Biodiversity sustainability analysis of the contribution of hardwoods to sustaining biodiversity in the Fort St John TSA[1]

Final Report

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March 2010

[1] Final Report of FIA Project No. 8047009

Executive Summary

Hardwood associates within the DFA

A total of 58 bird species within the Defined Forest Area (DFA) show preference for hardwood or mixed wood types. Some of these are strongly dependent on additional habitat elements: understory under canopy, cavity sites and wetland or riparian habitat. For these latter species, coarse-filter evaluation of effects of forest practice must first address the key elements – understory, dead wood and riparian (see Bunnell et al. 2009a,b). Of the 19 bird species responding primarily to forest type, the large majority are primarily tree nesters (15 of 19). Three of these are hawks taking primarily smaller birds, mammals and amphibians; the others forage predominately by gleaning foliage (13 of 16). Of the three that are not hawks, one forages primarily by probing bark (Black-and-white Warbler), one in hardwood litter (Ovenbird) and one is a flycatcher taking prey from the air and by hover gleaning. In short, the vast majority are responding to insects feeding on hardwood foliage that is less protected by secondary compounds than is conifer foliage. About half use shrubs as foraging substrate and as nesting substrate or cover.

The habitat types most preferred by bird species strongly associated with hardwoods are older hardwoods followed by older mixed woods and NT (non-treed). Fourteen species of birds designated as hardwood associates are ranked 2 for at least one Goal within the provincial system of conservation priorities; three are ranked 1.

Among mammals, 12 or 13 species have some affiliation with hardwood or mixed wood cover. Often the association is not pronounced and is a product of affinity for riparian areas (e.g., Pacific water shrew; western jumping mouse) or because they forage on young hardwood trees, shrubs and herbaceous vegetation that often is more abundant in hardwood than in conifer stands (e.g., long-tailed vole, Townsend's vole, elk during winter). Only the beaver appears largely limited to hardwood trees and shrubs, but will eat pine when hardwoods are unavailable. Because of its affinity for water, the beaver is monitored as a wetland species. Three of the bat species likely occurring within the DFA favour hardwood species (commonly aspen) as roosting or denning sites, as does the northern flying squirrel. They are accounted for as cavity-users. The association of some amphibians with hardwood stands is primarily a response to their seeking riparian areas.

Hardwoods also enrich forests by providing habitats for lichens and mosses specific to those substrates. As well, many butterflies and carabid beetles are found in hardwood stands and some use them preferentially. It is likely that some non-vertebrates do well in young hardwood stands, but literature from areas where forestry has been practiced longer suggests that most threatened species occur in older stands. It is less clear whether interior portions of hardwood stands are important for vascular plants or invertebrates, but some lichen and moss species that are specific to hardwoods appear sensitive to drying in edge habitats.

Major findings

1. Planning and practices of the SFM plan for the Fort St John Pilot Project appear well reasoned and well integrated, and should act to supply hardwoods with favourable attributes into the future. Table 8 summarizes uncertainties; the most troubling are:
    - potential declines in total area of hardwood (Figure 2),
    - realized butt-end diameter of logs left on site, and
    - consequences of harvesting practices around S4 streams and wetlands.

2. Targets are well-reasoned but should be evaluated through effectiveness monitoring (§7.3). The current trend to more wildfires in boreal forests suggests that targets based on historical natural disturbance regimes are no longer 'natural' and possibly unattainable.

3. The minimum diameter of 17.5 cm for single leave trees and stubs in the existing SFM plan is too low (Table 2) and should be raised to 23 cm. Note: the current revision of the SFM plan has incorporated this recommendation.

Recommendations for planning and practice

Tables 7 and 8 reveal four areas where current practice could be beneficially altered or, minimally, evaluated soon by implementation monitoring.

1. Guidelines for retention of single stems or stubs should be tree sizes >23 cm dbh; proposed new densities appear appropriate. Note: this change is being implemented.
2. Guidelines for retained wildlife trees in patch-wise retention should encourage retaining trees >23 cm dbh, with local densities of 3 per ha where possible. Greater densities of small snags also should be retained, not all hardwood.
3. All pieces of downed wood >17.5 cm (random diameter) should not be piled; some should be scattered on site to sustain poorly dispersing organisms.
4. Riparian management practices should ensure that larger, older hardwoods are retained in the Riparian Management Zones. This may not be a modification depending on the outcome of implementation monitoring (§7.3).

Recommendations for monitoring

Monitoring should focus on areas where direct or cumulative effects currently are unknown and potentially negative (Table 9), and on areas where potential problems are evident but existing data are inadequate to assess them. Monitoring should be directly linked to practices that offer opportunity for improvement.

Topics for implementation monitoring are ranked: habitat elements in the Riparian Management Zone and around wetlands (very high), trends in tree species composition (very high), trends in amounts of late seral (high), conditions within retention patches (high), pre-harvest stratification to assist assessment of vegetation management (high) nature and distribution of coarse woody debris left on site (medium) and late-seral patch size distribution (medium). Topics for effectiveness monitoring also are ranked: contributions of NHLB (very high), mixed wood boundaries (very high), evaluate whether findings from TFL 48 on vegetation management can be applied (very high), contributions of Wildlife Tree Patches (high), organism response (very high to low, dependent on group), effectiveness of practices in Riparian Management Zone (potentially high, dependent on outcome of implementation monitoring), late-seral boundaries (medium) and suitability of retained coarse woody debris (medium). See §7.3 for details.

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1 Introduction

Biodiversity sustainability analysis combines groupings of species derived from the Species Accounting System with coarse filter analyses developed to assess the degree to which forest practices contribute to sustaining biological diversity. Development of the Species Accounting System began with Tembec Inc and Canfor (FSP Y051045 through 073045); approaches to coarse filter analysis were developed for Canfor's TFL 48 within FSP Y071014 through Y093014. The combined analysis also is intended to reveal where current practices could be improved. This report focuses on species strongly associated with hardwoods.

Hardwoods are deciduous, broadleaved trees. None of the broadleaved trees on the TSA are evergreen. Larch, a conifer, is deciduous. Many forest-dwelling species show strong preferences for hardwood species and some prefer mixed wood stands of conifers and hardwoods. Forest practices can modify the abundance of suitable hardwoods in five broad ways: 1) reduce the amount of older age classes of hardwood or mixed wood types sought by some species, 2) reduce the proportion of hardwoods in mixed wood types below the level at which the mixed wood contribution to species richness is sustained, 3) reduce the amount of hardwoods through vegetation management, 4) convert significant amounts of hardwood or mixed wood types to conifer-leading types, or 5) inadequately protect riparian areas that are commonly hardwoods.

The report has three objectives:

1) It lists native forest-dwelling vertebrate species occurring in the Fort St John TSA dependent or strongly associated with hardwoods (derived from the Species Accounting System). Statistical strength of the association is reported.
2) It describes the process for coarse filter analysis of the effects on species using hardwoods, and
3) It presents the coarse filter analysis and findings for hardwoods and vertebrate species.

Structure of the report follows the five steps in a coarse-filter assessment of the effects of forest practices on contributions of hardwoods to sustaining biodiversity:

1) Review species present in the Defined Forest Area and dependent on or strongly associated with hardwoods.
2) Review natural levels of hardwoods in NE ecosystems.
3) Review impacts of current forest practices on hardwoods.
4) Assess the likelihood of 'unmixing' the mixed wood such that expected contributions to biodiversity are reduced.
5) Assess probable future amounts of hardwoods and their apparent adequacy.

The SFM plan referred to in this document is the of the Fort St. John Pilot Project participants, which include Canfor, four other licensees and BC Timber Sales.

2 Defining stand types

Practical definition of stand types is necessarily arbitrary. Stand types of Table 1 follow the BC Land Cover Classification Scheme (BCLCCS; BC MoSRM 2002). For example, hardwood-leading forest types are defined as having >75% hardwood species, conifer-leading as having >75% conifer species, and mixed wood as <75% hardwood or conifer. In the Northeast, Canfor participates in a regional working group that is formulating recommendations on boreal mixed wood management. That approach subdivides the mixed wood into two classes:

- Mixed-Coniferous: greater than 50% but less than 75% of total tree cover is coniferous
- Mixed-Deciduous: greater than 50% but less than 75% of total tree cover is deciduous

There are sound silvicultural reasons for distinguishing between conifer- and deciduous-leading mixed woods. It is also possible that some organisms distinguish between conifer- and deciduous-leading mixed wood as habitat. In the Fort St John TSA, most of the area is conifer-leading (63.5%); proportions of hardwood-leading (20.7%) and mixed wood (15.8%) are smaller. Within their planning for the Fort St John TSA, the Pilot Project further refines mixed wood by distinguishing leading species. We evaluated apparent selection ratios for mixed-coniferous and mixed-deciduous for 106 species. In total, 9 species showed statistically significant discrimination between the two broad mixed wood types, 6 of which are hardwood associates. Generally, for coarse-filter assessment of the DFA, three broad forest types (conifer, hardwood, and mixed wood) appear adequate when combined with age classes.

3 Species within the DFA associated with hardwoods

Data are most complete for vertebrates and among vertebrates are most complete for birds.

3.1 Birds

Habitat preferences are specified for the breeding season, with the exception of Ruffed Grouse that for most of the year feeds primarily on twigs and buds of mature male aspen. Current data indicate that 59 bird species within the DFA show preference for hardwood or mixed wood types or for hardwood cavity sites. Of these, 16 are responding primarily to understory under the canopy and 22 are cavity nesters. Hardwoods are sought as cavity sites because they are more rot-prone than conifers and compartmentalize fungi well, surrounding decay with sound wood. Still other bird species are strongly associated with willow or alder thickets, but predominantly in wetland or riparian habitats. Because habitat elements (understory, cavities, and wetland or riparian) can be critical, species dependent on them are assigned to Group 3 in the Species Accounting System (SAS; Bunnell et al. 2009b) and coarse-filter evaluation of effects of forest practice are addressed within understory, dead wood and riparian analyses. They can be tracked by forest type as Group 2 species *provided* the analyses of key elements show no probable limitation (see Bunnell et al. 2009a,b).

Table 1 lists all vertebrate species strongly associated with hardwoods, including those seeking cavity sites or understory under forest canopy. It summarizes the degree to which species are associated with forest types having a significant portion of hardwoods. Habitat types in Table 1 are designated: **NV** = non-vegetated (<5% tree cover; e.g., roadsides, gas wells, urban areas), **NT** = non-treed (<10% tree cover; e.g., non-commercial brush, wetlands, pasture, alpine meadows, seismic cutlines), **RD** = Recently disturbed (0-30 yrs); **H1** = Hardwood (31-90 yrs), **H2** = Hardwood (>90 yrs), **C1** = Conifer (31-140 yrs), **C2** = Conifer (>140 yrs), **MW1** = Mixed wood (31-90 yrs), **MW2** = Mixed wood (>90 yrs). Species listed **blue** rank highly (ranks 1 or 2) within the provincial Conservation Framework.[2] **Bold** in the table indicates a statistically significant preference for the habitat ($p < 0.05$); **red** indicates significant avoidance. Tests include the Bonferroni correction. 'Records' indicates the number of times the species was recorded from BBS routes over 3 years of sampling;[3] a value of 0 for records indicates the species was not encountered but is known or believed to be present. The habitat type to which it is assigned is given in [ ]. First and second choices indicate the apparent habitat preferences as expressed in the data. 'Avoid' represents habitats where observations are less than those expected if choice was not occurring. Significant indices of avoidance are emphasized.

The Pacific-slope and Cordilleran flycatchers are difficult to discern in the field and assumed sympatric in the region. The Bay-breasted and Cape May Warblers and Philadelphia Vireo are at the western edge of their range.

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[2] See Bunnell et al. (2009e)

[3] Data from the 3 years (2007, 2008, 2009) when orthophotos were used to accurately locate birds are employed in the analyses. Any analyses of trend should employ 2005 and 2006 data as well.

Table 1. Habitat affinity of birds known or believed present in the DFA and showing preference for hardwood and mixed wood forest types.

Species	Records	Habitat affinity: 1st Choice	2nd Choice	Avoid	Territory Size (ha)	Trend[a]
Group 2						
Hardwood leading						
American Redstart	191	**39/14 H1**	13/6 MW1	**14/50 C1**	0.4-0.7	-3.7
Bay-breasted Warbler	6	1/0 NV	1/0 H1		0.7-0.75[c]	11.4
Black-and-white Warbler	36	3/1 MW1	8/3 H1	**1/5 C2**	0.9-6.6	-1.7
Black-throated Green W	177	**62/21 MW2**	**39/14 H2**	**24/46 C1**	0.3-0.9	-4.7
Broad-winged Hawk	1	1/0 H1			1.5 km[b]	nd
Least Flycatcher	256	**92/13 H2**	**29/9 NT**	**4/50 C2**	0.1-0.2	**-4.9**
Ovenbird	193	**69/15 H1**	**41/16 H2**	**6/50 C1**	0.6-1.6	0.5
Philadelphia Vireo	12	1/0 MW1	3/1 H1	1/3 C1	0.3-4.0	0.2
Rose-breasted Grosbeak	136	**29/10 H1**	**29/11 H2**	**10/35 C1**	0.3-1.3	2.1
Ruffed grouse	19	5/1 H1	4/2 H2	**1/5 C1**	2.1-2.3	-1.2
Western Wood Pewee	20	5/2 MW2	2/1 NV	**0/1 MW1**	0.22-1.7	**-10.6**
Mixed wood						
Blue-headed vireo	16	1/0 MW1	5/2 MW2	0/1 NV	~3	1.0
Cape May Warbler	27	5/1 NV	2/1 MW1	**0/4 NT**	0.2-1.0	6.7
Magnolia Warbler	64	12/5 H2	14/8 MW2	**3/17 C1**	0.6-0.7	1.9
Merlin	1	1/0 MW2			0.16-4.6 km[b]	-4.3
Pacific-slope Flycatcher	4	2/0 MW2	1/0 H1		1-3.5	[-3.1]
Sharp-shinned hawk	2	1/0 MW2	1/0 C1		1.1-6 km[b]	nd
Warbling vireo	735	**103/55 H1**	**101/60 H2**	**88/192 C1**	1.2-1.5	-1.9
Western Tanager	113	**27/9 H2**	**37/13 MW2**	**2/9 H1**	1.4-4.0	0.0
Riparian						
Baltimore Oriole [R]	0	[riparian]			0.6-1.7	**-9.5**
Bohemian Waxwing[R]	2	1/0 H2	1/1 C1		nt	nd
Group 3c - cavities						
Upland birds						
American Kestrel s	3	2/0 RD	1/0 NV		0.1-1.75 pr/km^2	**-3.9**
Barred Owl	0				150-280	nd
Black-capped Chickadee	70	**18/5 H1**	7/3 NV	**0/10 C2**	1.5-5.3	**-5.7**
Boreal Chickadee	33	11/4 MW2	10/9 C1	**0/5 H1&2**	5+	-5.2
Boreal Owl **s**	0	[H2,MW2]			0.1-0.5 km[d]	nd
Downy Woodpecker	2	1/0 H1	1/0 H2		4.4-5.5	-1.8
Hairy Woodpecker	26	5/2 H2	6/3 MW2	**1/4 NT**	2.5+	1.5
House Wren **s**	2	1/0 H1	1/0 H2		0.2-1.7	-1.5
Mountain Bluebird **s**	4	2/0 NV	2/1 NT		5	-1.8
Northern Flicker	29	4/2 H1	5/3 MW2	**1/3 RD**	nso[e]	-0.2
Northern Pygmy-owl	0	[MW2,C2]			1.25-1.6 km[d]	2.5
Pileated Woodpecker	11	4/1 MW2	3/2 NT	0/3 C1	55-500+	2.5
Red-breasted Nuthatch	151	**48/18 MW2**	21/12 H2	**7/24 NT**	1-5+	**-13.1**
Tree Swallow s	0	[open,R]			0.1-0.2	0.2
Violet-green Swallow **s**	0	[open]			colonial	[**-4.8**]
Yellow-bellied Sapsucker	172	**47/20 MW2**	**28/14 H2**	**10/28 NT**	0.6-3.1	3.8
Riparian						
Barrow's Goldeneye s	0	[riparian]			0.05-1.85	[-5.3]
Bufflehead **s**	0	[riparian]			0.4-0.6	3.3
Common Goldeneye s	0	[riparian]			0.1	-3.4
Common Merganser **s**	0	[riparian]			none	19.0
Hooded Merganser **s**	0	[riparian]			none	[-3.8]
Group 3u – understory						
Alder Flycatcher	614	**283/99 NT**	**79/55 RD**	**33/85 C2**	0.2-3.0	**-4.1**
Canada Warbler	55	**19/4 H2**	15/7 MW2	**4/22 C1&2**	0.2-1.2	-2.5
Cedar Waxwing	15	7/2 MW2	3/1 H1	0/4 C1	nt[d]	-6.7
Common Yellowthroat	26	**16/4 NT**	3/2 RD	**0/4 C2**	0.2-0.9	-1.5
Connecticut Warbler	34	**17/3 H1**	7/3 H2	**1/14 C1&2**	0.25-0.5	-4.6
Dusky Flycatcher	2	[H,NT]			0.7	[2.7]
Fox Sparrow [f]	78	**20/2 MW1**	29/13 NT	**0/9 MW2** **1/11 C2**	0.25-1	-5.3
Lincoln's Sparrow	394	**53/8 NV**	**129/63 NT**	**30/55 C2**	0.1-0.2	-0.3

MacGillivray's Warbler[R]	34	7/3 RD	8/4 MW2	**0/1 MW1**	0.8-1.7	[-3.7]
Mourning Warbler	35	7/3 H2	4/2 NV	**3/9 C1**	0.6-1.0	4.1
Orange-crowned Warbler[R]	180	91/29 NT	36/16 RD	**5/25 C2**	0.2-0.7	-1.3
Red-eyed Vireo	108	**41/8 H1**	17/9 H2	**6/43 C1&C2**	0.9-3.7	0.7
Swainson's Thrush	937	**151/111 MW2**	**287/244 C1**	97/151 NT 19/42 NV	0.9-2.1	-0.4
Tennessee Warbler	**853**	**132/70 H2**	**213/137 NT**	**52/118 C2**	nt	3.7
White-throated Sparrow	539	**143/87 NT**	**73/48 RD**		0.2-3.0	**1.3**
Yellow Warbler[R]	51	16/4 H1	11/4 H2	**2/13 C1**	0.05-0.8	**-4.2**

[R] = frequently riparian; [a] Trend in Boreal Taiga Plains BBS routes (1998-2008) as analyzed by CWS; %/yr; significant trends in bold (negative in **red**); sample sizes usually are too small to yield significant estimates; [ ] trends for BC. [b] Mean distance between nests. [c] Territoriality breaks down during insect outbreaks. [d] No territory; does not defend a territory, likely because of patchy distribution of food. [e] nso = nest site only defended. [f] = the association with mixed wood appears anomalous; when tested in other DFAs, NV, NT and C are more often selected .

