



Habitat Supply Modelling TFL 14 Pilot Project



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FINAL REPORT

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Executive Summary

One of the principal challenges of land management in BC is developing methods to quantify and forecast the supply of habitat for wildlife over planning horizons in managed forests. The *BC Columbia River Basin Database for Terrestrial Vertebrate Species* and the spatial timber supply analysis conducted for Tembec Industries Inc. on TFL 14 provided the basis for a habitat supply modelling exercise we conducted in order to forecast the supply of important habitat features for wildlife over the next 250 years. This was the first of two pilot projects intended to investigate the utility of habitat supply modelling in planning in BC – Arrow IFPA being the other pilot.

We developed a process of querying the BC Columbia River basin database to identify key forest structural conditions and habitat elements that are used by a relatively large number of terrestrial wildlife species occurring on TFL 14. We also assembled a list of indicator species that could form the basis of a wildlife-habitat monitoring program.

We cross-referenced the habitat classification system used by the database to the output of the spatial timber supply analysis through a series of lookup tables derived from empirical data and expert opinion. We then used projection data from the spatial analysis to estimate the supply of key forest structural conditions and habitat elements at time zero (current conditions), 20, 70, 100, and 250 years. We also compared habitat supply projections to benchmarks interpreted from hypothesized ranges of natural variability.

The habitat supply forecast suggested that the timber harvesting land base of TFL 14 will become increasingly dominated by single canopy, mid-seral forests. The abundance of snags will decline over time, and the decline will be relatively insensitive to small changes in snag retention in harvested stands. Stands retaining adequate snag densities will become increasingly isolated on the timber harvesting land base.

Stands with low volumes of down wood will increase, but the effect of this on wildlife is not clear. Shrubs were identified as an important habitat element but no data were available to model their abundance over time.

Large live trees, and trees with ecologically functional bark, were also modelled in the habitat supply analysis, but we were unable to predict accurately the abundance of these important habitat elements because the output from the spatial timber supply analysis did not provide adequate data regarding the abundance and characteristics of residual structure.

There were a number of limitations and assumptions associated with the analysis. Most importantly, the spatial timber analysis was restricted to the current timber harvesting land base, which limited our analysis to only 35 percent of the total area of the TFL.

We recommend that forest planning incorporate strategies to increase the abundance of medium and large-sized trees, increase the retention of snags, and maintain down wood in harvested stands. We also recommend that additional data specific to TFL 14 be collected to refine the habitat supply lookup tables. Any additional spatial timber supply analysis should be designed to track habitat features important to wildlife.

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List of Acronyms

AU	Analysis Unit
AT	Alpine Tundra (biogeoclimatic zone)
BC	British Columbia
BEC	Biogeoclimatic Ecosystem Classification
CBD	Columbia Basin Database
DBH	Diameter at breast height
EFMPP	Enhanced Forest Management Pilot Project
ESSF	Engelmann Spruce- Subalpine Fir (biogeoclimatic zone)
IDF	Interior Douglas-Fir (biogeoclimatic zone)
MS	Montane Spruce (biogeoclimatic zone)
NDT	Natural Disturbance Type
PEM	Predictive Ecosystem Mapping
TEM	Terrestrial Ecosystem Mapping
TFL	Tree Farm Licence
THLB	Timber Harvest Land Base
TRIM	Terrain Resource Inventory Maps
TSR	Timber Supply Review
TUM	Timber Unit Mapping
US	United States
WTP	Wildlife Tree Patch
WTR	Wildlife Tree Retention

1.0 INTRODUCTION

1.1 BACKGROUND

The British Columbia government is investigating the *BC Columbia River Basin Database for Terrestrial Vertebrate Species* (Steege et al. 2001) and its possible application in the province. The BC database is an extension of the wildlife-habitat classification methodology outlined in “Wildlife-Habitat Relationships in Oregon and Washington” (Johnson and O’Neil 2001)⁴. Both the US and BC databases feature a list of vertebrate wildlife species occurring in the respective portions of the Basin and sets of digital matrices that relate species to *Wildlife Habitat Types*, *Structural Conditions*, *Habitat Elements*, selected *Life History* parameters, and *Key Ecological Functions*. It was developed to provide biologists, resource managers and other users with baseline information for modelling and monitoring possible effects of resource development on wildlife species and their habitat. Ketcheson et al. (2001) classified and mapped 17 of the US habitat types in the Canadian portion of the Columbia Basin, and a list of 447 terrestrial vertebrate species was compiled by habitat type, structural condition and habitat elements (Steege et al. 2001).

