens and Booth 1997 for further discussion). Small mammals, particularly microtines, are considered important prey for many "keystone" avian and mammalian predators (Banfield 1987; Johnsgard 1988, 1990). Consequently, quantity and quality of CWD in a forest can potentially affect overall stand productivity and biodiversity.

Small mammals tend to use connecting networks of CWD to travel and to provide protection (Carter 1993; McMillan and Kaufman 1995). It is likely that Red-backed Voles' main use of CWD was for short-range navigational cues and/or escape routes to avoid predators. Deer Mice often use the same pieces of CWD as travel routes on consecutive nights (Graves *et al.* 1988). Results of the marking study (Merkens and Booth 1997, 1999) confirm these patterns – vole and mouse travel routes were closely associated with debris, and whether they traveled along, beside, or under the debris depended on the height of the debris off the forest floor.

6 MANAGEMENT IMPLICATIONS

6.1 Wildlife Trees

Retaining wildlife tree patches can mimic the natural disturbance ecology of boreal and sub-boreal forests (Seip and Parker 1997). For example, wildfires historically burn these forest types at frequent intervals. However, fires do not necessarily destroy the entire forest. Fires typically miss some areas, resulting in scattered patches of unburned forest that comprise 5-15% of the burned area. These unburned patches, like wildlife tree patches, provide a source of mature forest attributes, including WLTs and CWD. In the MS and ESSF biogeoclimatic zones of southern British Columbia, levels of large WLTs peaked immediately after a fire (Gyug 2000). As the WLTs began to fall to the ground, CWD amounts peaked to levels similar to old-growth forests. However, after 100 years post-burn, both WLTs and CWD were at the low end of their cycles because most WLTs had fallen over and most CWD had decomposed.

In the Prince George Forest District, wildlife tree patches retained in clearcuts in the Sub-Boreal Spruce (SBS) biogeoclimatic zone were extensively used by forest birds (Seip and Parker 1997). Songbird detection rates in the wildlife tree patches were similar to adjacent contiguous forests and higher than in the surrounding clearcut or young forest. For several species, detection rates were higher in wildlife tree patches than in contiguous forests or clearcuts. Most forest-dwelling species that were present in wildlife tree patches were absent in clearcuts. The study concluded that the retention of wildlife tree patches provided habitat for forest birds that was not provided by clearcuts alone.

In the MS and ESSF biogeoclimatic zones of southern British Columbia, wildlife tree patches along riparian corridors that were <38 m wide (19 m on either side of a stream) did not provide suitable habitat for most forest-dwelling songbirds (Gyug 2000). Portions of riparian corridors that were >35 m from the stream tended to be dominated by "edge" species, while forest-dwelling species densities declined. Partial harvesting (<33% stem removal) had little effect on bird communities in wide riparian corridors (69-150 m forest buffer width). However, high levels of stem removal (48-85%) in narrow corridors (47-55 m) showed significant declines in many forest-dwelling songbird densities.

In the Sierra Nevada of California, 72% of nest trees for cavity-nesting birds were in WLTs (Raphael and White 1984). Compared with available WLTs, nest trees were larger in diameter, surrounded by a larger number of snags (>23 cm dbh), had more bark cover, and more often had broken tops. To support maximum cavity-nesting bird densities in wildlife tree patches, 8.5 suitable WLTs/ha (with one-third of these being in hard decay classes) was suggested as a management prescription (Raphael and White 1984). These data suggest that suitable WLTs should be managed as dispersed clumps (patches), rather than as isolated individual trees, to meet nesting and feeding requirements of cavity nesters. In order to maintain and recruit sufficient large-diameter WLTs, wildlife tree patches should be retained beyond typical rotation periods to allow mature forest attributes to develop.

In the Dawson Creek Forest District, advanced stages of stem rot in aspen WLTs, particularly that caused by *Phellinus tremulae*, was present only in mature stands (Merkens *et al.* 1995). Trees that were <40 years of age were rarely infected with *P. tremulae*; however, incidence of infection increases with age (Basham 1993 cited in Merkens *et al.* 1995). As a result, a minimum of a 40-year rotation may be required to allow stands to become susceptible to *P. tremulae* infection and therefore provide suitable nesting substrate for primary cavity nesters (Merkens *et al.* 1995).