Distinctions between hardwood-leading and mixed wood are not sharply defined, nor do we expect them to be. Where samples were small (e.g., the Bay-breasted Warbler occurs only casually in the DFA) we relied on literature and data from adjacent tenures to assign habitat type. Some species exhibit different preferences in different parts of their range (e.g., Black-throated Green Warbler; Morse and Poole 2005) – in the Fort St John TSA the species shows a statistically significant preference for H2 and MW2, but preferred NT and C2 in TFL 48 (Bunnell et al. 2009c). Likewise, the Baltimore Oriole and Bohemian Waxwing use a variety of habitats, but often in riparian areas where hardwoods are usually common. Northern Waterthrush is closely associated with hardwoods such as willow and alder, but breeds primarily in thickets in bogs, swamps or margins of lakes and streams; it is considered a Group 3 species (wetlands and riparian). Swainson's Hawk frequently nests in hardwood species, but often in solitary trees near its hunting sites – grassland, steppe or agricultural areas. It is assigned to Group 6 (non-forested, man-made). Similarly, several species show stronger relations with understory than with overstory, even though they show specific relations to hardwood or mixed wood types (e.g., Canada Warbler, Connecticut Warbler, Mourning Warbler and Red-eyed Vireo). These species require the presence of shrubs so are treated as understory associates in Species Accounting Group 3 during analysis. The distinction between shrubs and hardwoods is arbitrary because the foraging tactics of some species lead to a tradeoff between overstory hardwoods and understory shrubs.

Habitat affinity was evaluated for 7 forested habitats, including recently disturbed (RD), and two non-forested habitats (NV and NT). Each ratio in Table 1 can be interpreted as a simple selection ratio of times observed over times expected if the birds distributed themselves across available habitat types without expressing choice. A value of 30/30 (selection index of 1.0) indicates the species was recorded in the type in the same ratio as the type was sampled, indicating no preference for or against the type. For example, Least Flycatcher has a ratio of (92/13) in old hardwood-leading. That means it was observed 93 times in H2 although expected only 13 times if sightings were distributed proportional to habitats sampled, yielding a selection index for hardwoods of 7.08. For the Ovenbird, the selection index for its most preferred habitat, young hardwoods, is 4.6 (69/15) and 2.6 (41/16) for its second choice, old hardwoods. It strongly avoids old conifer, showing a selection index of 0.12 (6/50 in C2). The selection ratios provide a repeatable index of how highly the species itself ranked the different habitat classes. Data for amphibians and mammals are being acquired opportunistically, which does not allow statistical evaluation. Birds, however, are the richest group of vertebrates so are emphasized among vertebrates.

Statistically significant **preferences** (first and second) and **avoidances** are summarized for bird species that are hardwood associates and can be monitored solely by forest type below.

	Vegetation type						
Response	**H2**	**H1**	**MW1**	**MW2**	**NT**	**C1**	**C2**
Preference	**6**	**5**		**2**	**1**		
Avoidance		1	1		1	7	3

The single preference for NT indicates that areas with less than 10% tree cover were sought. That species (the Least Flycatcher) shows a preference for swampy or muskeg forests that would sometimes be typed as NT. Group 2 species (monitored solely by forest type) summarized in Table 1 are characterized by similar natural history features (Table 2).

Table 2. Nesting and foraging preferences of birds present in the DFA and designated as Group 2 species (**bold** = significant at p <0.05). SAS =group and modifiers assigned within the Species Accounting System.

Species	**Obs**	**1st Choice**	**SAS**	**Nesting**	**Foraging**[1]
Hardwood leading					
American Redstart	191	39/14 **H1**	2:H1,HMW	Tree or tall shrub	GL : foliage – trees & shrubs
Bay-breasted Warbler	6	1/0 NV		Trees, shrubs	GL: canopy limbs & foliage
Black-and-white Warbler	36	3/1 MW1	2:H1,MW1	Ground near tree or shrub	Pr: bark of trees; less GL: foliage
Black-throated Green W	177	**62/21 MW2**	2:MW2,H2	Trees – often low	GL: twigs & branches
Broad-winged Hawk	1	[H]	2:H	Trees	Perch hunts often under canopy
Least Flycatcher	256	92/13 **H2**	2:H2,MW2	Trees – generally smaller ones	HA: from air from top of shrubs into leafy canopy
Ovenbird	193	**69/15 H1**	2:H1,H2	Ground; avoids dense vegetation	GL & Pr: ground & low vegetation
Philadelphia Vireo	12	1/0 MW1	2:H,MW	Tree – well up	Perch & Sally GL: tree foliage
Rose-breasted Grosbeak	136	**29/10 H1**	2:H1,H2	Low trees & shrubs; openings	GL: tree foliage; understory when in fruit
Ruffed Grouse	19	5/1 H1	2:H1,H2	Ground	GL: foliage, fruit, buds (winter)
Mixed wood					
Blue-headed Vireo	16	5/2 MW2	2:Mw	Shrubs, saplings	Sally GL: branches, leaves
Cape May Warbler	2	2/0 MW2	2:MW2	Trees	GL: canopy leaves & branches; HA
Magnolia Warbler	64	12/5 H2	2:H2,MW2	Trees	GL: tree & shrub foliage
Merlin	1	1/0 MW2	2:MW2,NT	Trees - semi open	Aerial forager – primarily birds
Pacific-slope Flycatcher	4	2/0 MW2	2:MW	Highly variable	HA & GL
Sharp-shinned Hawk	2	1/0 MW2	2:all	Trees	Aerial forager – primarily birds
Warbling Vireo	735	**103/55 H1**	2:H1,H2	Trees, shrubs	GL: foliage
Western Tanager	113	**27/9 H2**	2:H2,MW2	Trees - semi-open	GL (foliage) and HA
Western Wood-Pewee	20	5/2 MW2	2:all	Trees	HA & hover gleans; upper canopy

[1] GL = gleaning; HA = hawking, PR = probing Sally gleaning = sitting on a perch and flying out to capture prey

The large majority are primarily tree nesters (15 of 19), secondarily using shrubs. First choice in Table 2 is assigned to nesting rather than foraging habitat where these differ. Three of these 19 species are hawks taking small vertebrates; the others forage predominately by gleaning foliage (13 of 16). Of the three exceptions that are not hawks, one forages primarily by probing bark (Black-and-white Warbler), one in hardwood litter (Ovenbird) and one is a flycatcher taking prey from the air and by hover gleaning. In short, the vast majority are responding to insects feeding on hardwood foliage that is provided less protection by secondary compounds than is conifer foliage. About half use shrubs as foraging substrate and as nesting substrate or cover.

Within the DFA, we considered 59 species to be strongly associated with hardwood or mixed wood forest types or to seek hardwoods as cavity sites for nests, roosts and dens (Tables 1 and 3). Still more use shrubby hardwoods, such as willow, in riparian areas. Most of these species seek deciduous cover because that is where their prey or forage is concentrated. Data suggest that older forests host the most favourable shrubby conditions under canopy (see Bunnell 2009d and Table 1), but provide little insight into appropriate ages, other than the statistical associations summarized in Table 1. The lower boundary (>90 years) for older hardwoods was initially estimated from the requirements of cavity nesters.

Cavity nesters are not well sampled by BBS routes, and Table 1 indicates few statistically significant associations for them. Their preference for hardwood or conifer nest trees is better documented in more southern forest types (Table 3). Two forms of data are included in Table 3. One is the sparse data available in the BC Nest Records Scheme and sampling of Yellow-breasted Sapsucker by K.A. Squires. Whether the nest site was conifer or hardwood was inconsistently recorded so the percent of nest trees that were hardwoods can rarely be extracted. Sample sizes also are small, and where <10 the range of diameters is given. The designation 'live' or 'dead' also was inconsistently applied, so is sometimes indicated 'both'. The second form of data is a compilation of >120 studies from more southern forest types (Bunnell et al. 2010). Data are restricted to inland sites; coastal studies show use of larger nest trees, often predominantly in conifers. In these data from southern forest types, species may show a preference for conifer nest sites even when they show a preference for hardwood or mixed wood stands in northeastern BC. That reflects that fact that hardwoods are less common in most of the more southern studies, and some species are dominated by a single large samples from studies of conifer forests. For example, the sample for Pileated Woodpecker is dominated by the large sample extracted from Bull (1980) in ponderosa pine forests of Oregon. Four mammal species also prefer hardwoods as cavity sites (Table 3).

Table 3. Attributes of nest trees sought by cavity-nesting species showing preference for hardwood cavity sites in the Fort St John TSA. 'nd' indicates no data found.

	Northeastern BC			More southern forest types					
		%	%	Diameter (cm)		% Hardwoods		% Dead[b]	
Species	**mean**	**HW**	**Dead[a]**	**Con**	**Hdwd**	**%**	**n**	**%**	**n**
Birds									
American Kestrel	24-42		both	40.9	40.7	38.5	144	55.2	114
Barred Owl	45.5	84.4	47.6	52.9	49.1	96.1	26	26.9	26
Barrow's Goldeneye	26-38		both	nd	48.2	72.0	41	59.5	42
Black-capped Chickadee	12.7-17.9		stub	20.4	16.4	88.9	27	67.8	161
Boreal Chickadee	15	38.5	stub	nd	nd	55.6	18	87.3	31
Boreal Owl				56.5	43.7	69.3	75	57.1	21
Bufflehead	21-31		both	57.8	33.3	81.0	100	81.0	105
Common Goldeneye	28-40		both	nd	nd	100.0	16	6.3	16
Common Merganser	38		stub	nd	nd	nd	nd		
Downy Woodpecker	22			25.5	26.2	81.4	102	66.9	151
Hairy Woodpecker	24		both	37.2	33.8	39.4	350	69.4	258
Hooded Merganser				nd	42.7	nd	nd	50.0	8
House Wren	17		both	42	27.6	58.6	219	71.6	451
Mountain Bluebird	15.2-20		both	41.7	29.4	12.6	118	85.1	168
Northern Flicker	27			59	39.4	52.1	1157	59.5	1009
Northern Pygmy-owl	20		stub	54	nd	58.3	12	100.0	7
Pileated Woodpecker	35.7		live	78.3	49.5	23.8	362	77.2	346
Red-breasted Nuthatch	21.6	35	stub	50.8	32.4	71.7	498	89.3	498
Tree Swallow	20		both	31.8	29.3	53.8	234	89.0	245
Violet-green Swallow	20		stub	97.2		nd	nd	100.0	34
Yellow-bellied Sapsucker	37.6	100	9%	58.7	36.9	89.1	274	22.1	240
Mammals									
Big Brown Bat				56.9	39.2	68.0	94	38.0	94
Little Brown Bat				49.5	40.6	60.0	55	36.4	55
Northern Myotis				65.0	47.1	48.9	182	62.6	182
Fisher					54.7	100	27	0	27

[a] 'Both' indicates trees were both live and dead within the small sample; then a % is given that refers to both conifers and hardwoods

[b] The % refers to all nest trees – both conifers and hardwoods

Four of the 22 species for which there were data (Table 3) selected <50% of nest trees from hardwoods in more southern forest types. We believe this reflects the fact that studies for those species were concentrated on sites where hardwoods were sparse. For example, where hardwoods are more common, the northern myotis locates 100% of its roosts in hardwoods (Menzell et al. 2002). Attributes sought by cavity users associated with older hardwood trees are summarized in Table 3.

The third major group of hardwood associates is that showing strong, frequently limiting, affinities for understory. Significant preferences for this group are summarized below.

	Vegetation type								
Response	**NV**	**NT**	**RD**	**H1**	**H2**	**MW1**	**MW2**	**C1**	**C2**
Preference	1	5	3	2	3	1	1		1
Avoidance						1	1	5	9

Of the 17 documented preferences, 6 were for sparsely- treed, non-commercial types, 7 for hard-wood leading and mixed woods and 3 for recently disturbed. The sole selection for conifer is the second preference of Swainson's Thrush. Of 16 significant avoidances, 14 are of conifer.

Affinities for hardwood habitats by other vertebrates and organism groups are summarized below.

3.2 Amphibians

Because amphibians are insectivorous and hardwood litter often is richer in invertebrates than is conifer litter, amphibian species could show a preference for stands with more abundant hardwoods. Data from northeastern BC on amphibians is sparse and opportunistically collected. Opportunistic collection prohibits statistical evaluation. The largest sample was available for wood frogs which occurred in all 7 major forest type-age class combinations. Existing data suggest that the need for appropriate breeding areas dominates potential differences in surrounding forest types. The assignment of these species within the Species Accounting System to Group 3 (wetlands and riparian) appears appropriate.

3.3 Reptiles

Both the common and western terrestrial garter snakes frequent the vicinity of water bodies, particularly the common garter snake. Riparian areas often host hardwoods so these species could be hardwood associates secondarily. Within the Species Accounting System, the common garter snake is assigned to Group 3w (wetlands); the western terrestrial is assigned Group 3w,r (wetlands, riparian). Both species are uncommon in the area. Neither species is commonly found in forests; the western terrestrial garter snake shows a preference for open areas.

3.4 Mammals

Mammals are not included in Table 1 because we could not test their habitat selection. Among mammals, 12 or 13 species have some affiliation with hardwood or mixed wood cover (presence of the eastern heather vole is not confirmed). In most instances, the association is not pronounced and is a product of affinity for riparian areas (e.g., Pacific water shrew; western jumping mouse) or because they forage on young hardwood trees, shrubs and herbaceous vegetation that can be more abundant in hardwood than in conifer stands (e.g., long-tailed vole Townsend's vole, elk during winter). Some cavity-using bats show a marked preference for hardwood trees as roosting or denning sites (big brown bat, little brown bat, and to a lesser degree northern myotis; Table 3). These sites are sought out even when hardwoods comprise only small portions of the stand, so small inclusions of hardwoods in conifer stands can contribute significantly. Hardwoods are sought because they are more cavity-prone than are conifers. All den sites of fisher reported from the boreal (n=27) were large *Populus* (Weir 2009). Findings of Poole et al. (2004) and Porter et al. (2005) suggest that, in northeastern BC, marten also are seeking large hardwoods as denning sites, but that is not documented. About 42% of northern flying squirrel dens in boreal forests are reported from hardwoods (Bunnell 2010).

Browsing mammals (e.g., snowshoe hare, moose, mule deer and white-tailed deer) often favour young hardwood species as forage, but their diet typically is broad and also includes a large variety of forbs, shrubs and conifers. Most of these species are better considered shrub associates than hardwood associates. Only the beaver appears largely limited to hardwood trees and shrubs, but will take pine when hardwoods are unavailable. Because of its affinity for water, the beaver is classified 3w,r.