One of the principal challenges of land management in BC is developing methods to quantify and forecast the supply of habitat for wildlife over planning horizons in managed forests. The “Columbia Basin Database” (CBD) provides a comprehensive and peer-reviewed method of linking forest attributes to habitat for wildlife species. The link between specific forest attributes and wildlife habitat in the CBD provides the opportunity to use it as a basis for quantifying and forecasting habitat supply for wildlife, thereby highlighting issues of future habitat supply that can be addressed through forest and silviculture planning.

This project is one of two provincial habitat supply modelling pilot projects conducted on Tree Farm Licence (TFL) 14 and on the Arrow Timber Supply Area (TSA). This report presents the results of the TFL 14 pilot project.

1.2 OBJECTIVES

The objectives of the TFL 14 habitat supply modelling pilot project were

- to use the Columbia Basin database to develop a list of important habitat features and species to track in habitat supply forecasts;
- to use existing timber supply models and the Columbia Basin database to develop habitat supply forecasts for important habitat features;
- to identify shortfalls relative to identified natural ranges of variability; and
- to suggest strategies to address habitat supply shortfalls.

⁴Also see <http://osu.orst.edu/dept/press/WildlifeHabitat.html>

2.0 METHODS

2.1 STUDY AREA

TFL 14 is located on the west side of the Columbia River valley northwest of Invermere, BC (Figure 1). It falls primarily in the East Kootenay Trench and East Purcell Mountain ecosections, with a small amount of high elevation area located in the North Kootenay Mountains ecosection (Demarchi 1996). Biogeoclimatic zones include Alpine Tundra (AT), high-elevation Engelmann Spruce-Subalpine Fir (ESSF) forests, Montane Spruce (MS) at moderate elevations and in wetter sections of the TFL, small amounts of Interior Cedar Hemlock (ICH), and Interior Douglas-fir (IDF) forests at low elevations in the south.

The total area of TFL 14 is 150,715 ha, with a current Timber Harvesting Land Base (THLB) of 53,862 ha. The predominant timber types (*i.e.*, leading species) in the THLB are; lodgepole pine (46%), spruce (16%), subalpine fir (14%), Douglas-fir (13%). There is also a minor component of primarily deciduous forest. Approximately 45% of the THLB is comprised of stands 61-100 years old, and 16% is >140 years old.

At present, five blue-listed species occur, or potentially occur, on TFL 14: Great Blue Heron (*Ardea herodias*), Flammulated Owl (*Otus flammeolus*), Northern Long-eared Myotis (*Myotis septentrionalis*), Grizzly Bear (*Ursus arctos*), and Wolverine (*Gulo gulo*). The Western Grebe (*Aechmophorus occidentalis*) is the only red-listed species known to occur on the TFL.

2.2 DATA SOURCES

2.2.1 TFL 14 Spatial Timber Supply Analysis

Johnson and O'Neil (2001) defined the following terms to describe wildlife-habitat relationship in the US portion of the Columbia River basin.

- *Wildlife-habitat Types*: These are groups of vegetation cover types (or land use/land cover types) that are broadly based on wildlife-habitat relationships.
- *Forest Structural Conditions*: Structural conditions are plant succession stages (*i.e.*, early grass/forb to old-growth). Definitions are based on tree size (diameter at breast height; dbh), percent canopy cover, and number of canopy layers (see Section 2.4).
- *Level of Association between Wildlife and Structural Conditions*: Three categories are used to describe the degree of association between wildlife species and forest structural conditions:
 - *Closely Associated*. A species is widely known to depend on a habitat or structural condition for part or all of its life history requirements. It has an essential need for this habitat or structural condition for its maintenance and viability.
 - *Generally Associated*. A species exhibits a high degree of adaptability and may be supported by a number of habitats or structural conditions. The habitats or structural conditions play a supportive role for its maintenance and viability.