In the Dawson Creek Forest District, conk density in nest trees and nest plots was higher than in random trees and random plots. This suggests that areas with concentrations of *P. tremulae* stem rot may provide important nesting habitat for primary cavity nesters. However, the density of stem scales, caused by the pathogen *Polyporous sp.*, was significantly lower in nest plots compared to random plots (Merkens *et al.* 1995). The lack of scales in nest plots may be related to the antagonistic relationship between the two pathogens, *P. tremulae* and *Polyporous sp.* (Hiratsuka 1987). However, the presence or absence of either of these pathogens may help forest managers to identify appropriate wildlife tree patch areas.

6.2 Coarse Woody Debris

In much of British Columbia, including the Dawson Creek Forest District, most forest harvesting is by clearcutting that leaves little standing timber for CWD recruitment. Clearcut logging is thought to set CWD at a very low level that occurs naturally only in a few exceptional cases (*i.e.,* where a site was affected by two fires in <50 years) (Gyug 2000). After a stand is harvested, logging debris, particularly larger pieces, is typically piled and burned to facilitate tree planting and stand regeneration, and to reduce wildfire hazard.

In the Dawson Creek Forest District, volumes of CWD were not significantly different between recently cut and mature aspen and mixed-wood sites; however, piece length and diameter size were smaller in cut sites compared to mature sites (Merkens and Booth 1999). Smaller CWD pieces tend to decay faster than larger pieces (Lee *et al.* 1995; Gyug 2000). Consequently, the smaller pieces of CWD that are typically left behind after harvesting decay quickly and their ecological benefits are lost before a stand fully regenerates. In young stands, CWD recruitment is primarily from stand self-thinning (Pollard 1971; Lee *et al.* 1995). However, with current forest practices, in many cases relatively few standing trees are left after harvesting, leaving a void for CWD recruitment between the time of harvesting and when a stand begins to self-thin.

In the Dawson Creek Forest District, the amount of CWD layering in recently cut sites was less than that found in mature sites (Merkens and Booth 1999). Generally, after harvesting, logging debris is piled and burned, which leaves the remaining CWD unevenly distributed across a cutblock. The use of heavy machinery within the cutblock tends to orient CWD in a non-random fashion that reduces the connectivity of pieces for small-mammal travel routes. Additionally, in recently cut aspen and mixed-wood sites, there were few CWD pieces of decay class 1 or 2 (most heartwood is still hard). These CWD classes tend to last longer than later decay classes and therefore provide forest structure and small-mammal habitat for a greater period of time. As a result, later CWD decay classes that are typically left after harvesting decay at a faster rate, thus reducing piece layering and connectivity.

In the MS and ESSF biogeoclimatic zones of southern British Columbia, Red-backed Voles dominated small-mammal communities in unharvested forests (66% of captures) (Gyug 2000). Riparian areas that were clearcut were dominated by Meadow Voles (*Microtus pennsylvanicus*) (56% of captures), while harvested upland areas were dominated by Deer Mice (35% of captures). Clearcutting did not affect the total small-mammal abundance in riparian areas (17.8 vs. 13.2 captures/100 trap-nights), but did affect abundance in upland habitats (13.2 vs. 6.2 captures/100 trap-nights). Partial harvesting (<33% stem removal) in forest stands did not seem to affect small-mammal communities. Red-backed Voles were present in all sizes of forest-corridor leave areas, however, they were most abundant in corridors that were wider than 100 m. Riparian corridors probably provide the best option for conserving small-mammal diversity, since these areas tend to support most microtine species that are found in a particular area (Gyug 2000).

In the United States, studies have suggested that between 10-20% CWD cover, well distributed across the forest floor, is adequate for maintaining most ecological functions associated with small mammals (summary in Loeb 1999; Bowman *et al.* 2000; Carey and Harrington 2000). On the Olympic Peninsula in Washington State, habitat complexity, including the amount of CWD, standing dead trees, stumps, shrub cover, floor litter, and other mature forest attributes, were highly correlated to the total relative abundance of small-mammal species in both old-growth and second-growth stands (Carey and Harrington 2000).

7 MANAGEMENT RECOMMENDATIONS

The following recommendations are suggested as guidelines for managing WLTs and CWD in aspen-dominated and mixed-wood stands in northeastern British Columbia.