3.5 Invertebrates

In Sweden about 115 macro-lepidoptera and 350 beetle species inhabit living aspen (Bernes 1994). We know less about northeastern British Columbia (Kremsater and Bunnell 2010). We consider five butterflies in the northeast to prefer deciduous habitats: Long Dash (*Phyciodes batesii*), Meadow Fritillary (*Erynnis persius borealis*), Uhler's Arctic (*Limenitis arthemis rubrofasiata*), Alberta Arctic (*Roddia l-album watsoni)*, and Aphrodite Fritillary (*Polygonia faunus rusticus*). Several others use hardwoods (e.g. Mustard White, *Pieris oleracea*) but not as primary habitats. Carabid beetles have been studied in many forest types, but differences between hardwood- and conifer-dominated forests are not consistently evaluated. Several studies have documented Carabids in hardwood forests of adjacent Alberta (e.g., Jacobs et al. 2007, Langor et al. 2006, Niemelä and Spence 1994). We note 12 species in the northeast that typically prefer hardwood forests: *Cybaeopsis euopla, Pardosa mackenziana, Pardosa moesta, Pterostichus pensylvanicus, Trochosa terricola, Xysticus luctuosus, Ozyptila sincera canadensis, Patrobus foveocollis, Calosoma frigidum, Carabus chamissonis, Pterostichus oblongopunctatus and,Allomengea dentisetis,* More than 20 other species are also commonly found in hardwood and mixed wood forests (including *Agonum retractum, Calathus ingrates, Platynus decentis, Pterostichus melanarius, Scaphinotus marginatus* and *Synuchus impunctatus)*. Still more are forest generalists using all forest types. Generally, studies have focused on identifying carabids typical of younger or older stands and have not evaluated preferences for hardwood or coniferous forest. Jacobs et al. (2007) collected saproxylic[4] beetles on aspen and spruce snags in hardwood-dominated, hardwood-dominated with coniferous understory, and mixed wood stands in Alberta: 56 species were collected on both aspen and spruce, 22 only on aspen and 36 only on spruce. A total of 157 species were collected from aspen trees in hardwood-dominated (with and without coniferous understory) and mixed wood stands. Beetle species were different in hardwood-dominated stands compared to the hardwood-dominated with conifer understory or to mixed wood stands (there were no significant differences between the hardwood stands with coniferous understory and mixed wood stands). Jacobs et al. include a large appendix listing species and habitat associations. Lists of invertebrates confirmed in boreal forests can also be found at the
EMEND website:
http://www.emend.rr.ualberta.ca/Species_list/index.asp?page=EMEND_Species_List.
EMEND intends to analyze their data to look at associations of carabids with major forest types.

Throughfall below northern hardwood species is typically richer in basic elements, has a significantly higher pH and yields greater availability of nutrients (e.g., nitrogen) than does throughfall below conifer species (Nordén 1991). These factors can increase the abundance of forest floor invertebrates. Small natural or experimental inclusions of aspen litter in conifer forests created aggregations of land snails and predatory forest-floor arthropods (Niemelä 1997, Niemelä et al. 1992, 1996).

Because associations with tree species are less commonly reported than associations with diameter or decay state, most of the following comments on non-vertebrates do not distinguish between hardwoods and conifers. Once the tree, hardwood or conifer, is dead, it is impossible to separate the responses of invertebrates and fungi within wood because they influence each other. In old living trees, some suite of fungi will be present and may have initiated decay of the

[4] The long-standing definition associates saproxylic organisms principally with 'moribund or dead trees'. It is now appreciated that healthy living trees are arguably more important for many saproxylic invertebrates (Alexander 2008).

heartwood before the tree dies. These or similar fungi may not be present in a younger tree of smaller diameter, so when a young tree dies it often follows a different pathway during decomposition. There is thus strong potential for differences between large and small logs that can influence faunal diversity. These differences appear in wood-inhabiting invertebrates as well as fungi. For example, some lucanid and prostomid beetles are found only in red-brown rotted wood in advanced stages of decay (Araya 1993; Lawrence and Britton 1994). By contrast, some tipulid flies live only in wood invaded by white rot fungi and with very high moisture content; some elaterid beetles prey on these tipulids (Dajoz 2000). One consequence is that where a long history of forestry has reduced amounts of down wood in some decay classes, insect and fungal species dependent on down wood have declined or been extirpated (Eriksson 2000; Kaila et al.1997; Kirby and Drake 1993; Martikainen et al. 1999; Sippola and Renvall 1999; Väisänen et al. 1993). In such regions, a disproportionately large percentage of species dependent on woody debris of either hardwoods or conifers are either red-listed or considered rare and threatened (Ehnström 2001; Kirby and Drake 1993; Ranius and Jansson 2000).

Insects colonizing living or freshly dead wood often show narrow host specificity (Hamilton 1978), but specificity declines as decay progresses although large differences remain between hardwood and conifer trees (review of Grove 2002). Relations with piece size for insects are similar to those for fungi and smaller pieces are exploited than is true of vertebrates. Different diameters of down wood host different species assemblages. Small pieces serve some species, but larger diameters host more species (Grove 2002) and are particularly important for species that are now rare and threatened elsewhere (Araya 1993; Edmonds and Marra 1999; Kruys and Jonsson 1999; Ranius and Jansson 2000; Warren and Key 1991).

Critical metrics for insects are thus diameter, as for vertebrates, and a more finely-scaled gradient of decay than is true for vertebrates. Insects inhabit *all* stages of decay (review of Grove 2002). The role of wood-inhabiting invertebrates in decomposition, thus nutrient cycling, and presence through all decay classes indicate the importance of sustained provision of all decay classes by allowing some hardwood trees to die a natural death.

3.6 Fungi

Some fungal species show strong preferences for either hardwoods or conifers (Rydin et al. 1997; Sippola et al. 2005). Generally, hardwood logs host fewer species than do conifer logs. In Sweden, spruce logs hosted more fungal species than did aspen, birch or oak (Lindhe et al. 2004). Nonetheless, 312 fungal species are restricted to aspen in Sweden (Almgren 1990). Among fungal species, host specificity is highest in living or newly dead wood (Kaila et al. 1994) and declines as wood is decomposed.

As for vertebrates and insects, decay state and size are important metrics. To sustain the succession of decay and species richness there must be continual recruitment of down wood on site. Where forestry has been practiced longer, as in Europe, large portions of the threatened forest-dwelling organisms are dependent on dead wood (references for invertebrates above and review of Yee et al. 2001). Swedish studies have found that fungal species richness peaks in the intermediate stages of decay (class 2 and 3; Bader et al. 1995; Kruys et al. 1999). However, the requirement to retain a range of decay classes means there must be recruitment of dead wood in managed forests just as there is in natural stands. Most threatened down wood associates in Sweden (53%) preferred logs 5 to 50 years after death; 18% preferred younger logs (0 to 5 years old), and only 2% preferred logs >50 years old (Berg et al. 1994). In managed stands, early stages of decay were abundant and the oldest stages were still present as old stumps, but the lack of recruitment of down wood reduced the amounts of preferred age classes, and apparently has influenced the persistence of some fungal species. Given that some vertebrates forage on fungi and insects in downed wood, reductions of these food sources eventually appear higher in the food chain.

Fungi profit from a greater range in size classes of downed wood and length of piece becomes more important than is documented for vertebrates. Among fungi, small diameters host specific species, but pieces of larger diameter support more species of fungi, including species limited to large pieces (Kruys and Jonsson 1999; Nordén and Paltto 2001). In Danish beech stands, smaller pieces hosted more fungal species per volume than did larger pieces (Heilmann-Clausen and Christensen 2004). Although there was no association of species richness with piece size, some threatened species were absent on small pieces. The authors concluded, "…[pieces of] small diameter wood appear to be unable to support heart-rot agents and other species depending on a long and diverse infection history and thus the integrity of saproxylic[5] communities may be seriously undermined if only small diameter cwd is left for decay." (Heilmann-Clausen and Christensen 2004:105). They continued (p. 105), "Therefore, we strongly recommend that whole, naturally dead trees, representing the full range of cwd habitats, are prioritised for natural decay in managed forests whenever possible."

Swedish data, across a variety of tree species, report significantly greater fungal species richness in larger diameter logs. While larger diameter pieces support greater species richness, fine debris (twigs, small branches) is necessary, with different groups of fungi better represented in either fine or coarse material (Nordén et al. 2004). Length of dispersed logs is less informative than diameter for most fungal species, but may be important for some. For example, the abundance of truffles and truffle-like fungi was related to the amount of forest floor covered by logs in Douglas-fir forests (Amaranthus et al. 1994, Carey and Johnson 1995). These species fruit below ground so spores are not dispersed by wind; they are generally dispersed by small mammals feeding on the fruiting body (Maser et al. 1978; Maser and Trappe 1984; Carey and Johnson 1995). Contact with the ground is important for colonization of new substrate and more forest floor is covered if logs are longer and not piled. In summary, a range of diameters, including very small, is necessary to support the entire range of fungi, length of piece is significant for species requiring contact with the ground, and dispersed debris contributes more to sustaining fungal richness than piled debris.

The EMEND website (noted above) has lists of fungi, lichen and bryophyte species found in Alberta's boreal forest and therefore expected in BC's boreal forests, but details on habitat associations are not included. In Alberta, Lazaruk et al. (2005) examined effects of partial cutting on the ectomycorrhizae of white spruce but did not include hardwood stands.

3.7 Lichens

In European boreal forests, *Populus tremula* (aspen) could be viewed as a keystone species, being a host for many species of epiphytes (Almgren 1990; Berg et al. 1994; Gustafsson and Eriksson 1995; Gustafsson et al. 1992a,b, 1999; Hazell et al. 1998; Hedenås and Ericson 2000; Kuusinen 1996) and insects (Bernes 1994; Siitonen and Martikainen 1994). Features contributing to nutrient rich throughfall and the abundance of forest floor invertebrates also are important influences on species composition and diversity of lichens and bryophytes (Barkman 1958; Sjögren 1995; During and Verschuren 1988; Weibull 2001). Because of these influences, northern hardwood species in Europe sometimes are referred to as rich-bark species (Du Rietz 1945). North American aspen (*Populus tremuloides*) also is a 'rich-bark' species.

There are two potential ways, not readily separable, by which the presence of hardwoods can increase the richness of lichens in an area. One is that some epiphytic lichens are specifically associated with hardwood tree species (likely in response to bark characteristics). The second is that the presence of hardwoods may increase lichen species richness in their immediate surrounds. The relative role of hardwoods and conifers as substrate for lichens is difficult to quantiy and varies regionally. We know:

- In boreal forests generally, a proportion of epiphytic lichens are completely or largely restricted to hardwood tree species (Brodo 1974; Gustafsson et al. 1992a; Kuusinen 1994a,b; 1996).

[5] The broad definition is organisms that depend on wood, usually but not always dead wood, for some part of their life cycle.

- In their review of northern lichen florae, Lõhmus and Lõhmus (2001) found that hardwoods generally supported greater richness than did conifers.
- In Sweden, 82 lichen species are restricted to aspen (Almgren 1990).
- In Finland, the average number of lichen and bryophyte species per tree varied with area but ranked: spruce – 18, aspen – 20 and willow – 31 species (Kuusinen 1996). In this study, most species on aspen were bryophytes, not lichens, but findings of Lõhmus and Lõhmus (2001) indicate that hardwoods support significant lichen richness in some areas, even when trees are dead.
- Boudreault et al. (2008) reported 41 epiphytic lichens from aspen in northeastern BC.
- In their review of lichens occurring on wood without bark in the Pacific Northwest and Fennoscandia, Spribille et al. (2008) found that of 122 lichen species for which substrate was well documented, 80 appear restricted to conifers, 13 occur on both hardwoods and conifers and only 9 appear restricted to hardwoods. Given the role that bark plays in substrate specificity (Barkman 1958; Culberson 1955) the proportion restricted to hardwoods among living trees is almost certainly higher.
- In British Columbia, marginally more cyanolichen species have been collected from conifers (43) than from hardwoods (38), even though conifers cover a much larger area (Goward and Arsenault 2000b). Overall, 12 cyanolichens are reported exclusively from conifers and 4 exclusively from hardwoods. The latter may be a product of cyanolichens being much more prevalent in wetter climates (ICH, CWH), where hardwoods are less abundant. Boudreault et al. (2008) reported 7 epiphytic cyanolichens on aspen in northeastern BC.

Combined, these studies reveal that a significant portion of lichen species are unique to hardwoods, so hardwoods contribute significantly to lichen species richness simply by providing favourable substrate. It is noteworthy that the proportion of cyanolichens supported by hardwoods increases dramatically in 'dry maritime' variants compared to wetter variants (Goward and Arsenault 2000b). That may occur because the orientation of hardwood branches encourages a more centripetal flow of water than in conifers and helps maintain the moisture levels required by cyanolichens.

The presence of hardwoods appears to increase the richness of both lichens and bryophytes in an area beyond that directly attributable to substrate specificity (Goward and Arsenault 2000a; Hauck and Spribille 2002; Gustafsson et al. 1992b; Neitlich and McCune 1997; Rambo and Muir 1998). For lichens the phenomenon appears to be a response to the 'dripzone effect' – *Populus* species stimulate greater richness on adjacent conifers (Goward and Arsenault 2000a; Hauk and Spribille 2002). The specific mechanism is unclear, but higher levels of calcium and lower levels of manganese in leachate from *Populus* and *Acer* may be involved.

Bunnell et al. (2009f: Appendix 1) lists lichens that are potentially found on hardwoods in the northeast of BC. That list was extracted from the larger document of Houde and Paczek (2003) and Kremsater and Bunnell (2010) that listed all lichens potentially occurring in northeastern BC and listed their habitats. Of the 58 lichens that are sometimes found on hardwoods, seventeen (*Bacidia carneoalbida, Bacidia obsurata, Caloplaca cerina, Catillaria glauconigrans, Lecanactic sp., Lecania dubitans, Lecanora impudens, Lecidella euphoria, Melanelia trabeculata, Melanohalea olivacrodies, Melanelia septentrionalis, Cladonia umbricola, Ramalia dilacerta, Usnea substerilis, Physcia stellaris, Usnea glabrata, Leptogium saturninum*) seem to use hardwoods as their primary habitat. *L. saturninum* is found mostly on old hardwoods (2:H2). In total, 77 other species are associated with conifers; of those, some use hardwood trees as secondary habitats.

3.8 Bryophytes

Many bryophytes appear to be habitat generalists, which suggests that their diversity might be maintained by differences in reproductive niches or by stochastic factors affecting disturbance or success in establishment, rather than by sharply defined niches as expected under classical niche theory (Slack 1990). Nonetheless, richness of bryophytes may be increased by the presence of hardwoods in the same two ways noted for lichens. Ranges of mosses in the province are poorly understood; the EMEND website (noted p. 13) lists bryophytes occurring in Alberta that likely also occur in northeastern BC. We note 7 mosses (*Timmia megapolitana*, *Orthotrichum elegans, Othrotrichum obtusifolium, Pylaisiella polyantha, Sanionia uncinata*, *Orthotrichum striatum*, *Ptilidium pulcherrimum*) and one liverwort (*Porella cordaena* on maples) closely associated with deciduous forests. Available data do not permit determining whether ranges of all of these include northeastern BC (Kremsater and Bunnell 2010).

The data base summarizing conservation priorities within the provincial conservation framework lists more than 100 bryophyte species as priority 2 and about 20 as priority 1.[6] A blue-listed moss (*Timmia megapolitan)*, noted above as usually found in hardwood habitat, is apparently present in the northeast but is not listed in the database as priority 1 or 2. That is, no bryophyte species known to occur in northeastern BC and primarily associated with hardwoods is designated priority 1 or 2 within the BC system of conservation priorities. Boudreault et al. (2008) documented the epiphytic lichen and bryophyte flora on aspen trunks in northeastern BC, but did not make comparable assessments on conifers. As with lichens the relative contributions of hardwoods and conifers as bryophyte substrate is difficult to quantify and varies regionally, being greater where hardwoods are more prevalent. More generally, it is documented that:

- Much of the high epiphyte species richness reported from *Populus* in Finland was attributable to bryophytes, not lichens. (Kuusinen (1996: 456) noted that "The most conspicuous difference between the conifers and the deciduous trees was the absence of bryophytes on the former trees". Actually, they were not 'absent', but significantly reduced.
- In Sweden, 15 bryophyte species are restricted to aspen (Almgren 1990).
- In north and central Sweden, 20% of the red-listed epiphytic bryophytes occur on aspen (Hallingbäck 1996).
- The nemoral forest of Sweden (hardwoods: maple, beech, oak) hosted a greater richness of red-listed bryophytes than did other forest types (Gustafsson et al. 1999). This forest type, however, is much reduced from its original extent.
- Boudreault et al. (2008) reported 13 epiphytic bryophytes from aspen in northeastern BC.
- In northern Alberta, hardwood logs had higher bryophyte species richness than did conifer logs (Mills and Macdonald 2004).
- For coastal forests in Oregon, Rambo (2001) reported 3 moss and 1 liverwort species restricted to hardwood stem bases. These mosses have been found on other substrates in other studies, indicating that substrate affinities are variable and ill understood.
- On bigleaf maple in coastal forests of Washington, epiphytic mass (predominately bryophytes) was 35.5 kg/tree, equivalent to about 4 times the foliar biomass of the host tree (Nadkarni 1984).
- Bryophytes in dry Garry oak areas differ from coastal coniferous areas (Sadler 2004).