- *Present*. A species demonstrates occasional use of a habitat or structural condition. The habitat or structural condition provides marginal support to the species for its maintenance and viability.
- *Habitat Elements*: Components of the environment believed to most influence wildlife species' distribution, abundance, fitness, and viability. Habitat elements include natural attributes, both biological and physical (e.g., large trees, woody debris, cliffs, and soil characteristics).
- *Key Ecological Functions*: The principal set of ecological roles performed by each species in its ecosystem. Key ecological functions refer to the main ways organisms use, influence, and alter their biotic and abiotic environments. The classification system developed for the US part of the basin (Johnson and O'Neil 2001) includes 85 categories of ecological functions, including major headings and subheadings.

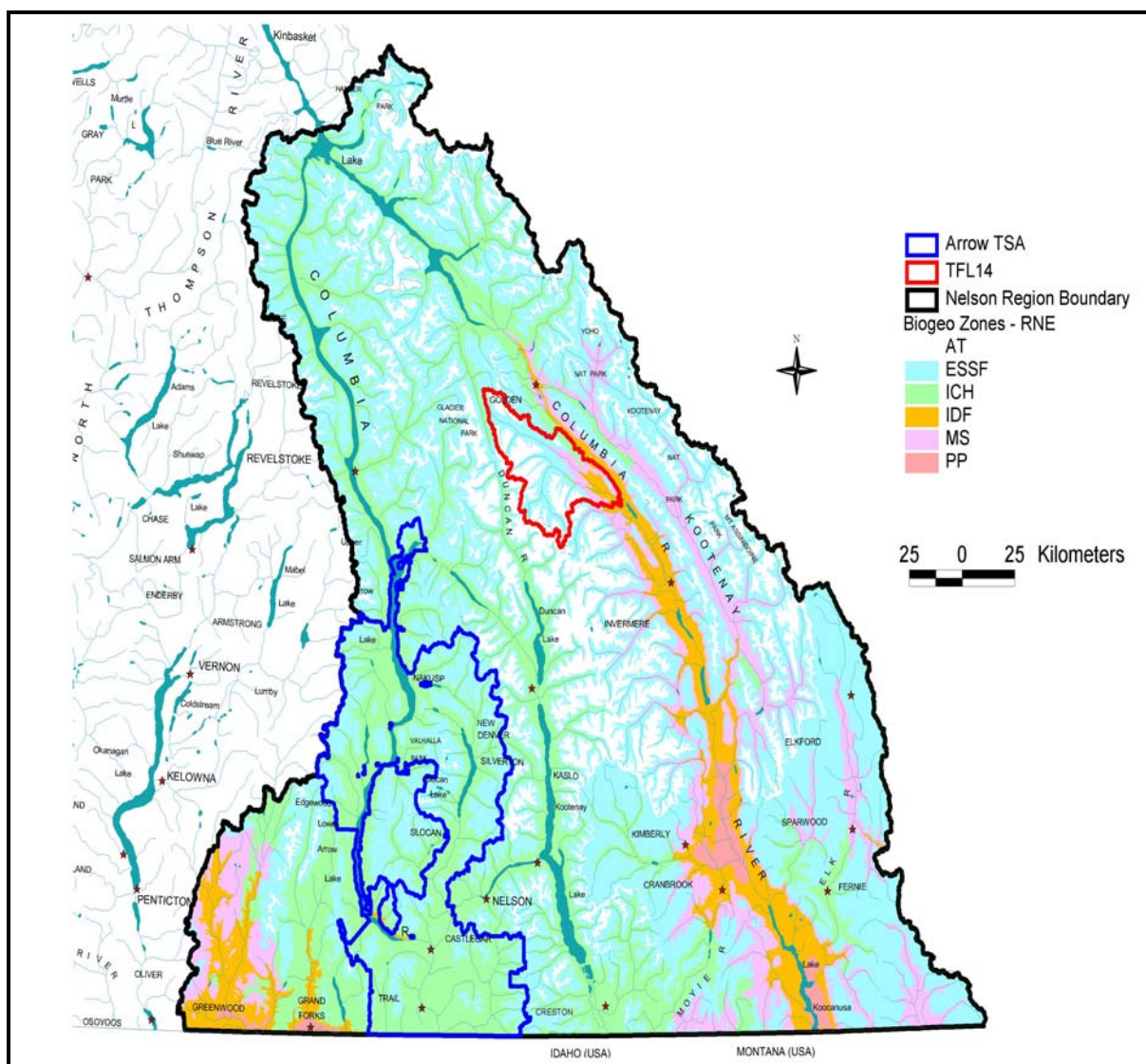


Figure 1. Location of Habitat Supply Modelling Pilot Projects: a) TFL 14 (outlined in red) and b) the Arrow TSA (outlined in blue)

Steeger (et al. 2001) revised the US species list (Johnson and O'Neil 2001) by deleting species that do not occur in BC and adding species that occur only in BC. The resulting vertebrate species list was then reviewed by wildlife experts familiar with the BC portion of the Basin. The reviewers also revised the species-habitat matrices to reflect known wildlife-habitat relationships in the province.

Using the BC Columbia Basin Database, we developed a filtering process (Figure 2) to establish a wildlife species list for TFL 14 that was: (i) realistic in that it reflects actual or very probable occurrence of species in the TFL area, (ii) relevant with respect to timber harvesting and silviculture, and (iii) manageable for modelling applications with respect to the number of species considered. The purpose of the filtering process was to establish a list of species that are closely associated with forested structural conditions found on TFL 14, and to then use the list to determine important forest structural conditions and habitat elements to track in the habitat supply forecasting exercise. The process involved both database queries and expert review at various stages.