In general, establish and maintain wildlife tree patches (WTPs) across the landscape. Wildlife tree patches provide protection from predators and weather, alternate nest and den sites, and roosting and foraging habitat. To increase their value for wildlife, WTPs should be located near other important habitat features, including riparian areas, gullies, wetlands, and rock outcrops. Wildlife tree patches should contain various structural attributes including suitable WLTs, CWD, and intact forest-floor structure at levels that approximate the conditions found in mature, pre-harvest stands.

7.1 Wildlife Trees

1. Wildlife tree patches should contain a significant proportion of deciduous trees, particularly trembling aspen and paper birch. In mixed-wood stands, deciduous trees are often preferred nesting habitat while conifers are used for foraging. Consequently, WTPs should contain a mixture of live aspen or birch (black cottonwood can be a minor component), as well as live and dead conifers (spruce or pine, tree decay classes 1-6).

2. Wildlife tree patches should contain some live aspen (decay classes 1 and 2 with unbroken tops) that are as large as possible for the site (in the upper 10% of the diameter-range distribution). Preferably, these trees will be >25-30 cm dbh and >10 m height.

3. Some live aspen within patches should have visible external conks and/or canker faces. Old nest holes and feeding excavations are also important features to look for when identifying candidate areas for WTPs.

4. Across landscape planning units, extend rotation lengths beyond 40 years (to 60-80 years) for some harvest blocks to allow aspen stems to mature and develop heart rot. Stands in this condition provide ideal nesting habitat for cavity-excavating species.

5. Wildlife tree patches should be of adequate size to be attractive to cavity nesters and to support large-diameter aspen trees over time.

6. Creation of stubs (stems cut at 4-6 m high with a mechanical harvester) should be considered in blocks containing conifers. No specific density of stubs is recommended; however, trees selected as stubs should have some defect in the lower bole (*e.g.,* scar, split trunk, fungal conk) and should be located near a WTP or other valuable habitat feature (*e.g.,* wetland, gully, or deciduous patch).

7.2 Coarse Woody Debris

1. Logging debris should be left on site. Some debris should be scattered over the entire harvest block, and some should be left in small piles to mimic natural distribution patterns. Longer pieces of debris should not be bucked-up, but should be left in their entirety because they provide travel routes and habitat connectivity for small mammals.

2. Where available, maintain a range of piece sizes (diameter and length) of CWD distributed across harvest blocks. Larger CWD pieces provide wildlife habitat for a longer period of time because they decay at a slower rate than smaller pieces. Consequently, management prescriptions should make provisions to retain some larger-diameter, relatively undecayed CWD pieces on site.

3. Maintain some CWD in loosely layered, low-height (<1 m) piles. Loose piles will provide travel routes and thermal and protective cover for small mammals and their predators (*e.g.,* weasels and marten). Some pieces that radiate from the piles should be longer (piece length not determined) to provide linear travel corridors for small mammals.

4. Where available, retain some large-diameter (20-50 cm), recently decayed coniferous CWD (log decay classes 1-3) distributed across harvest blocks.

8 CONCLUSION

Although research has been conducted on wildlife trees and coarse woody debris in the Dawson Creek Forest District since 1993, current results should be considered preliminary. Further research is required in the mixed-wood forests of northeastern British Columbia to determine natural levels, distributions, and characteristics of WLTs and CWD. To date, only a few forest types and age classes in the Dawson Creek Forest District have been studied. No research has been conducted on how natural conditions such as wildfire, topography, insect or disease infestation, and soil moisture and nutrient regimes affect levels of WLTs and CWD.

Our current understanding of the boreal forest of northeastern British Columbia suggests that appropriately selected wildlife tree patches (WTPs) can provide habitat for forest-dwelling species and for maintaining stand-level biodiversity. Where possible, WTPs should be located near other valuable habitat features such as riparian areas, wetlands, gullies, and rock outcrops. Wildlife tree patches should contain a representative sample of the proportion and variety of tree species found in the original pre-harvest stand. Leave trees should be selected so that WTPs are a mosaic of larger, live trees that are mixed with other stems of more advanced decay. Loose piles of CWD consisting of a range of piece sizes (length and diameter) and decay classes should be distributed across harvest blocks. Longer CWD pieces should be randomly distributed across cutblocks to provide linear travel corridors for small mammals. Where possible, create man-made stubs and distribute some large-diameter, recently decayed coniferous CWD across harvest blocks.