In short, hardwood trees in areas adjacent to or similar to the Fort St John TSA (and elsewhere) are an important substrate for bryophytes and host some species that are not found on conifers.

Bryophytes also appear to exhibit an apparent 'adjacency' effect analogous to that for lichens in which areas with hardwood cover support greater bryophyte richness beyond that expected from simple substrate specificity. In Oregon, Rambo and Muir (1998) reported that the presence of hardwoods in a conifer stand increased richness of bryophytes on the forest floor. They attributed this to either temporary incorporation into the ground layer via litterfall or to establishment in humus (Rambo and Muir 1998). They did not exclude phenomena similar to the

[6] See Bunnell et al. (2009e) for discussion of the provincial conservation framework and its goals.

'dripzone effect' reported for lichens, and that effect appears real (e.g., Du Rietz 1932; von Krusenstjerna 1965; Weibull 2001). It has been elegantly demonstrated in Sweden by Weibull and Rydin (2005). Boulders under base-rich tree species (ash, elm and maple) were occupied by twice as many bryophyte species as boulders under spruce (Weibull and Rydin 2005). Because siliceous boulders are so chemically homogeneous, the differences among them should be largely attributable to the canopy directly overhead. The rank order of bryophyte richness on boulders was as expected from values of bark pH and litter decomposability of the tree species above them, suggesting that throughfall and litter quality are important factors behind the relationship between canopy species and bryophyte species composition and richness, even on rocks.

In summary, hardwoods definitely increase bryophyte richness in stands by provision of suitable substrate, often more suitable than conifers in northern forests, and also may increase richness through mechanisms apparently related to leachate from hardwood canopy.

3.9 Vascular plants

Unlike temperate forests, vascular plant epiphytes on standing trees in boreal forests, including mistletoes, are absent or rare. Both hardwood and conifer logs host vascular plants. Conifer logs make a greater contribution primarily because they last longer. Rotting wood is particularly important in conifer forests of the Pacific Northwest because it covers more of the forest floor there than in other regions (6 to 25%; Harmon et al. 1986), and because seedling density is greater on rotten wood than on the forest floor (Christy and Mack 1984; McKee et al. 1982). In aspen forests, logs and stumps >20 cm diameter captured 95% of the colonizing vascular plant species (Lee and Sturgess 2002). Smaller diameter logs and stumps were colonized only by small forbs such as *Mitella nuda, Linnaea borealis*, and *Cornus canadensis*, whereas larger diameter logs and stumps were colonized by shrubs and saplings as well.

None of the red- or blue-listed vascular plants in northeastern BC appear to be largely limited to hardwood stands Kremsater and Bunnell (2010). Nor are any of the high priority (priority 1 or 2) plants listed in the Conservation Framework database as occurring in the forest districts of northeastern BC associated with hardwoods. One candidate vascular plant*, Prenanthes alata* (priority 2 for Goal 2*)*, is not associated with a Forest District associated in the conservation priorities database, but the known distribution suggests it could occur in northeastern BC and it is associated with broadleaved forests.

3.10 Summary

The presence of hardwood trees in otherwise homogeneous coniferous forests increases species richness and may increase ecosystem productivity (Boettcher and Kalisz 1990; Saetre 1998). Appropriate forest age classes for describing hardwood associates were initially derived from the larger vertebrate data base. Review of bird associations with hardwoods indicates that amounts and age are informative metrics. Among hardwood associates responding primarily to forest type (cf. habitat elements such as cavity sites or understory), about 60% of first and second significant preferences were for older hardwoods and mixed wood and 35% for younger hardwoods (31 to 90 years old; the single preference for NT cannot be assigned an age); more than 75% of significant avoidances were for conifer stands (Table 1). The proportion preferring older hardwood or mixed wood stands increases when cavity users are added. Non-vertebrate groups were evaluated to ensure that approaches developed for coarse-filter assessment of vertebrates did not omit important measures. Knowledge in British Columbia for non-vertebrate groups using hardwoods as substrate is less complete than for vertebrates, but generalities can be extracted from the literature. For the Fort St John TSA, literature from boreal regions is most applicable. It is likely that some non-vertebrates do well in young hardwood stands, but current literature from areas where forestry has been practiced longer suggests that most threatened species occur in products of older stands (references above). That, in turn, suggests that the metrics informative for evaluating dead wood (specifically: amount, decay state and diameter) are sufficient to assess contributions of hardwoods.

Specific values, however, may differ. In Fennoscandia, several authors have reported the number of epiphytes on *Populus tremula* is strongly correlated with trunk diameter (e.g., Gustafsson and Eriksson 1995; Hazell et al. 1998; Ojala et al. 2000). Although decay and tree species have greater influences on the species composition of communities of wood-inhabiting organisms, log diameter has greater influence on species richness for fungi (Bader et al. 1995; Høiland and Bendiksen 1997; Heilmann-Clausen and Christensen 2004), lichens (Bunnell et al. 2008; Söderström 1988), bryophytes (Andersson and Hytteborn 1991; Humphrey et al. 2002; Söderström 1988,1989), insects (Grove 2002; Jonsell et al. 2001; Siitonen and Saaristo 2000) and vascular plants (Lee and Sturgess 2002). Fungi and possibly invertebrates benefit from much smaller pieces of debris than are exploited by vertebrates. Wind speeds are much slower near the ground hindering dispersal of some species, so dispersed down wood is more beneficial than piled down wood. Moreover, for species growing on down wood, piling debris reduces the surface area exposed to reception of propagules. In northeastern BC, epiphytic flora on aspen trunks varied with site index, seemingly as a function of bark roughness; Boudrealt et al. (2008: 101) noted that "…management for epiphyte community diversity in aspen dominated landscapes will necessitate the retention of mature aspen stands from across a range of site productivities."

No metrics beyond those used to assess contributions of dead wood appear necessary. Both vertebrate and non-vertebrate associates of hardwoods are accommodated by metrics used for coarse-filter evaluation of dead wood (Bunnell et al. 2009a); nor is there evidence to suggest that the boundary used to designate older age classes (90 years) differs between vertebrates and non-vertebrates. Small diameter pieces, however, make greater contributions to non-vertebrates and length of log is more important than for vertebrates.

4 Natural levels of hardwoods in the Fort St John TSA

Many of the species that occur in the TSA and are strongly associated with hardwoods seek older hardwoods (review above). SFM plan participants adopted the Land Use Planning Guidelines to create 'natural' targets for species composition by Landscape Unit. Late-seral targets currently are specified by BEC and LU and broad terrain units (e.g., upland, mountain and alluvial). The plan is undergoing revision and those targets will be stratified by Natural Disturbance Unit rather than Landscape Unit. The targets presently do not explicitly specify forest type (e.g., conifer-leading, hardwood-leading) but the BEC and terrain combinations represent broad natural strata for forest type. For forest type the overall goal is to retain the proportion of each broad forest type over the entire DFA similar to natural baselines. Targets are specified for each of 4 forest types within each Landscape Unit – deciduous (hardwood) leading, conifer-leading, deciduous-mixed wood, and conifer-mixed wood. Recall that stands labeled 'conifer-leading' can have up to 25% inclusions of hardwoods.

Levels assessed from 2008 data (Table 4) are: 63.5% conifer-leading, 20.7% hardwood-leading and 15.8% mixed wood. About 41% of mixed wood is deciduous leading. Global warming appears to be shifting 'natural' targets by encouraging hardwoods (Bergeron et al. 1998; Grant et al. 2006). Long-term downward trends in the proportions of hardwood-leading and mixed wood should be interpreted as 'unnatural'.

5 Current forest practices and hardwoods

Practices that can have a deleterious effect on amounts and kinds of hardwoods within the DFA are those that:

1) reduce the amount of older age classes of hardwood or mixed wood types sought by some species,
2) reduce the proportion of hardwoods in mixed wood types below the level at which the mixed wood contribution to species richness is sustained,
3) reduce the amount of hardwoods through vegetation management,
4) convert significant amounts of hardwood or mixed wood types to conifer-leading types, and

5) inadequately protect riparian areas that are predominantly hardwoods.

The ways in which each of these effects can be influenced by forest practices and key measures of the potential impact are briefly reviewed before assessing current practices.

5.1 Reduction of amounts of older age classes of hardwood or mixed wood types

Species showing an affinity for hardwood or mixed wood types most often sought the oldest age class (>90 years; Table 1). That is true whether they were responding primarily to forest type, hardwoods as cavity sites or shrubs under canopy. There are three potentially useful descriptors for assessing the amounts of older age classes of hardwood or mixed wood types: 1) total and reserved area of the types, 2) age distribution within types as an index of continued provision, and 3) patch size distribution (particularly of older age classes where these are relatively uncommon). The latter two are potential modifiers of the suitability of the total area of hardwoods or mixed woods. Appropriate total area of hardwood types can be indexed only by current natural levels and these appear to be changing with climate change. Older age classes are a key feature of hardwoods because these provide cavities necessary for several cavity users and substrate for various lichens, mosses, and habitat for invertebrates. In some forest types, organisms avoid forest edge and use only larger patches. That tendency is not pronounced in hardwood or mixed wood types (see below).

i) Age of trees

In the SFMP, late seral is defined as greater than 100 years for deciduous-leading stands (compared to greater than 140 years old for conifer-leading stands). Hardwood trees are typically shorter lived than conifer trees, and when hardwood stands are left undisturbed for long periods they either die and cycle back to a similar species composition or convert to coniferous stands (the latter tendency is increasingly unlikely as climate change shortens the fire-return interval and encourages hardwoods). The length of period to die back is ill-defined in a clonal species, but appears to be about 100 years. In Alberta, Stelfox and co-workers described forest structure and composition of plant and animal communities in young (20–30 years), mature (50–65 years) and old (120+years) aspen mixed wood stands of fire origin (Stelfox 1995). Hardwood stands greater than 120 years old were structurally distinct from young and mature (50-65 year-old) stands. The older stands contained fewer stems, larger diameter trees and higher levels of coarse woody debris. There is, however, a large gap between 65 and 120 years and a biological lower limit to 'old' stands is unclear; nor is a sharp boundary expected.

Stand age is most clearly important for the cavity users because of the role that decay and size play in cavity-tree selection. Fifteen cavity-nesting bird species and at least 3 mammals seek hardwood trees as nesting, den or roosting sites, including the keystone excavator for the region, the Yellow-bellied Sapsucker (Table 3). Farther south the fisher uses primarily conifers; in northeastern BC, Weir (2009) found 27 maternal and natal dens of fisher, all in hardwoods ranging from 37 to 65 cm dbh (mean 54.7 cm). By evaluating quadratic mean diameter of major forest types by age class (see Bunnell et al. 2009a) we can determine lower boundaries that will provide suitable trees, guided by values of Table 3. We determined these boundaries to be >90 years for hardwoods and mixed wood and >140 years for conifers. Review of the literature for non-vertebrate organisms provides no evidence that hardwoods markedly older than 90 years are required. That is expected given that aspen stands begin to break up at about 100 years of age or soon after.

ii) Age distribution

Age distribution is revealing of potential future problems in sustained provision of all decay stages or older age classes. Any gaps in the existing distribution foretell potential problems. Similarly, some practices have the potential to create gaps in the distribution of age classes, or the broad equivalent of decay stages (e.g., intensive utilization of downed wood).

iii) Patch size

Potential effects of patch size on the quality of deciduous forest habitats are not well documented. As for conifer forests, edge effects will benefit some species and negatively affect others. Stand structures and attributes vary around edges, where there may be more blowdown, more radiation and lower humidity. In terms of responses of organisms to patch size of hardwood forest, none of the species listed in Table 1 are reported to avoid edges, and many in fact prefer edges. North American work evaluating effects of edge on epiphytic lichens and mosses has concentrated on species preferring conifers. Work elsewhere addressing epiphytic species with affinities for hardwoods included species present in North America and found few strong negative edge effects (e.g., Coote et al. 2008; Dettki et al. 2000; Löbel and Rydin 2006; Pharo and Zartmann 2007), though there are exceptions (Belinchón et al. 2007). Both bryophytes and lichens in small patches or on single trees after harvest are less robust than when within larger patches (e.g., Hazell and Gustafsson 1999; Lõhmus et al. 2006) but bryophytes and particularly liverworts generally suffer more in small patches (e.g., Botting and Delong 2009; Gignac and Dale 2005; Lõhmus et al. 2006; Nelson and Halpern 2005). In their review, Pharo and Zartmann (2007: 317) concluded that "reduced dispersal capacity, as opposed to the impacts of altered forest edge micro-climates is the causal mechanism accounting for abrupt declines in bryophyte diversity in [small patches]." What is 'small' is less clear, definitely less than 10 ha, but 1 ha may be adequate for 'life boating' the species until the forest regenerates (Hazell and Gustafsson 1999; Lõhmus et al. 2006; Nelson and Halpern 2005). The smallest patch size class in analyses following is 2 to 10 ha, which appears adequate; even single trees are some help (e.g., Hazell and Gustaffson 1999). Given our incomplete knowledge, it is prudent to have some deciduous stands, particularly older stands, in forest interior conditions. There is no unequivocal way to develop credible targets for patch size distribution from available data. What we know about patch size is that a range of patches generally is appropriate.

The most useful broad measure for assessing the contribution of hardwoods to sustaining biodiversity is total area of hardwood-leading and mixed wood types in age classes >90 years old. Patterns of age class distribution can foretell potential problems resulting from gaps in the age distribution (thus decay stage). Trends in patch size distribution (e.g., towards smaller average patch size) also may foretell problems, but categories of patch size are necessarily arbitrary (see p. 27).

5.2 Reduction of the proportion of hardwoods in mixed wood types below the level at which the mixed wood contribution to species richness is sustained

Because some species prefer hardwoods and others conifers, mixed wood stands are expected and appear to support uncommonly high levels of biodiversity and contribute disproportionately to species richness (Bunnell et al. 2002; Hobson and Bayne 2000). It is for that reason that mixed wood types were treated separately in evaluating species associations with broad forest types. Concern has been expressed about 'unmixing' the mixed wood and losing that contribution to sustaining biodiversity (Cumming et al. 1994; Enoksson et al. 1995; Hobson and Bayne 2000). It is a concern primarily where mixed wood types are common, as in the boreal, sub-boreal and southern interior, but small inclusions of hardwoods increase species richness in coastal forests as well (Huff and Raley 1991). Potential consequences cannot be evaluated without an ecologically-based definition of the boundaries of conifer and hardwood that confer the apparent 'mixed wood benefit'.

Currently, the principles in the SFMP include providing for stand composition and stand structure that emulate natural baseline information as reflected in the forest type composition at the time of writing of the SFMP. Conifer-leading and conifer-leading mixed wood types contribute to the coniferous timber harvesting land base; deciduous (hardwood)-leading types and deciduous-mixed wood types contribute to the deciduous timber harvesting land base. The SFMP identifies a strategy for managing the reforestation of mixed wood stands that allows them to be blended into the harvest profile. Mixed wood stands, although composed of different species, tend to be broadly even-aged as a result of forest succession following disturbance. In coniferous-leading mixed wood stands, the conifers may not have reached typical harvesting age when hardwoods or deciduous already are in decline. It is not the intention to consistently regenerate an area back to the same species composition as was harvested. Instead, over the broader landscape and through time, the distribution of forest types will be maintained within the baseline target range for each broad forest type (Natural levels, §4 above). Management does not plan for mid-rotation hardwood entries, but anticipates waiting until conifers are large enough to form a saw log.[7] The management intent is to regenerate these sites back to a similar species composition when tracked at the Landscape unit. The current SFMP suggests biological constraints must also be considered within a mixed wood management strategy (but does not elaborate on those constraints).

Similarly, the SFMP suggests that minor components of commercial hardwood species that occur in coniferous stands will be managed over the total land base to achieve a variety of landscape level objectives (but doesn't expand on what the objectives and impacts on hardwood might be). Targets for proportions of forest types to be retained are based on what occurred in each LU at the time of analysis for SFMP (give or take 20%). The assumption that these values are "natural" is credible, but unlikely to remain applicable in the face of climate change. If the proportion of each type over the entire DFA remains similar to targets derived from nature, the various treatments of hardwoods should result in hardwoods of a variety of age classes over the landscape. Management regimes will range from maintaining mature hardwood stems on site (to contribute to non-timber resource values) to removing all hardwood volume where resource values will not be compromised and economic conditions permit. Hardwoods harvested incidentally from conifer-leading stands contribute to the conifer AAC and are accounted for accordingly. Hardwood species in predominantly conifer stands are likely old and making their greatest contribution to sustaining biodiversity. Small inclusions of hardwoods appear to make significant contributions to biodiversity, so monitoring should not rely only on accounting used to track AAC.