2.2.2 TFL 14 Spatial Timber Supply Analysis

Timberline Forest Inventory Consultants Limited conducted a spatial timber supply analysis on TFL 14 (Timberline 2001) in order to model the impacts of implementation of Kootenay-Boundary Higher Level Plan Order (HLPO). The analysis was considered “spatial” because, unlike analyses used in Timber Supply Reviews (TSR), the location of stands (Timber Unit Mapping or TUMs) was spatially referenced in a Geographic Information System (GIS). These TUMs were aggregated into about 120 Analysis Units (AUs) with similar stand and growth characteristics that were modelled over a 250-year forecast period under different constraints. The timber analysis was restricted to the THLB.

The spatial analysis tracked stand structure to meet specific environmental and timber targets defined by the HLPO. This was accomplished by using a lookup table to reset partially harvested stands to earlier stand ages. Stands with high retention levels (*i.e.*, >70%) were reset to stand ages of ≥ 100 years, while stands where more timber was removed were reset to younger ages. Growth and yield curves (stand volume) were defined for natural, clearcut, and partial cut stands. Curves for partial cut stands were simple “flat lines” at given stand volumes. This avoided the problem of defining stand volume by age in partially cut blocks with complex stand characteristics, while still providing a reasonable method of tracking volumes available for harvest.

Our habitat supply projections capitalized on the availability of this detailed timber supply analysis by tying habitat supply forecasts for wildlife directly to the spatial project output through a series of lookup tables. The lookup tables linked stand information tracked by the spatial project to forest structural conditions and habitat elements defined by the CBD.