Forest attributes like WLTs and CWD are dynamic and in flux, much like the forests they are found in. To provide a better understanding of these natural fluctuations, research in northeastern British Columbia should be compared with studies that are occurring in other parts of the boreal forest and to research in the United States. Such comparisons may provide meaningful recommended ranges for quantities and qualities of WLTs and CWD that should be retained and managed after forest harvesting. This data will be instrumental in helping forest managers preserve these important natural resources in the forests of northeastern British Columbia.

LITERATURE CITED

Banfield, A. 1987. The mammals of Canada. Univ. Toronto Press, Toronto, ON. 438pp.

Barnum, S.A., C.J. Manville, J.R. Tester and W.J. Carmen. 1992. Path selection by *Peromyscus leucopus* in the presence and absence of vegetative cover. J. Mammal. 73:797-801.

Basham, J.T. 1987. Assessment and prediction of stem decay in aspen stands. Pages 110-117 *in* Aspen Quality Workshop. Proc. Canada-Alberta For. Resour. Dev. Agreement, Feb. 12, 1987, Edmonton, AB.

Basham, J.T. 1993. Trembling aspen quality in northern Ontario – various aspects of stain and decay studies and their implications. For. Can. Ont. Region, Sault St. Marie, Ont. Rep. O-X-421. 47pp.

Booth, B., and M. Merkens. 1996. Monitoring changes in wildlife diversity during operational hardwood harvesting - aspen clearcutting in the Dawson Creek Forest District. Prog. Rep. 1995/96. B.C. Minist. Environ., Lands and Parks, Wildl. Branch, Victoria, BC.

Booth, B.P. 1996. A pilot study of the forest bird and vegetation communities in mixed wood forests in the Dawson Creek Forest District – progress report 1995/96. B.C. Minist. Environ., Lands and Parks, Wildl. Branch, Victoria, BC. 47pp.

Bowman, J.C., D. Sleep, G.J. Forbes and M. Edwards. 2000. The association of small mammals with coarse woody debris at log and stand scales. For. Ecol. and Manage. 129:119-124.

Carey, A.B., and C.A. Harrington. 2000. Small mammals in young forests: implications for management for sustainability. For. Ecol. and Manage. 5395(2000):1-21.

Carter, D. 1993. Use of habitat in coastal forest seral stage by deer mice. M.Sc. Thesis. Simon Fraser Univ., Burnaby, BC.

Conner, R.N., O.K. Miller and C.S. Adkisson. 1976. Woodpecker dependence on trees infected by fungal heart rots. Wilson Bull. 89:122-129.

Darling, L.M. 1995. Monitoring changes in wildlife diversity during operational hardwood harvesting - aspen clearcutting in the Dawson Creek Forest District. Working plan 1995/96. B.C. Minist. Environ., Lands and Parks, Wildl. Branch, Victoria, BC.

Darling L.M., and D.R. Farr. 1994. Monitoring changes in wildlife diversity during operational hardwood harvesting – aspen clearcutting in the Dawson Creek Forest District. Prog. Rep. 1994/95 and working plan 1994/95. B.C. Minist. Environ., Lands and Parks, Wildl. Branch, Victoria, BC.

Graves, S., J. Maldonado and J.O. Wolff. 1988. Use of ground and arboreal microhabitats by *Peromyscus leucopus* and *Peromyscus maniculatus*. Can. J. Zool. 66:277-278.

Guy, S., and E.T. Manning. 1995. Wildlife/danger tree assessor's course workbook. 4th ed. Canada-British Columbia Partnership Agreement on For. Resour. Dev. and B.C. Minist. For., Victoria, BC.

Gyug, L.S. 2000. Timber-harvesting effects on riparian wildlife and vegetation in the Okanagan Highlands of British Columbia. B.C. Minist. Environ., Lands and Parks, Wildl. Branch, Wildl. Bull. No. B-97, Victoria, BC. 112pp.

Harestad A.S., and D.G. Keisker. 1989. Nest tree use by primary cavity-nesting birds in south central British Columbia. Can. J. Zool. 67:1067-1073.

Hiratsuka, Y. 1987. Forest tree diseases of the prairie provinces. Can. For. Serv. North. For. Cent., Inf. Rep. NOR-X-286, Edmonton, AB.