Although first principles suggest that current practices will maintain varying forms of hardwood cover, lack of clarity about the ecological contributions of mixed wood remains. It is possible that quite small amounts of either hardwoods or conifers make a significant contribution to maintaining species richness within mixed wood types (see lichens and bryophytes above). Consequences of forestry practices on mixed wood would be better evaluated with an ecologically-based appraisal of suitable proportions of hardwood and conifer in mixed stands to confer the apparent mixed-wood increase in richness.

Currently, there is no simple measure of amounts of either conifers or hardwoods in mixed wood that confer benefits to biodiversity. The approach used here to define mixed wood from the BCLCCs (e.g., Table 1) is potentially inadequate. Studies working towards an ecologically-credible definition have been initiated in the Fort St John TSA (Preston 2008a, 2009a).

5.3 Reduction of amount of hardwoods through vegetation management

Vegetation management to permit establishment of crop trees can deliberately or inadvertently reduce the amount of hardwood tree species. Species targeted during vegetation management are diverse and include grasses, herbs, shrubs and young hardwood trees. During vegetation management, hardwood species are reduced, but frequently only temporarily.

Questions helpful in assessing the long-term consequences of vegetation management on sustained provision of hardwoods and associated biodiversity include:

- What area is treated by vegetation management annually to control hardwoods?
- How quickly do hardwood tree species (including willow) recover following vegetation management?
- What proportion, if any, of hardwood species is 'permanently' removed by vegetation management?

[7] Note this policy helps to ensure the presence of older hardwood trees.

The latter question can be addressed only through long-term study. Addressing the first two questions can estimate the short-term reduction in hardwood cover below amounts that would follow harvest without subsequent vegetation management. Much of this reduction is likely temporary and relevant only if amounts of hardwood and mixed types appear limiting. Given that duration of treatment effects plays an important role, the simplest measure is how quickly and to what degree hardwood vegetation recovers after vegetation management. That question also is under study (Preston 2008b, 2009b).

5.4 Conversion of hardwood or mixed wood types to conifer-leading types

As noted in §5.2 above, conversion to conifer-leading may be deliberately planned for some sites, but the intent is maintain the mix of forest types across the DFA that existed at the time of writing the initial SFM plan. Revisions to the plan exploit updated inventory. In some instances, local conditions, are more likely to favour conversion to conifer-leading than to hardwood-leading stands. In other areas (such as those supplying the OSB mill), stands will likely be kept predominantly hardwood. When we consider conversion of hardwoods to other stand types, we are primarily focused on practices such as planting and selective harvesting that, together with vegetation management, can convert hardwood or mixed wood types to conifer-leading types on a permanent basis.

The simplest measure is trend in the relative areas of conifer-leading, hardwood-leading and mixed wood forest types. However, ecological consequences of increasing the proportion of conifers in stands are difficult to evaluate without a better understanding of the proportions of deciduous or coniferous trees that confer the mixed wood advantage to biodiversity.

5.5 Retention of riparian and associated hardwoods

Hardwoods are abundant in riparian areas of the DFA. Some of these hardwood species are non-commercial (e.g., willows, old poplar), but still make significant contributions to biodiversity. There may be pressure to convert some riparian areas to conifers because: i) conifers often are more valuable species, ii) some down wood in streams is beneficial and conifer wood lasts longer. To assess the impacts of forest practices on hardwoods within riparian areas, the simplest set of questions is:

- To what degree are riparian areas protected?
- Can hardwood elements in riparian areas be mapped and monitored?
- Do practices in the Riparian Management Zone protect hardwoods?

For some non-vertebrates susceptible to microclimate (e.g., bryophytes; Hylander et al. 2005) actual buffer width is important. For vertebrates, buffer width is important primarily as it influences amount of habitat, probability of disturbance and the integrity of the wetland or stream. Birds strongly associated with riparian areas show little edge effect, making width a simple determinant of amount of habitat. The SFMP of the Fort St John Pilot Project follows regulatory widths for Riparian Reserves and Riparian Management Zones by appropriate stream, lake or wetland classification within cut blocks (Table 6). Likely these levels of protection will maintain a significant proportion of hardwoods, but the questions noted should be assessed within implementation monitoring (§7.3).

6 Probable future status of hardwood types

The probable future status of hardwood types is assessed for each of the potential impacts noted.

6.1 Amounts of older hardwood and mixed wood forest

The SFM Plan for the Fort St John Pilot Project is currently being revised. New targets for late-seral hardwoods (>100 years) will be by Natural Disturbance Units (NDUs) (DeLong 2002). These targets are based on guidance from Delong who suggested that 10 to 15% of deciduous-dominated landscapes be maintained in stands greater than 100 years old (C. Delong pers. comm.).

Provided old, often uncommonly large hardwoods in riparian areas are not harvested, current evaluation of age suitable for cavity-nesting species indicates that >90 years is an adequate lower threshold for older age classes for species using hardwoods (Table 3; Bunnell et al. 2009a). A lower boundary of >90 years was used to designate late seral hardwood-leading and mixed wood stands. It is this value that yielded the significant associations with older hardwoods and mixed wood summarized in Table 1.

Trees in the non-harvestable land base (NHLB) are allowed to die a natural death. The current area of forest currently reserved from harvest (NHLB) for various reasons is summarized in Table 4. Tables 1 and 4 do not make a distinction between conifer- and hardwood-leading mixed wood. Of 106 species tested, only 2 hardwood associates showed discrimination between conifer- and hardwood-leading mixed wood. Our analyses of impact treat mixed wood as a single class.

Table 4. Areas of different habitat types within the Fort St John TSA (ha) as of 2008.

Habitat Type	THLB Age (yrs)			NHLB Age (yrs)	
	0-30	31 to 90	>90	>90	All ages
Recently disturbed	63537	NA[a]	NA	NA	NA
Conifer-leading	NA	353775	185215[b]	234159[b]	746891
Hardwood-leading	NA	119488	106851	54813	191980
Mixed wood	NA	82692	112561	50317	124914

[a] NA = not applicable. [b] Age class for conifers is 140 years plus.

Most of the DFA is conifer-leading. Currently about 192,000 ha of hardwood-leading stands and 125,000 ha of mixed wood stands occur in the NHLB and are excluded from harvest (Table 4). That represents 45.9% and 39%, respectively, of all hardwood-leading and mixed wood forest. Within the NHLB, proportions older than 90 years are 28.6% and 40.3%, respectively. Values of Table 4 indicate that significant amounts of hardwoods occur naturally within the DFA and that much of this is within the NHLB.

Harvesting will add to the natural disturbance regime. The simplest index to historical disturbance, whether natural or by harvesting, is the current proportion of recently disturbed area. Current proportions by major forested BEC are: BWBSmw1 – 7.7%, BWBSwk2 – 7.6%, BWBSmw2 – 3.2%, ESSFmv4 – 1.1%, and SWBmk – 0.2%. Figure 1 illustrates combined amounts of older forest in the THLB and NHLB by major forest type for these forested variants. It is apparent that the proportion of NHLB generally follows the inverse order to the natural disturbance rate, from 29% in the BWBSmw1, to 57% and 69% in the SWBmk and ESSFmv4. It also is apparent that hardwoods and mixed wood comprise a much larger proportion of the BWBS than either the ESSF or SWB. This pattern most likely results from natural disturbance than from harvesting; harvesting in the area has not been of long duration and fire tends to encourage the continuation of hardwood cover (Bergeron et al. 1998).

Figure 1 represents a 'snapshot' in time and its major contribution is towards evaluating trends. It is nonetheless informative and illustrates three points. First, the TSA is predominantly conifer and for most variants in the DFA older age classes are predominantly conifer (the BWBSmw1 and 2 are exceptions and are the most species rich variants in the northeast). Second, natural distribution of hardwoods is not even across variants – they are much less well represented in the ESSF or SWB than in the BWBS. Third, given the smaller proportions of hardwood and mixed wood types evident in Figure 1, these types are the most likely to become limiting. Given that many species, including species strongly associated with dying and dead wood, are strongly associated with hardwoods (Table 1), trends in older hardwoods and mixed wood merit monitoring.

About 46% of older forest is within the NHLB (Table 4): most of that, however, is conifer-leading. Among all five forest variants, 30% or more of the older forest is in NHLB in all but the BWBSmw1

(29%). The small proportions of hardwood-leading or mixed wood stands in the NHLB of some variants (e.g., ESSFmf4) do not foretell a problem; that is their natural condition. Moreover, the total areas are large. The finding does indicate the need to sustain older hardwood age classes in those variants where hardwoods occur more commonly. The fact that the TSA also employs retention within cutblocks (emphasizing ecosystem representation) and emphasizes hardwoods for retention as snags and stubs increases the likelihood of sustaining species dependent on hardwoods.

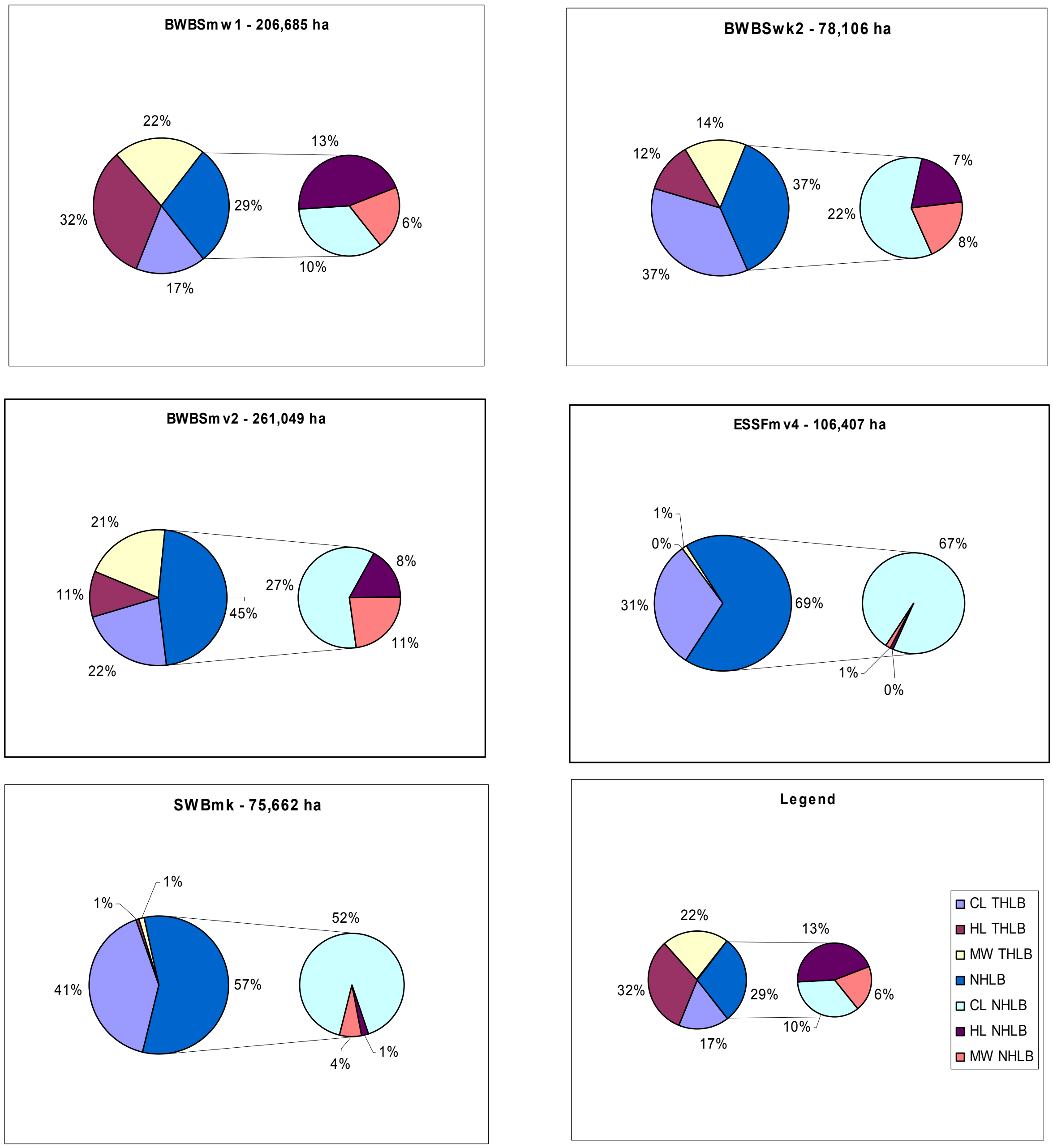


Figure 1. Area of older forest (>90 yrs for hardwoods and mixed wood; >140 yrs for conifers) by major forest type and occurrence within the THLB and NHLB (smaller circle). All major forested variants are illustrated.

The utility of data in Table 4 and Figure 1 will emerge as forest management continues. Current amounts of older forest appear adequate and are significantly buffered by amounts in the NHLB. The older THLB also contributes and is unlikely to be shifted to predominantly younger age classes so quickly that older stands are not recruited. The practice of retention helps ensure that species dependent on older stands will remain well distributed. Fort St John takes its targets for WTPs (Wildlife Tree Patches) or retention from the Land Use Planning Guide which sets targets for each Landscape Unit. These, however, are based on disturbance regimes that no longer occur (Flannigan et al. 2005; Stocks et al. 1998; Xiao & Zhuang 2007). WTPs are required only when more than 200 ha are harvested cumulatively within a Landscape Unit. Targets for WTPs range from 3 to 8% by Landscape Unit. Actual amounts of WTPs appear to be somewhat above targets, ranging from 8 to 12% by Landscape Unit. Guidelines in the SFM plan ask for wildlife tree patches >0.25 ha and encourage biological anchor points and representation of stands within WTPs.

The snapshot of Figure 1 is insufficient to assess continued provision of hardwoods. Sustained provision depends on the current age distribution. Elsewhere, older forest stands have frequently proven limiting, particularly for non-vertebrates (Ehnström 2001; Eriksson 2000; Kaila et al. 1997; Kirby and Drake 1993; Martikainen et al. 1999; Ranius and Jansson 2000; Sippola and Renvall 1999; Väisänen et al. 1993). Whereas vertebrates typically seek a relative narrow range of decay, non-vertebrates exploit all stages of decay and their continued presence appears dependent on provision of all stages of decay. The limitations documented elsewhere usually are attributed to gaps in age class distribution that fail to sustain the entire range of decay states. Retention patches where trees are left to die a natural death help to sustain decay stages in harvested areas. A broader picture across the entire tenure is attained by examining the age structure of hardwood and mixed wood forest types. Current age-class distributions are summarized in Figure 2.

Figure 2 also is a “snap shot”, but projections are becoming increasingly suspect as climate change encourages reduction in the fire-return interval and larger areas are burned in the boreal forest (Flannigan et al. 2005; Stocks et al. 1998; Xiao & Zhuang 2007), which is shifting the forest increasingly towards hardwoods (Bergeron et al. 1998; Grant et al. 2006). In the absence of fire, aspen stands older than about 100 years are beginning to break up and be replaced by younger stands (Stelfox et al. 1995); mixed wood >120 years will become increasingly dominated by conifers. Despite these limitations, two points are apparent in Figure 2: 1) there are no apparent gaps in existing age structure that would prohibit sustaining all decay classes when the entire tenure is considered, 2) current harvest rates are unlikely to encourage a major decline in amounts of hardwoods and mixed wood >90 years in the near term, but could encourage decline in hardwoods over the longer term (see Table 5).