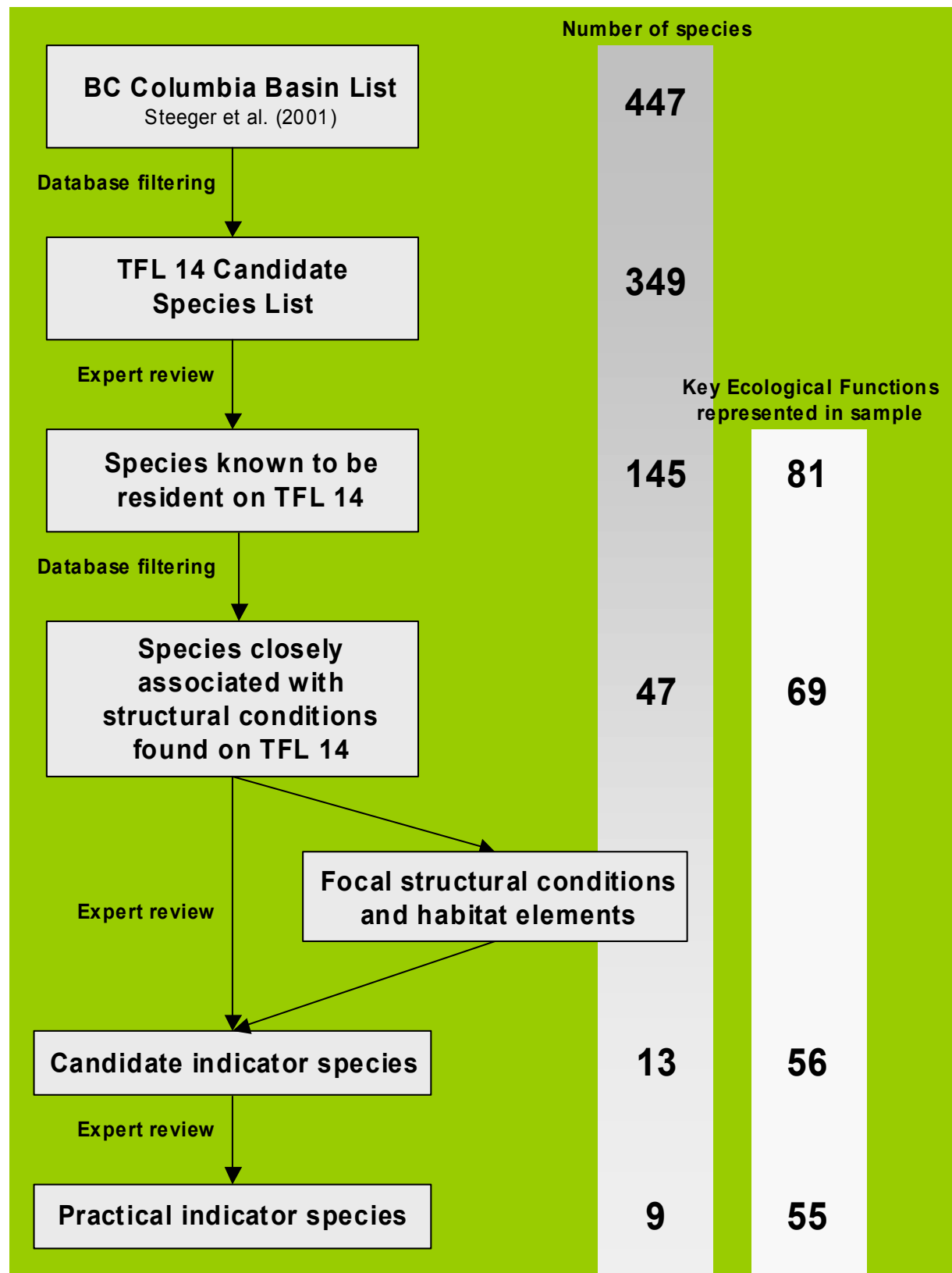


Figure 2. Methodology used to generate species lists and to determine focal structural conditions and habitat elements for the TFL 14 pilot project.

2.2.3 TFL 14 Range of Natural Variability

As part of the environmental component of the TFL 14 spatial analysis project, Utzig and Holt (2002) estimated the variability in forest seral stage distribution for TFL 14 based on natural disturbance return intervals (*i.e.*, in the absence of harvesting). They then used fixed percentage variations to establish maximum and minimum “ranges of natural variability” in seral stage distribution. The analysis was stratified by biogeoclimatic subzone variant.