Johnsgard, P.A. 1988. Hawks, eagles and falcons of North America: biology and natural history. Smithsonian Inst. Press, Washington, DC.

Johnsgard, P.A. 1990. North America Owls: biology and natural history. Smithsonian Inst. Press, Washington, DC. 403pp.

Lance, A.N., and M. Phinney. 1995. Bird diversity and abundance following aspen clearcutting in the Boreal White and Black Spruce Biogeoclimatic Zone. Project B28, Hardwood and Vegetation Manage. Res., B.C. Minist. For., Victoria, BC.

Lee, C.L., S. Crites, M. Nietfeld, H. Van Hguyen and J.B. Stelfox. 1995. Changes in snags and downed woody material characteristics in a chronosequence of aspen mixed-wood forests in Alberta. *In* J.B. Stelfox, ed. Relationships between stand age, stand structure, and biodiversity in aspen mixed-wood forests in Alberta. Alta. Environ. Cent. (AECV95-R1), Vegreville, AB. 308pp.

Lemen , C.A., and P.W. Freeman. 1985. Tracking mammals with fluorescent pigments: a new technique. J. Mammal. 66:134-136.

Loeb, S.C. 1999. Responses of small mammals to coarse woody debris in a southeastern pine forest. J. Mammal. 80:460-471.

Lofroth, E. 1992. Measurements of habitat elements at the stand level. *In* L.R. Ramsey, ed. Methodology for monitoring wildlife diversity in B.C. forests. Proc., B.C. Minist. Environ., Lands and Parks, Victoria, BC. 77pp.

Lutes, D.C. 2001. Methods for the quantification of coarse woody debris and the identification of its spatial patterning. *In* B.F. Laudenslayer, ed. Draft Proc. Symposium on the ecology and management of dead wood in western forests, Nov. 1999, Reno, NV. US For. Serv., Pacific Southwest Res. Stn., Fresno, CA.

Machmer, M.M., and C. Steeger. 1995. The ecological roles of wildlife tree users in forest ecosystems. B.C. Minist. For., Land Manage. Handb. No. 35, Victoria, BC. 54pp.

Manning, E.T., and P. Chytyk. 1997. An analysis of wildlife trees and coarse woody debris in mature aspen and mixed-wood stands in Dawson Creek Forest District. B.C. Minist. Environ., Lands and Parks, Wildl. Branch, Victoria, BC. 28pp.

Manning, E.T., and J.M. Cooper. 1996. An assessment of woodpecker foraging, home range and patch utilization at Wallace Creek, British Columbia. Prog. rep. B.C. Minist. Environ., Lands and Parks, Penticton, BC. 9pp.

McCallum, B. 1984. Ecological considerations for the wildlife of the Champion Forest Management Area, Alberta. Alberta For. Lands Wildl., Edmonton, AB.

McMillan B.R., and D.W. Kaufman. 1995. Travel path characteristics for free-living White-footed Mice (*Peromyscus leucopus*). Can. J. Zool. 73:1474-1478.

MELP and MOF (Ministry of Environment, Lands and Parks and Ministry of Forests). 1998. Field manual for describing terrestrial ecosystems. B.C. Minist. Environ., Lands and Parks, Resour. Inv. Branch, and B.C. Minist. For., Res. Branch, Land Manage. Handb. No. 25, Victoria, BC.

Merkens, M., and B.P. Booth. 1997. Use and availability of wildlife trees and coarse woody debris in aspen forests and clearcuts of northeastern B.C. (Prog. rep. 1996 – final draft). B.C. Minist. Environ., Lands and Parks, Wildl. Branch, Victoria, BC. 45pp.

Merkens, M., and B.P. Booth. 1998. Monitoring changes in wildlife diversity during operational hardwood harvesting: aspen clearcutting in the Dawson Creek Forest District (1992-1997). B.C. Minist. Environ. Lands and Parks, Wildl. Branch, Victoria, BC. 80pp.

Merkens, M., and B. Booth. 1999. Availability and use of coarse woody debris by Red-backed Voles (*Clethrionomys gapperi*) within selected habitat types in northeastern British Columbia. B.C. Minist. Environ., Lands and Parks, Wildl. Branch, Victoria, BC. 28pp.