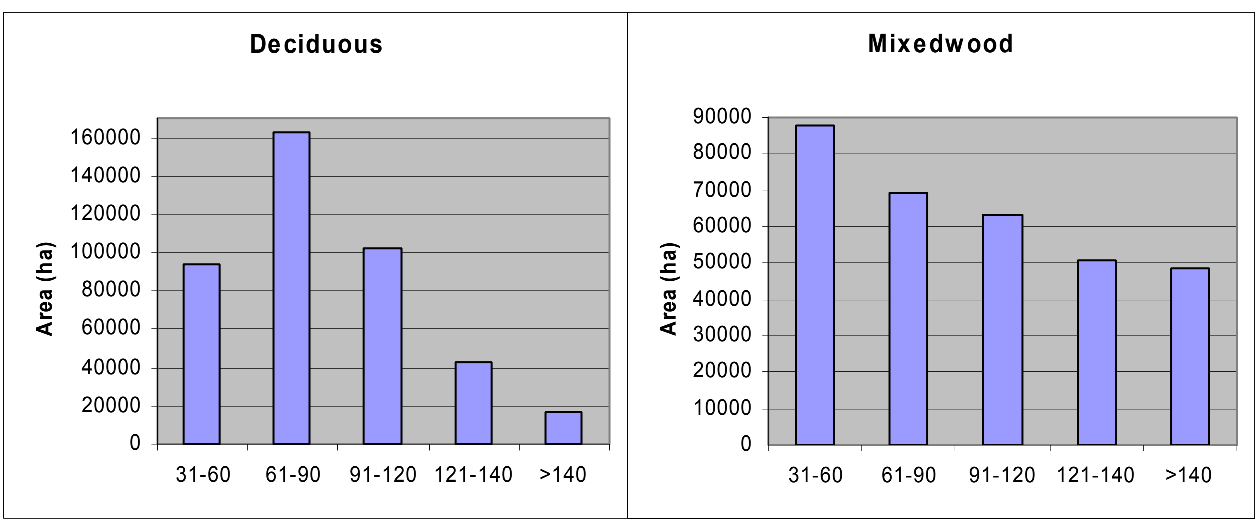


Figure 2. Current age distributions of hardwood-leading and mixed wood forest types in the Fort St John TSA.

Total area and the distribution of age classes are the most informative measures of late seral hardwoods and mixed woods. Negative edge effects (patch size effects) are reported more commonly from conifer than from hardwood forest. The common structure of hardwood types makes negative edge effects unlikely, but prudence suggests retaining some larger patches. Forest practices create patches in three broad ways: 1) by reserving forest in different sized blocks or patches within the NHLB, 2) by creating future patch sizes by implementing cut blocks in the THLB (thereby also altering the size of pre-harvest patches), and 3) by retaining patches of various sizes within cut blocks. That is, both the non-harvestable land base (NHLB) and timber harvesting land base (THLB) can contribute to sustaining hardwoods; the latter through various forms of retention. Forest practices likely are not the greatest influence on patch size. Fire often influences more area annually than does harvest and creates an unpredictable array of patches as it skips across a landscape. The NHLB is unaffected by harvest. The current distribution of patch sizes within the NHLB is shown in Figure 3.

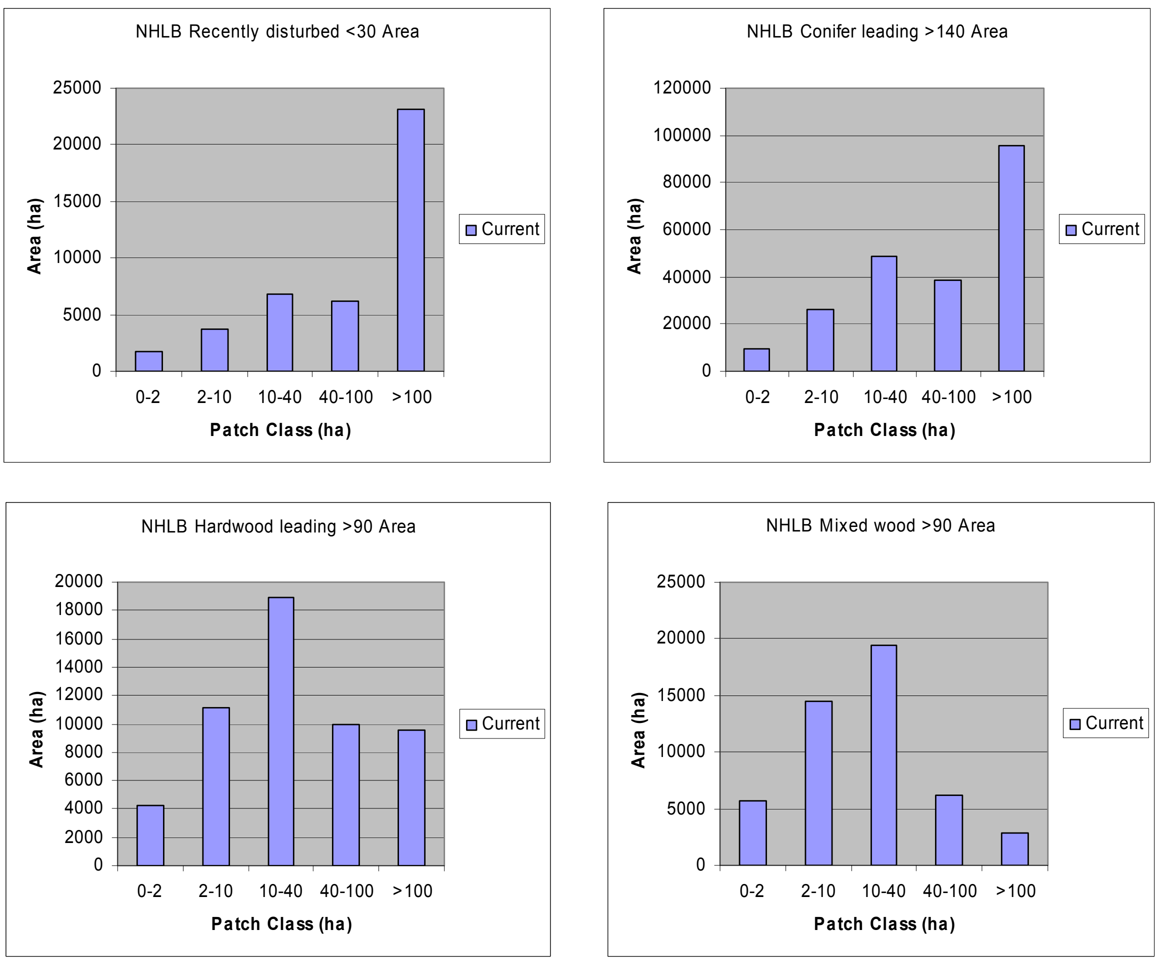
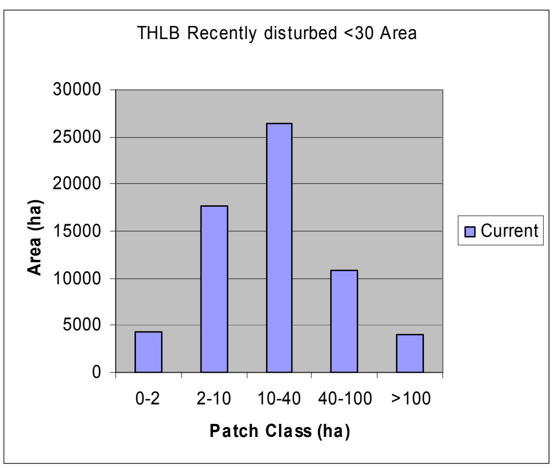
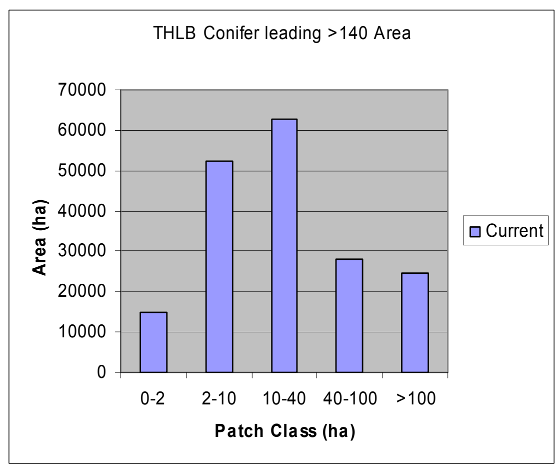


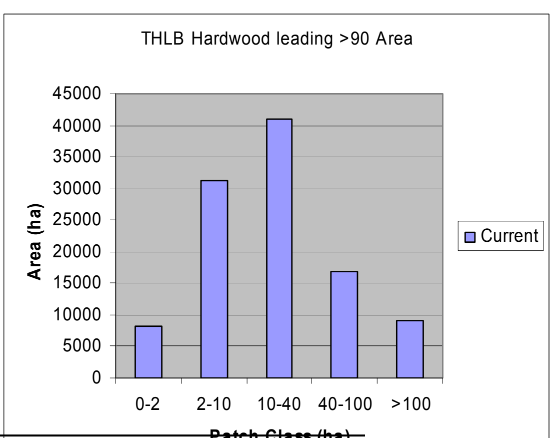
Figure 3. Current areas of different patch sizes within the NHLB for recently disturbed areas and older forest of the three major forest types in the Fort St John TSA (as of 2008).

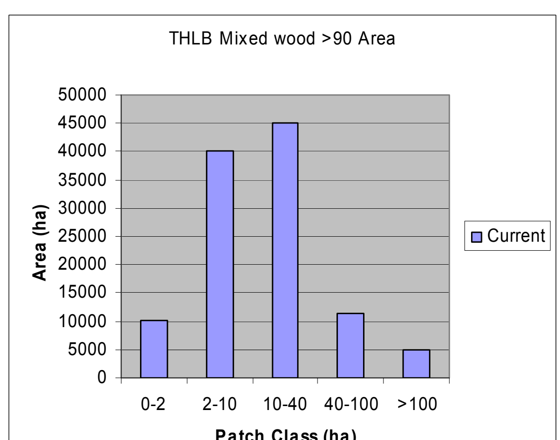
There is little unequivocal guidance on appropriate patch size, or how amounts of older forest should be distributed to best support biodiversity. Science provides only broad guidelines for patch distribution within the NHLB and THLB: *a range of patch sizes is preferable*. Estimates of the distribution of patch sizes in naturally disturbed areas reveals large differences among NDUs and provides general guidance to planning and operations. These estimates provide a useful general 'target' indicating in which NDU x BEC unit combinations patch sizes are generally larger or smaller, but offer no further contribution to evaluating effectiveness. Guidelines for retention patches within the THLB can be made more explicit than for larger blocks across the landscape. For example, 1) retention patches will be large enough to permit retained trees ≥23 cm to die naturally and fall to the ground (this permits sustaining the full range of decay classes), and 2) where snags are retained as stubs, these also will be allowed to die, fall to the ground, and remain on site as logs.

We examined the distribution of patch sizes using five size classes we considered biologically or socially meaningful. The smallest size (<2 ha) is less applicable to the NHLB and is poorly represented there. It was chosen specifically for the THLB on the basis of estimates for the smallest effective size for sustaining snags in retention patches within the THLB; it is no more than a reasoned estimate from coastal data. Assuming a tree height of 30 m and a no-work zone of 1.5 times tree height, the smallest patch sustaining a single tree is about 0.16 ha. We suggest that the lower boundary for effective patches should be set at 0.25 ha,[8] until further evaluated. No patches less than 0.25 were tallied (in most instances these are GIS 'slivers'). The patch size class of 2-10 ha encompasses home range or territory size of many forest-dwelling species; 10 to 40 ha reflects a common regulatory constraint restricting size of cutblocks to 40 ha. The sizes 40 to 100 ha and 100+ ha reflect two classes that clearly contain interior forest conditions, the latter contributing to even the most wide-ranging species. Patch sizes within the NHLB in 2008 are summarized in Figure 3; sizes within the THLB are in Figure 4.







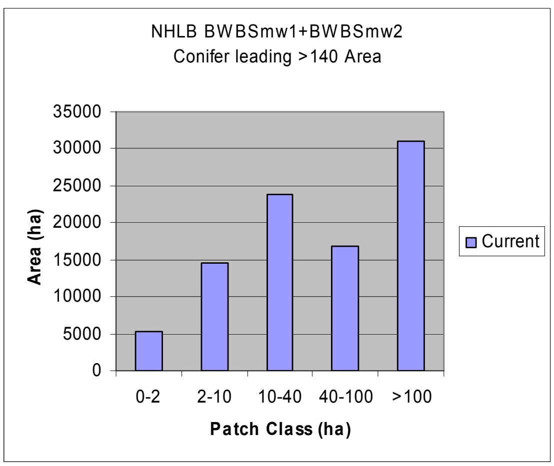


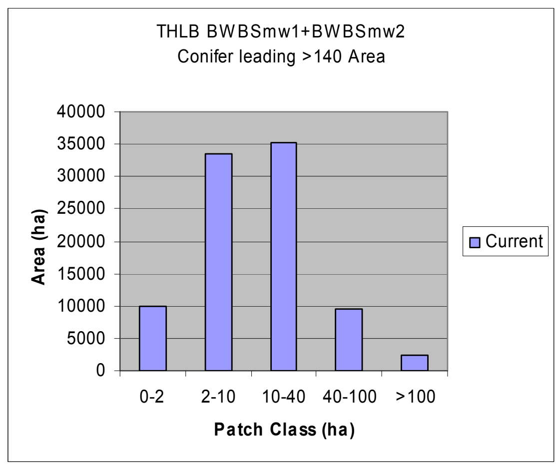
8 This value is consistent with BC MoWLP (2005) for the Omineca Region, based on reasoned estimates from coastal research.

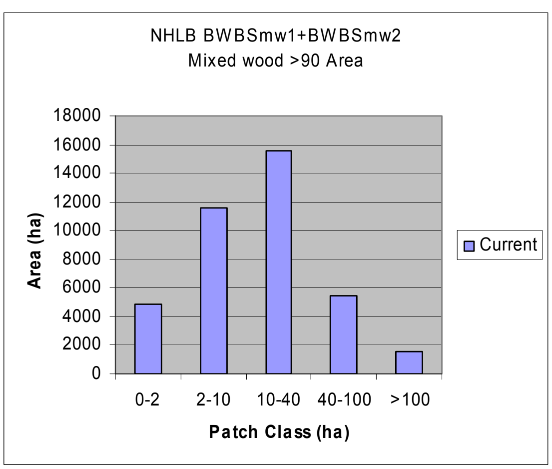
Figure 4. Current patch sizes of areas within the THLB for recently disturbed areas and older forest for the three major forest types in the Fort St John TSA (as of 2008).

Figure 3 illustrates that much larger areas occur in larger patch sizes for both recently disturbed and older conifer-leading stands. We cannot predict the impact fire or other natural disturbances will have. It is apparent that hardwood and, particularly, mixed wood types occur in relatively small patches within the NHLB (Figure 3). The NHLB also encompasses a large area in recently disturbed in larger patch sizes.

In the Fort St. John TSA, the pattern of patch size distribution differs between the NHLB and the THLB (compare Figures 3 and 4). Generally, less area is found in larger patches in the THLB than in the NHLB. A much smaller area of recently disturbed and conifer-leading is in patches >100 ha in the THLB. Hardwood-leading types show about the same total area in patches >100 ha in both NHLB and THLB; mixed wood currently shows more area of larger patches in the THLB. Polygons are updated about every five years at each timber supply review. Those updates will permit reanalysis of patch size distribution. These should be conducted for both the NHLB and THLB. Given the diversity of response among species dependent on older forest there, is no specific 'target' array for distribution, but it is important to avoid a long-term trend towards homogeneity in patch size – either all large or all small.







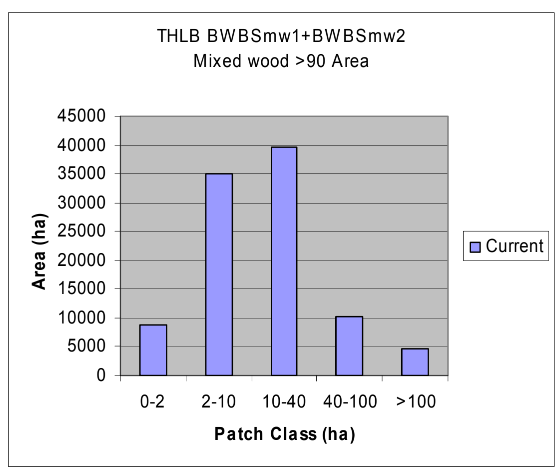


Figure 5. Patch-size distribution in favoured fisher habitat within the BWBS of the Fort St John TSA.

Group 5 species of the Species Accounting System are those for which at least some literature suggests that habitat distribution (e.g., patch size) is more important than total amount. Six occur on the TSA - Golden-crowned Kinglet, Northern Goshawk, Spruce Grouse, caribou, American marten and fisher. None of the birds,[9] nor the caribou, are associated with hardwood types. Although they are conifer associates in more southern forests, both the marten and fisher appear reliant on hardwoods in northeastern BC. Hardwoods appear to provide denning sites, while conifer types are more likely to maintain their prey. For example, there is a healthy marten population on the Rice property within adjacent TFL 48 (Poole et al. 2004; Porter et al. 2005). The Rice property is a former agricultural area now covered with regenerating forest that is 90% hardwood-leading; about 65% of the property is <65-years-old and 45% is <25-years-old. Likewise, fisher dens in northeastern BC are consistently reported from hardwood trees. We thus expect mixed wood to provide the most favourable habitat. The fisher has a larger home range than the marten and is the example treated here. The only work in northeastern British Columbia conducted on the fisher has been in the BWBS. That appears to be favourable habitat, possibly because it contains abundant large hardwoods required by the fisher as denning sites (Table 2) as well as the conifers supporting the prey base. We considered patch sizes of both old conifer and old mixed wood (Figure 5).