2.3 HABITAT TYPES

We determined the CBD habitat types occurring on TFL 14 directly from digital maps prepared by Ketcheson et al. (2001; Table 1, Figure 3). These maps were developed at a relatively broad scale (1:250,000) from a variety of resource inventories including Terrain Resource Inventory Maps (TRIM), forest cover, biogeoclimatic (BEC) maps, Terrestrial Ecosystem Mapping (TEM), biophysical mapping, existing Predictive Ecosystem Maps (PEM) and Landsat satellite imagery. Wildlife-habitat types were assigned to areas by a subjective scoring process that related each attribute within each inventory to US wildlife-habitat types. The maps are not designed to provide detailed habitat information and the accuracy of them is unknown.

The CBD relates wildlife species occurrence to wildlife-habitat types, which we used to generate a list of potential species for TFL 14 (349 species; Figure 2). For our analysis of supply of structural conditions and habitat elements (see below), we focused on forested habitats, within TFL 14. Non-forested habitats were not considered in the analysis because succession characteristics were not defined for these habitats and, therefore, habitat supply forecasting was not possible. We also did not model supply of forested habitat types because (i) TFL 14 is too small for addressing trends in the amount of broad-scale habitat types, (ii) habitat type mapping is general and accuracy is unknown, and (iii) forest successional pathways could not be inferred easily from the resource inventories on which the classification was based.

Table 1. Area covered by different habitat types on TFL 14.

Columbia Basin Database Habitat Type	Area (ha)
Montane Mixed Conifer Forest	73,106
Eastside (Interior) Mixed Conifer Forest	23,578
Lodgepole Pine Forest and Woodlands	9
Upland Aspen Forest	3
Subalpine Parkland	19,155
Alpine Grasslands and Shrublands	4,589
Urban and Mixed Environs	38
Open Water	1,052
Herbaceous Wetlands	633
Montane Coniferous Wetlands	2,281
Eastside (Interior) Riparian-Wetlands	11
TOTAL	161,108