Merkens, M., L. Darling and B. Booth. 1995. Use and availability of wildlife trees in aspen stands of northeastern B.C. Pages 35-44 *in* Wildlife tree/stand-level biodiversity workshop proceedings. B.C. Minist. Environ., Lands and Parks and B.C. Minist. For., Victoria, BC.

Miller, E., A.D. Partridge and E.L. Bull. 1979. The relationship of primary cavity nesters and decay. Trans. N.E. Sect. Wildl. Soc. 36:60-68.

Parker, R.E. 1979. Introductory statistics for biology, 2nd ed. Edward Arnold Publ. Ltd., London, UK. 122pp.

Pollard, D.F.W. 1971. Mortality and annual changes in distribution of above-ground biomass in an aspen sucker stand. Can. J. For. Res. 1:262-266.

Raphael, M.G., and M.L. Morrison. 1987. Decay and dynamics of snags in the Sierra Nevada, California. For. Sci. 33(3):774-783.

Raphael, M.G., and M. White. 1984. Use of snags by cavity-nesting birds in the Sierra Nevada. Wildl. Monographs. 86:774-783.

Seip, D., and K. Parker. 1997. Use of wildlife tree patches by forest birds in the Sub-Boreal Spruce (SBS) zone. For. Res. Note, B.C. Minist. For., Prince George For. Reg., For. Resour. and Practices Team, Prince George, BC. 6pp.

Siegel, S., and N.J. Castellan, Jr. 1988. Non-parametric statistics for the behavioral sciences. McGraw Hill, New York, NY. 399pp.

Steeger, C., M. Machmer and E. Walters. 1996. Ecology and management of woodpeckers and wildlife trees in British Columbia. Environ. Canada, Fraser River Action Plan. 23pp.

Thomas, J.W., R.G. Anderson, C. Maser and E.L. Bull. 1979. Snags. Pages 60-70 in J.W. Thomas, ed. Wildlife habits in managed forests: the Blue Mountains of Oregon and Washington. U.S. Dep. Agric. For. Ser. Agric. Handb. 553. 512pp.

Zar, J.H. 1974. Biostatistical analysis. Prentice-Hall Inc., Englewood Cliffs, NJ. 620pp.

Appendix 1. Classification of wildlife tree characteristics.

Species Code

Species	Aspen	Cottonwood	Spruce	Lodgepole Pine	Birch	Unknown
Code	A	Ct	S	Pl	Ep	unkn.

Height Class

Code	Height
1	<3 m
2	3-10 m
3	10-25 m
4	>25 m

Soundness (sapwood, roots and heartwood)

Code	Decay
0	0%
1	<50%
2	>50%

Trunk Condition

Code	Condition
1	whole
2	broken top (>20 m)
3	broken trunk (3-20 m)
4	stub (0.5-3 m)
5	stump (<0.5 m)

Bark Condition

Code	Bark Remaining
1	<20%
2	20-40%
3	40-60%
4	60-80%
5	>80%

Deformities

Code	Type
G	gall
M	mistletoe
C	crooked
L	lean (>20°)
O	other

Damage (2-letter code)

Code	Type
*S/	superficial
*H/	heartwood
S	sunscald
F	frost crack
B	burned
M	mechanical

Disease/Insects

Parameter	Code	Description
#, # sites	F	few; 1-5 sites, instances
	M	many; >5 sites, instances
location	U	upper third of trunk
	M	middle third of trunk
	L	lower third of trunk
prevalence	L	< a third of trunk affected
	H	> a third of trunk affected
age	O	old
	N	new, fresh, recent
type	W	wood-boring insect
	L	leaf-damaging insect
	B	bud or flower insect

Appendix 1. Continued.

Snag Class

Code	Description
0	live – green cambium
1	dead – recently killed
2	dead – twigs, leaves lost; bark intact; wood hard
3	dead – small branches lost; bark peeling; wood hard
4	dead – major branches lost; >20% bark lost; wood variable
5	dead – canopy broken; bark and wood variable
6	dead – decomposing stump; wood soft; bark peeling

Branch Condition

Code	Description
1	all green, live
2	most green, live
3	many whole dead limbs, upper canopy
4	many stub dead limbs, upper canopy
5	many whole dead limbs below canopy
6	many stub limbs below canopy
7	no branches

Wildlife Signs/Use

Parameter	Code	Description
#, # sites	F	few; 1-5 sites, instances
	M	many; >5 sites, instances
age	O	old
	N	new, fresh, recent
location	U	upper third of trunk
	M	middle third of trunk
	L	lower third of trunk
species	4-letter species code for suspected species	
function	M	marking
	C	climbing
type	S	sap feeding holes
	I	insect excavation holes
size	approximate dimensions (cm) of cavity entrance hole	

Appendix 2. Classification of coarse woody debris characteristics.