Findings are difficult to interpret because in northeastern BC there is no evidence that the fisher prefers large continuous tracts (e.g., Weir 2008). It is apparent in Figure 5 that when analyses are restricted to what is believed to be the most favourable BEC subzone, only a small portion of older conifer-leading forest in the THLB occurs in larger tracts. The same is true for older mixed wood in both the NHLB and THLB. The apparent preference for older conifer documented by literature from southern forest types may be a product of fisher there denning inside logs (they do not in northern forests) and seeking large conifers for cavity sites (in the absence of hardwoods). There is no lack of older conifer in the ESSF or SWB (Table 4, Figure 1). In short, we can state only that southern literature cannot be applied and that the scant boreal literature suggests no problem.

Analyses summarized in Table 4 and Figures 1 through 5 suggest that current planning and practice are doing an adequate job of maintaining hardwood stands and their associates, though a potential shortfall of older hardwoods is evident in Figure 2. The trend in amounts of hardwood and mixed wood and their age distributions merits monitoring, because these forest types are less common than are conifers

6.2 Maintenance of hardwood-leading and mixed wood types

We noted ways in which these types could be reduced (e.g., vegetation management and conversion to conifer-leading). We also noted that while there are arbitrary conventional definitions of mixed wood, there has been little attempt to define compositional boundaries of mixed wood in terms of their contribution to species richness. We first treat conventional definitions.

The principles in the SFMP include providing for forest composition and stand structure that approximate natural baseline information. Targets for forest type composition are based on the proportion of these types found in the landscape at the time of writing of the SFMP. These targets are being updated in the current revision of the plan by more accurate inventory. The SFMP includes an indicator that monitors the change in the proportion of forest type groups (>20 years old) within each variant over time. Stands less than 20 years of age are not included because it is expected that 0 to 20-year-old stands will show significant fluctuations in tree

[9] In the Fort St John TSA, the Golden-crowned Kinglet showed significant preferences for conifer-leading mixed wood, followed closely by old conifer. We consider it a conifer associate, as in other DFAs tested.

species composition each year, due to silviculture practices and rapid natural ingress of species in regenerating stands. We tested whether bird species seeking early seral stages discriminated between two age classes: 0-10 years and 11 to 30 years after logging or other disturbance. We found no statistical differences, so elected to use >30 years as the age at which stands were assigned a particular forest type. That usage is consistent with the definition of early seral employed in analyses of adjacent Canfor tenures.

The Pilot Project's deciduous fibre supply strategy is to maintain the existing commercial deciduous production from the operable hardwood land base. Crude projections of harvest under current conditions indicate that the harvest can be sustained without significantly reducing amounts of hardwood-leading forest (Table 5). Principles proposed for sustaining mixed wood stands were noted earlier (§5.2). Basically, the intention is not to manage for a mid-rotation hardwood entry, but to wait until the conifers are large enough to form saw logs. The intent is to regenerate these sites back to a similar forest type composition as tracked at the landscape level.

Currently, we have poor understanding of mixed woods but know that a significant portion of their value to biodiversity derives from hardwoods present. Mixed wood stocking standards are being developed; it is equally important that the fraction of hardwood or conifer in mixed wood stands that confers the 'mixed wood benefit' also be estimated. Long-term monitoring of change in composition of tree species within managed stands will occur through Change Monitoring Inventory (CMI) plots established over the DFA. These plots are systematically established across the DFA based on a 3-km grid in managed stands 15 years after harvesting. They will provide a representative sample of all managed stands over time. In total, 78 CMI plots were established between 2003 and 2007.

There currently is no evidence suggesting a long-term decline in hardwood volume or area of hardwood-leading stand types. Because there is no ecologically-based definition of mixed wood, trends in mixed wood cannot be evaluated. The amounts of hardwoods or conifers needed to sustain species richness may differ from mixed wood stocking standards derived for silvicultural reasons. Research in the Fort St John TSA currently is addressing the issue of what range of hardwood to conifer ratios encourage the mixed wood advantage for bird species.

6.3 Reduction of amount of hardwoods through vegetation management

Within the DFA, the Pilot Project has guidelines for procedures of vegetation management but few guidelines for the amount of vegetation management. Both shrubs and grasses respond strongly after forest harvest and compete with crop trees. Currently, most conifer cut blocks receive some form of vegetation management, primarily chemical administered aerially; about 7% is administered by backpack. Over the past 4 years, most hardwood blocks have received no vegetation management. A small portion of blocks is treated mechanically, by brushing. There has been an erratic but downward trend in total area treated from 1999 to 2009.

Reductions in hardwood through vegetation management could be either temporary or permanent. Because hardwood species in the region regenerate readily, both vegetatively and by seed, the period immediately after vegetation management is unrevealing of longer-term consequences. Hardwoods could be absent immediately following treatment but gradually return. It is for this reason that polygons are not assigned a forest type until 30 years have passed since disturbance. Long-term reduction is more likely to occur through conversion from hardwood-leading to conifer-leading types and is addressed under conversion below.

Short-term reduction is significant primarily if hardwoods are limiting overall. Many bird species strongly associated with hardwood types nest in trees, though several also use shrubs for nesting and foraging for insects and fruits (Table 2). All shrubby growth, including young hardwoods such as willow, is thus important to these species. Understory is equally significant to the understory associates that may be less firmly associated with hardwood types. The magnitude and duration of potential impact can be addressed by considering the area treated and duration of effect (§5.3).

Over the 11-year period (1999-2009) for which we have data, the size of harvested area on which vegetation management was applied averaged 2327 ha per year. From the perspective of biodiversity the duration of effect can be estimated only in terms of species' response. Study of the response of bird species and shrubs after vegetation management has been initiated (Preston 2008b, 2009b), but documenting the response pattern requires time.

6.4 Conversion of hardwood or mixed wood types to conifer-leading types

Hardwood trees and stands make major contributions to sustaining biodiversity. The issue of potentially 'unmixing' the mixed wood was noted. The fact that the proportion of each broad forest type over the entire DFA is intended to remain similar to baselines (within 20% of composition at the time the SFM plan was written) provides some confidence that the various treatments of hardwood types ultimately will result in hardwoods of a variety of age classes over the landscape. Major hardwood species in the area reproduce readily, mostly by suckering but also by seeds. The Pilot Project has not planted any hardwood seedlings or vegetative propagates on the Fort St John TSA. If planting or seed collecting was embarked on, it would be done according to regulations that conserve genetic diversity of tree stock. The current approach offers potential for gradual conversion to conifer-leading stands, but the potential is likely to be thwarted ecologically by the regenerative capacity of hardwoods and economically by the OSB mill.

Patch size does not appear to be a factor for vertebrates present and patches above about 2 ha appear to accommodate smaller organisms, such as bryophytes. The major issue is the total amount of hardwoods. To ensure we accommodate potentially sensitive species, we recommend some larger patches of hardwoods be maintained. The NHLB currently provides that security. Data summarized (Figures 3 and 4) indicate that large patches of older hardwood-leading and mixed wood types comprise a relatively small area. In the absence of data that permit projecting harvest or evaluating stand conversion, potential trends cannot be evaluated. Trends do, however, merit monitoring.

The degree of interspersion of hardwoods with conifers is recognized in the four major forest types of the SFM plan: hardwood-leading, conifer-leading, hardwood-leading mixed woods, and conifer-leading mixed woods. Within its SFM plan, the Fort St John Pilot Project adopted the Land Use Planning Guidelines to create 'natural' targets for species composition by Landscape Unit. As noted earlier global warming appears to be shifting 'natural' targets by encouraging hardwoods. To date, survey data show only 9 of 106 species discriminating between hardwood-leading and conifer-leading mixed wood. We present combined data here as hardwood-leading and mixed wood. These types encompass all stands with a significant proportion of hardwoods. Useful measures of coarse filter effectiveness are the total area and proportion of current hardwood-leading and mixed wood stands reserved from harvest, and the area of these stands in older stands. Those values are summarized in Table 4 and Figures 3 and 4. Currently, about 192,000 ha of hardwood types and 126,000 ha of mixed wood types are designated non-harvestable and are within the NHLB (Table 4). These areas represent 18% and 11.8%, respectively of all forest >31 years within the NHLB. The proportion of these types that is older and within the NHLB is 28.6% for hardwoods and 40.3% for mixed wood (Table 4). At the level of VRI, at which much of the coarse filter is evaluated, the hardwood presence is likely underestimated because inclusions of < 25% hardwoods in conifer-leading types are not included.

Current economic conditions hamper any projection. Recent harvesting has been about 25% or more below historic levels. Historically, harvest was about 1,070,500 m^3 of conifer and 992,300 m^3 of deciduous (hardwood) fibre. Planning typically uses net values of 270 m^3/ha for conifer and 180 m^3/ha for deciduous. That translates into about 3965 ha of conifer-leading and 5510 ha of deciduous-leading stands with a minor amount of mixed wood contributing to the total.

Table 5. Proportions (%) of conifer, hardwood and mixed wood as of 2008 in the BWBSmw1 and BWBSmw2 and approximate area cut annually across the DFA.

	Current area (ha)	Current %	Projected Annual Cut	
			Area (ha)	%
Conifer	533,990	56.1	3965	0.74
Hardwood	226,333	23.6	5510	2.43
Mixed wood	195,253	20.3	?[a]	

[a] The proportion of mixed wood contributing to the deciduous fibre cut varies from year to year and is generally minor.

Most of the harvest is extracted from the BWBSmw1 and BWBSmw2. Simple implications are summarized in Table 5. Note that in its revised SFM plan, the Fort St John Pilot Project will use ≤20 years to designate recently disturbed and new vegetation resources inventory which will change the values summarized.

Under the current AAC, there is no apparent potential shortfall of conifer, but potential long-term problems with deciduous. Current Timber Supply Review information assumes that deciduous areas will come back to deciduous areas and so the target for composition will be met unless an aggressive program of deciduous control is deliberately instituted. Such control has not been contemplated. If the assumption is correct, hardwood areas could be forecast using simple spatial models. The current regeneration practice in the DFA is that pure deciduous or deciduous-leading mixed wood areas will be regenerated back to deciduous areas. In fact, at full capacity the mills are capable of consuming more than is available. Mixed wood itself remains a challenge. Operationally, the retention of suitable spruce understory in mixed stands is a tactic to successfully grow spruce and aspen concurrently and have them reach merchantability at the same time. Climate change already has shortened the fire-return interval, which favours deciduous. It is possible that mixed wood will be shifted ever more to hardwood-leading, thus compensating for apparent shortfall in hardwoods. Currently, there is no way to project the consequences because: 1) consequences of climate change remain unclear, 2) there are no well-developed mixed wood models for projecting either the most appropriate silvicultural practices or the consequences on species mix, and 3) the lower boundaries for the proportion of hardwoods and conifers in a mixed wood stand that confer the mixed wood enhancement of bird species richness are unknown (one way to evaluate thresholds by current monitoring is suggested in §7.3).

The most significant issue is the projected total area, but the actual trajectory of mixed wood should be monitored. To some extent, there is a natural buffer beyond hardwoods' ability to regenerate rapidly – hardwoods are likely to make particularly disproportionate contributions even where conifers are dominant, so large amounts of hardwoods are not required (Bunnell et al. 2009f). In summary, trends in amounts of hardwoods and mixed woods should be monitored; currently there is no evidence of conversion of hardwoods and mixed woods to conifer.

6.5 Retention of riparian and associated hardwoods

The SFM plan follows regulatory widths for Riparian Reserve Zones (RRZ) and Riparian Management Zones (RMZ) by appropriate stream, lake or wetland classification within cut blocks (Table 6). This protection represents 'potential' hardwoods because riparian areas commonly contain hardwoods; classification of riparian areas within VRI and GIS is not consistent. Along rivers and around lakes, riparian areas often are large enough to be typed as hardwood-leading where appropriate. Along many smaller streams, they are too narrow to be mapped separately so appear as part of a larger polygon, which may or may not be hardwood-leading.

Table 6. Required riparian reserve zones around lakes and wetlands.

Riparian Class	Riparian Reserve Zone width (m)	Percent retention in RRZ	Riparian Management Zone width (m)	Percent retention in RMZ[1]

Lakes L1-B	30	100[a]	70	0
Lakes 3 and 4	0	No buffer	0	None required
W1	10	100	40	40
W3	0	0	30	40
W5	10	100	40	30
Forested wetlands	None required	None required	None required	None required
S1	50	100	20	None required
S2	30	100	20	None required
S3	20	100	20	None required
S4	0	0	30	Remove dominants, keep 50% non-dominants
S5	0	0	30	50% dominants
S6	0	0	20	none

[1] Percent retention refers to best practices to guide volume remaining after merchantable stems are removed. Values of this table are derived from MoF&R regulation, not from the SFMP. [a] The only lakes with a riparian reserve zone are between 5 ha and 1000 ha in size. Smaller lakes and larger lakes have no required buffer.

Lakes and wetlands less than 5 ha currently are not buffered. The Riparian Reserve Zone is a no-touch zone, but in the RMZ most trees are removed with intention to protect the understory shrubs and retained trees. In "machine free" zones along an RMZ, the feller buncher often can reach in to cut trees and drop them outside the RMZ. That does not work when trees are large or leaning the wrong way.

To evaluate the likely impact of current riparian practices on hardwoods we should know the amounts of hardwoods retained in the RRZ and RMZ (see §5.5). Broad amounts of riparian habitat around larger streams and lakes that are reserved from harvest can be estimated (Table 6). However, the amount of riparian, and, specifically, the amount of hardwood or mixed wood riparian cannot be identified by VRI, and thus are unavailable to coarse-filter analyses. Helpful data could be acquired by implementation monitoring (how much riparian hardwood is maintained). Given the number of species that use riparian habitat, the priority for such monitoring is very high.

Additional areas of concern are S4 streams and forested wetlands. Recent reviews have found that S4 streams without a buffer become degraded and may lose their potential to support fish species seeking cool water (Maloney 2004; Nordin et al. 2008; Rex et al. 2009). A buffer of 10 m is recommended (Rex et al. 2009). Harvesting near wetlands is a *potential* problem, particularly during winter logging, and merits implementation monitoring to assess whether it is a problem or not.

6.6 Key measures and cumulative effects

Preceding discussion illustrates that relatively few measures are key to coarse-filter evaluation of effectiveness of practices at sustaining hardwoods and that these can have cumulative effects. Table 7 summarizes key measures, their modifiers for particular forest types and the major practices that can influence them. Planning and practices are the 'levers' managers can use to modify trends that are undesirable. There are two major limitations to evaluating effectiveness at the level of the coarse filter. The first is the omission of natural disturbance from estimates of future conditions. The ability to project disturbance accurately has become more challenging in the face of climate change. A second limitation is the absence of fine-filter corroboration or data from organisms intended to be sustained (in this case by hardwoods). We used data from organisms occurring within the DFA to quantify modifiers, such as appropriate diameters. To provide greater confidence to the analysis, effectiveness monitoring would include species believed to be particularly susceptible to changes in the way hardwoods and mixed wood are sustained (see §7.3 Effectiveness monitoring). Susceptible species and other monitoring efforts should be selected to assess impacts of any trends that coarse-filter analysis suggests are negative (see Table 8).

Table 7. Key measures for coarse-filter analysis of the provision of hardwoods, their modifiers and practices influencing them.

Measure	Modifiers	Planning and practices
Amount of older age classes (ha)	Diameter at age Patch size	Natural NHLB All reserves (WTPs, OGMAs, etc) Size of retention patches
Amounts of older hardwood and mixed wood (ha)	Diameter at age	As above, plus: silvicultural conversion of hardwoods to conifer
Post-harvest debris	Diameter (cm) Distribution	Utilization and waste mgmnt. Piling or not
Contributions of retention	Diameter (cm) Number (snags, logs) Patch size (ha)	Retention guidelines

Variables used to index the provision of hardwoods influence each other. Amount of area reserved from harvest (NHLB) and uninfluenced by current practice influences the need for provision of hardwoods within the THLB. Measures of tree species composition influence the suitability of areas reserved from harvest. Because of the dependency of many cavity nesters on hardwoods, measures of tree size and decay also influence the suitability of areas reserved from harvest. All variables change with time – e.g., tree diameter and decay state with age. In Table 8 we have summarized the effect of key individual features so that potential cumulative interactions can be exposed. We use two time frames: short-term (based on current 'snaps shots' of conditions) and potential permanent reduction (permanent reduction results when the effect of the practice *could* be permanent in the area where it is applied). The latter can be no more than a reasoned guess.