Species Code

Species	Aspen	Cottonwood	Spruce	Lodgepole Pine	Birch	Unknown
Code	A	Ct	S	Pl	Ep	unkn.

Bark Classes

Code	Range (%)
0	none
1	<25
2	25-75
3	>75

Diameter Classes

Code	Range(cm)
1	5-10
2	10.1-15
3	15.1-20
4	20.1-50
5	>50

Height Classes

Code	Range(cm)
1	on ground
2	0-5
3	5.1-10
4	10.1-20
5	>20

Layering

Code	Range
0	on ground
1	1 or 2
2	>2

# of debris pieces >10 cm in diameter overlaid with piece within 1 m of transect.

Decay Class – deciduous debris

Code	Description
1	hard heartwood, freshly fallen, twigs present, branches supporting trunk above ground, supports person's weight across span
2	hard heartwood, branches reduced to stubs, wood self-supporting across span, larger pieces springy rather than brittle, may be <50% bark left
3	hard heartwood at core and soft towards bark layer, wood fungi present, seldom any bark, varying levels of decay along stem length
4	soft heartwood throughout, not crumbling or mushy, unable to support own weight
5	heartwood reduced to wet mush or stringy pulp

Decay Class – coniferous debris

Code	Description
1	hard, branches attached, freshly fallen, twigs present, self-supporting across a span, bark mostly intact
2	hard, few branches, self-supporting across a span, sagging slightly, bark mostly intact or beginning to split and peel or partly missing
3	soft, sagging near ground or broken, beginning signs of heartwood decay, breaks into large fairly solid chunks, loose bark
4	soft, breaks into cubes or chunks, not self-supporting, very little bark
5	very soft, crumbles to dust or mush, well integrated into soil, sunken

Appendix 3. Statistical tables for determining coarse woody debris clumping.

Table A. Kruskal-Wallis table for the presence of CWD clumping in different sample blocks with ≥ two degrees of freedom among mature aspen and mixed-wood stands of northeastern British Columbia.

Sample	n	KW_{value}	Chi^2 critical*	df	*P*
Mature Aspen					
AM1	36	12.8	7.82	3	<0.01
ASP	108	59.5	19.68	11	<0.01
ASP1	9	–	–	–	–
DRN	54	7.7	11.07	5	0.18
KC1	27	13.6	5.99	2	<0.01
KC2	27	14.7	5.99	2	<0.01
L24	36	6.8	7.82	3	0.08
L25	36	7.4	7.82	3	0.06
L30	36	2.7	7.82	3	0.43
L6	36	2.2	7.82	3	0.54
Mixed-wood					
ADDMW	63	8.9	12.95	6	0.18
ASP1	99	28.4	18.31	10	<0.01
ASP2	27	2.8	5.99	2	0.24
ASP3	36	19.8	7.82	3	<0.01
CONN	63	26.0	12.95	6	<0.01
CONS	54	24.2	11.07	5	<0.01
LPMIX	45	7.8	9.49	4	0.10
MW	27	4.7	5.99	2	0.09

*α=.05

Table B. Mann-Whitney U table for the presence of CWD clumping in different sample blocks with one degree of freedom among mature aspen and mixed-wood stands of northeastern British Columbia.

			Chi^2 approximations			
Sample Block	n	U_{value}	critical*	value	df	*P*
Mature Aspen						
B1	18	20.5	3.84	3.38	1	0.07
B2	18	60.5	3.84	3.39	1	0.07
B3	18	37.5	3.84	0.07	1	0.79
C1	18	28.0	3.84	1.31	1	0.25
C2	18	31.0	3.84	0.72	1	0.39
CC	18	49.0	3.84	0.61	1	0.43
NC	18	7.0	3.84	9.18	1	<0.01
Mixed-wood						
PINMIX	18	43.0	3.84	0.53	1	0.82

*α=.05