Table 8. Apparent trends in key variables determining effectiveness of hardwoods in sustaining biodiversity in the Fort St John TSA (HL = hardwood-leading, MW = mixed wood). The most troubling trends are ↓. Practices governing trend are noted.

Variable	Apparent trend		Practices
	Short term	Permanent	
Area HL	↔	↓?	Harvest rate; retention guidelines
Area MW	↔?	↔?	Above plus conversion to conifer
Area old HL	↓?	↓?	Harvest rate; retention guidelines
Area old MW	↔	↔?	Above plus conversion to conifer, vegetation management
Patch size old HL	↔	↔	Harvest
Patch size old MW	↔	↔	Above plus conversion to conifer, vegetation management
Tree Ø HL & MW	↔	↔	Harvest, retention guidelines (e.g., leave tree diameter)
Log Ø HL & MW	↓	↓	As above
Decay range HL & MW	↔	↔	Waste management
Hardwoods in riparian	?	?	Riparian guidelines

Table 8 summarizes several uncertainties that, if negative, when combined, could produce cumulative effects. When increased harvest (e.g., a new mill) is introduced to a region, the area of older forest is expected to decline, modified primarily by retention guidelines. We are unable to assess trends in mixed woods, and estimates are further hindered by changing rates of natural disturbance. Current age structure (Figure 2) and projected harvest rates (Table 5), suggests a decline in hardwoods 30 years from now, but the apparent decrease will be somewhat ameliorated by recruitment of stands currently <30 years old and not yet typed. Revision of the minimum diameter for single tree retention (from 17.5 to 23 cm) should retain tree size; trends in log size are unclear because of reporting as top-end diameter. The potential downward trend in amounts and patch size of hardwoods and mixed wood types (e.g., Figures 2 and possible stand conversion) should be monitored. Few organisms appear dependent on larger tracts of these hardwood forest types, but a decrease in patch size affirms trends in total amount and could become a problem.

The NHLB acts as a large buffer of the few potentially negative trends in the THLB. Currently 45.8% and 39.0%, respectively, of all hardwood-leading and mixed wood forest are constrained from harvest.

There also are cumulative effects that are not a product of forestry. The area denuded by oil and gas will impact availability of hardwoods. The area denuded is tracked in SFMP. There is no apparent reason to assume that oil and gas activities will disproportionately affect hardwoods. More importantly, the area experiencing natural fires already is increasing and will continue to grow. More frequent fires are likely to encourage hardwood cover (e.g., Bergeron et al. 1998; Grant et al. 2006).

7 Summary

We summarize major findings and recommendations regarding practice and monitoring derived from these findings.

7.1 Major findings

The coarse-filter evaluation is meant to evaluate effectiveness of planning and practices intended to sustain biodiversity. In several instances (e.g., appropriate patch size) effectiveness cannot be evaluated against data collected on site, but must be assessed on the basis of literature. The evaluation is thus a combination of specific findings that can be supported from data collected on site and relevant literature.

1. Planning and practices of the SFM plan for the Fort St John Pilot Project appear well reasoned and well integrated, and will help supply hardwoods with favourable attributes into the future. Table 8 summarizes uncertainties; the most troubling are:
   - potential declines in total area of hardwood (Figure 2; Table 5),
   - realized butt-end diameter of logs left on site, and
   - consequences of harvesting practices around S4 streams and wetlands.

2. Targets are well-reasoned but should be evaluated through effectiveness monitoring (§7.3). The current trend to more wildfires in boreal forests suggests that targets based on historical natural disturbance regimes are no longer 'natural' and possibly unattainable.

3. The minimum diameter of 17.5 cm for single leave trees and stubs in the existing SFM plan is too low (Table 2) and should be raised to 23 cm. Note: the current revision of the SFM plan has incorporated this recommendation.

7.2 Recommendations for practice

Tables 7 and 8 reveal five areas where current practice could be beneficially altered or, minimally, closely monitored through early implementation monitoring.

1. Guidelines for retention of single stems or stubs should be tree sizes >23 cm dbh; proposed new densities appear appropriate. Note: this change is being implemented.
2. Guidelines for retained wildlife trees in patch-wise retention should encourage retaining trees >23 cm dbh, with local densities of 3 per ha where possible. Greater densities of small snags also should be retained; not all should be hardwood.
3. All pieces of downed wood >17.5 cm (random diameter) should not be piled; some should be scattered on site to sustain poorly dispersing organisms.
4. Riparian management practices should ensure that larger, older hardwoods are retained in the Riparian Management Zones. This may not be a modification depending the outcome of implementation monitoring (§7.3).
5. Areas of older hardwoods merit close monitoring as anticipated trends are downward.

7.3 Recommendations for monitoring

Recommendations are summarized separately for **i**mplementation and effectiveness monitoring.

Implementation monitoring

Implementation monitoring should focus on areas where direct or cumulative effects currently appear negative or highly uncertain (Table 8). It should be directly linked to practices that offer opportunity for improvement. Note that in some instances it is important that implementation monitoring be initiated before effectiveness monitoring because implementation monitoring can determine whether effectiveness monitoring is required. We have estimated priorities for specific habitat attributes (**VH** = very high; **H** = high; **M** = moderate); issues following are ordered by priority.

Species composition: There is some indication that the relative amount of mixed wood stands will be reduced. Current natural targets are unlikely to represent a critical limit, but are the only available natural targets. CMI plots should help to detect changes. Hardwood species make a disproportionate contribution to sustaining biodiversity. It is important that the area of hardwood-leading and mixed wood types, particularly late seral classes, be tracked over time to ensure there is no strong, harvest-driven trend away from present proportions. Amounts in both NHLB and TFLB should be tracked (**VH priority**).

Riparian: Some hardwood associates in the DFA are known to be associated with riparian hardwoods around streams and larger lakes (e.g., cavity nesting ducks). The degree to which larger hardwoods (and shrubs) are retained in the riparian management zone should be evaluated – pre- and post-harvest comparisons (**VH priority**). More than 50 species within the DFA are associated with wetlands and lakes <5 ha. Current guidelines do not buffer small lakes and wetlands (<5 ha). The number of small lakes and wetlands encountered within treatment units, and the proportion of those harvested with and without buffers, should be tracked until it is apparent what portion is unaffected by forest activity (**VH priority**). Wetland size distribution should be recorded in 1-ha classes up to 5 ha. The degree to which conifer stems are retained around small streams, particularly in areas likely to be inhabited by bull trout, merits monitoring (**M priority**).

Late seral targets: Status relative to current targets should be assessed every 5 years (at TSR review) for the three broad forest types in both the NHLB and THLB (conifer-leading, hardwood-leading, and mixed wood). Late seral targets appear to have greater impact on sustaining biodiversity in hardwood stands than do early seral targets (e.g., Bunnell et al. 2009f). That could change if climate change significantly increases the incidence of forest fire. Trends in late-seral hardwoods and mixed wood are of concern (**VH priority**).

Retention patches: Within the THLB, the state (size, age, tree and log attributes, species composition, anchor points) should be monitored to assess trend in older blocks or patches across the landscape.

Size: The lower boundary for effective patches should be set at 0.25 ha,[10] until further evaluated.
Age: Recommended targets for age of old hardwoods and mixed woods are >90 years. Actual age should be estimated.
Tree and log attributes: Number, dbh, species, and height should be measured for live trees and snags; number, diameter, decay state and length should be measured for logs.
Anchor points: Rationale for patch locations should be recorded. Natural anchor points may be riparian boundaries, wetlands, appropriate wildlife trees, etc. Minimum limits for 'large' wildlife trees should be 23 cm dbh for hardwoods. The limits are particularly important when retained patches are small (< 2 ha). Larger retention patches need not target particular tree sizes, but can use age as a surrogate. In these cases the age classes should be at least age class 5 for hardwood and mixed wood stands. Minimum densities of wildlife trees should be 3/ha in patches less than 2 ha. Actual conditions should be recorded (**H priority**).

Vegetation management: Pre-harvest forest cover on sites selected for treatment should be recorded so that potential changes in conifer to hardwood and vice versa can be assessed in the future (**H priority**).

Coarse woody debris: Natural levels of coarse woody debris are rarely helpful in creating targets because they are so variable. Amounts and distribution of pieces left behind and unburned can be informative if either butt-end or a random sample of diameter is measured by an adequate sample. Some sampling of length is informative. Total area from which all wood >17.5 cm in diameter is removed should be recorded, as should the relative proportion of debris left scattered and piled. Height of unburned piles should be estimated. Little advantage is gained beyond 1 m in height. We rate this as M **priority** because data permitting interpretation of finds are currently sparse.

Late seral patch sizes: Status should be assessed every 5 years when polygons are updated for TSR review. Trends in size of older forest patches should be tracked by forest type within BEC variant for both the NHLB and THLB. Current analyses suggest potential for reductions in patch size distribution of hardwood-leading and mixed wood types that merits monitoring. Targets derived from historical disturbance regimes may no longer apply. Two trends are undesirable: 1) a long-term tendency towards homogeneity in patch size, 2) a decline in mean size of patches with appropriate attributes (age, tree size; **M priority** for hardwood types).

Effectiveness monitoring
Effectiveness for biodiversity can only be credibly assessed in terms of organisms themselves. While those data accumulate, effectiveness can be inferred. Note that portions of implementation monitoring inform effectiveness monitoring. Major management 'levers' that can be used to counter unfavourable trends are summarized in Table 8. We have estimated priorities for specific attributes (**VH** = very high; **H** = high; **M** = moderate); issues following are ordered by priority.

NHLB contributions: Our assessment of the relative suitability of current practices to sustain hardwood associates was influenced by the assumption that old hardwoods in the non-harvestable land base were contributing significantly. Much of the NHLB is lower in productivity and Boudreault et al. (2008) noted that site productivity influences the contribution to sustaining some organisms. The assumption that NHLB contributes significantly should be checked. Currently of the 12,345 sample points through 2009, 55.7% are in the THLB, 22.7% are in the NHLB, and 21.6 % are in land excluded from productive forest (e.g., non-commercial brush classified as NT). NT is actually a productive habitat, particularly for understory associates, but some other hardwood associates as well (Table 1). Comparisons between NHLB and THLB of relative abundance for selected species would help address the validity of the assumption regarding contributions of the NHLB (**VH priority**). This should first be done with existing sample

[10] This value is consistent with BC MoWLP (2005) for the Omineca Region.

data. If NHLB is less productive for hardwood associates and THLB is potentially limiting, the appropriate management lever is retention.

Mixed wood: Currently, boundaries of amounts of hardwoods or conifers that confer the mixed wood advantage to species richness are unknown. The most cost-effective way of estimating them is to acquire simple measures from existing BBS stations (% hardwoods, simple indices of shrub abundance based on height and % cover classes; M. Preston has collected relevant data)[11]. Assessment can be informed by relating the abundance of species closely related to hardwoods (e.g., American Redstart, Hammond's Flycatcher, Least Flycatcher, Magnolia Warbler, Rose-breasted Grosbeak and Warbling Vireo) to the proportion of hardwoods present. The 9 species currently showing a distinction between hardwood-leading and conifer-leading mixed wood are: Black-throated Green Warbler, Fox Sparrow, Golden-crowned Kinglet, Pine Siskin, Red-breasted Nuthatch, Warbling Vireo, Western Tanager, White-winged Crossbill and Yellow-bellied Sapsucker. This is assigned **VH priority** because it will help guide the priority with which the potentially declining trend in amounts of older mixed wood should be addressed. The major management 'levers' are retention guidelines and possibly vegetation management.

Vegetation management: Provided data on species composition noted above and under implementation monitoring can be acquired, potential effects of vegetation management in modifying the mixed wood contribution to biodiversity and duration of any reduction in hardwood cover can be evaluated. Study is now underway on TFL 48 that may permit this; continuation of that study is assigned **VH priority**.

Wildlife tree patches: The degree to which WTPs retain hardwood associates is undocumented. The relative proportions of patches within the three broad forest types are informative (acquired by implementation monitoring). Relevant habitat variables for WTPs are noted under implementation monitoring. In the near term, effectiveness can be evaluated in terms of the target diameters and ages noted, especially when late-seral relations are documented (**H priority**). Longer-term, more credible evaluations require assessment of patches for a suite of organisms responsive to specific habitat elements, such as hardwoods, cavity sites and understory (**H priority**; see organisms below). Evaluation could lead to refinement of retention guidelines; e.g., downward trends in mixed wood forest would encourage mixed wood as anchor points.

Organisms: Response of organisms is the most credible, and ultimately a necessary measure of effectiveness. Candidate organisms for the Fort St John TSA are listed with priorities derived from review of current data and the literature. Different candidate groups are assigned the priorities of management issues noted above. Focus is on a suite of species to attain an aggregate response less susceptible to vagaries of individual species. The aggregate number of observations form that group can be compared to the mean over the initial 5-year monitoring period; a 30% decline merits further examination.

<u>Cavity nesters</u> – focus should be on groups of species that are largely conifer dependent and largely hardwood dependent. For hardwoods, examples included: Black-capped Chickadee, Hairy Woodpecker, Northern Flicker, Red-breasted Nuthatch and Yellow-bellied Sapsucker. Although suites are important, the sapsucker merits some individual attention because it is the keystone excavator in the region. Initial efforts should focus on retention patches; documented relations to larger retention patches will assist scaling up over the entire tenure (**VH priority**).

<u>Old hardwood and mixed-wood suite</u> – these can include appropriate cavity nesters noted above but also candidate species from Table 1, such as American Redstart, Black-throated Green Warbler, Least Flycatcher, Magnolia Warbler, Rose-breasted Grosbeak and Warbling Vireo. Given that all are migratory and affected by conditions outside the DFA, it is especially important that they be monitored as a suite. Assessment of structure (%

[11] There is a documented trade-off between percent hardwoods and shrub abundance.

hardwoods and percent shrubs) in a sub-sample of BBS sites will assist scaling up (**VH priority**).

Old riparian suite **–** these species are not readily monitored by Breeding Bird Surveys (e.g., cavity-nesting ducks). Implementation monitoring of riparian practices would indicate whether they 'should be' there, but that ultimately needs confirmation. We have ranked it **M priority** because no problem is apparent and the surveys are specialized.

Fisher – in northeastern BC the fisher relies on large hardwoods as denning sites. Canfor has contributed to a regional fisher study. **H priority** for further boreal literature review; **L priority** for further field study.

Bryophytes and lichens – among species showing affinity for hardwoods, bryophytes are likely the most sensitive to edge effects. Standing old hardwoods appear to support high richness of these groups; those dependent on down wood or stem bases appear more likely to be threatened. Tree species, diameter and decay state should be recorded during surveys of snags and down wood. Initial efforts should focus on retention patches with adjacent 'natural' controls and the contributions of riparian buffers. We ranked this **M priority** primarily because of the difficulty in finding qualified personnel.

Riparian areas: Because current guidelines do not buffer small lakes and wetlands (<5 ha), and more than 50 species are associated with wetlands, ponds and small lakes (though not consistently with hardwoods), we do not know whether a significant portion of biodiversity is exposed to habitat degradation. Monitoring should assess species presence in small wetlands with (if such exist) and without adjacent harvesting; these should be stratified by 1-ha size classes up to 5 ha (**H priority**). If the implementation monitoring recommended above discovers that proportionately few small lakes and wetlands receive adjacent harvest the priority should be lowered. That is, implementation monitoring should be done first.

The effectiveness of riparian management guidelines at maintaining hardwoods in Riparian Management Zones and the species associated with riparian areas around streams and larger lakes has not been assessed. The current approach to monitoring organisms (Breeding Bird Survey routes) assesses riparian areas only poorly. Some preferred NT sites appear to be a product of high moisture levels. A focused evaluation of the effectiveness of practices is needed. Specific questions include: 1) are species expected in wetland/riparian areas actually present, and 2) do practices around areas classified as NT maintain the ability of NT to support understory associates. Measures of shrub abundance attained under implementation monitoring of shrub abundance in the RRZ and RMZ will assist interpretation. We rank this as **M priority** simply because we do not anticipate problems and surveys are specialized; the number of species potentially affected, however, may encourage a higher ranking.

Late seral: Apparent effectiveness of the current lower boundary for 'old' hardwoods and mixed wood age was evaluated indirectly by forest inventory data and diameter of cavity trees sought by vertebrates in the area; appropriate boundaries should be checked more directly for vertebrates. Their applicability to other organisms was estimated primarily from European data. Forest interior plots should be used to assess projected effectiveness for cavity nesting birds (**M priority**) and for bryophytes and lichens (**M priority**). See also organisms above. Significant downward trends in older age classes can be ameliorated by increased retention.

Coarse woody debris: Collate estimates of use of down wood by marten and fisher in the study area and other boreal forest sites and relate these to measures derived from implementation monitoring (**M priority)**. Pursue an analogous approach for bryophytes and lichens relying on down wood (**M priority)**. Major management 'levers' are retention guidelines and waste management practices.

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