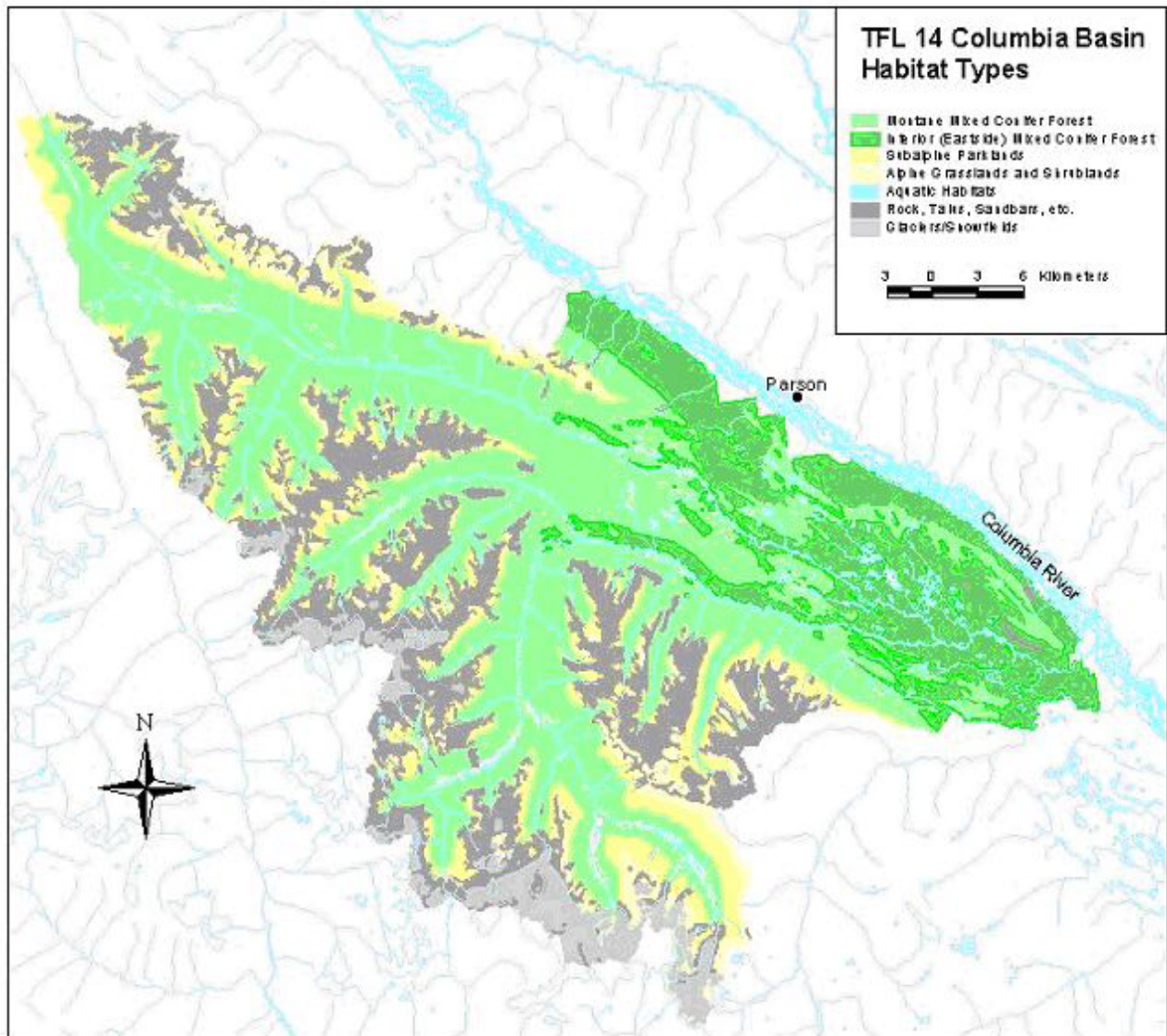


Figure 3. TFL 14 and associated habitat types as defined by the Columbia Basin Database.

2.4 FOREST STRUCTURAL CONDITIONS MODELLING

We mapped forest structural conditions by relating the TFL 14 Spatial Project's analysis units (Timberline 2001) to parameters used in the CBD to define structural conditions. As a result, the basic units of mapping and analysis for the habitat supply analysis were the TUMs defined by the Spatial Project. Future forest conditions were based on the spatial project's HLPO base case (Timberline 2001).

2.4.1 Tree Size

Tree size, as defined by the CBD (Table 2), was determined from dbh-stand age curves defined for each analysis unit (Timberline 2001). Curves were available only for harvestable analysis units.

Table 2. Tree size classes from the Columbia Basin Database (CBD).

Tree size class name	Diameter at breast height (dbh)
Shrub/Seedling	<2.5 cm
Sapling/Pole	2.5-24 cm
Small Tree	25-37 cm
Medium Tree	38-49 cm
Large Tree	50-75 cm
Giant Tree	≥76 cm

2.4.2 Percent Canopy Cover

The CBD defines three canopy cover classes: *open* (10-39%), *moderate* (40-69%) and *closed* (70-100%). We related these classes to analysis units by site productivity (good, medium, poor) and stand type. We categorized leading species for analysis units into four stand types:

1. Lodgepole Pine (PI)
2. Engelmann Spruce/Subalpine Fir (Se/BI)
3. Douglas-fir (Fd)
4. Mixed conifer

Defining percent canopy cover classes for natural and clear cut analysis units involved two lookup tables (Tables 3a and 3b) that estimated stand ages at which canopy cover changed from open to moderate and from moderate to closed. Tembec staff estimated these stand ages based on expert opinion. We considered stand ages when canopy cover changed from closed to moderate to be the same ages at which stands change from single to multi-storey canopies (see Tables 3a and 3b). We assigned partial cut analysis units to the *moderate* canopy cover class. All stands in the Shrub/Seedling tree size class were considered *open* stands.

Table 3(a) Lookup table defining stand ages (year) at which canopy cover classes change from *open* to *moderate*, by stand type and site productivity.

Leading species	Canopy closure change from <i>open</i> to <i>moderate</i>		
	Good	Medium	Poor
PI	20	20	20
Se/BI	30	30	40
Fd	20	20	20
Mixed (average)	20	20	30

Table 3(b) Lookup table defining stand ages (year) at which canopy cover classes change from *moderate* to *closed*, by stand type and site productivity.

Leading species	Canopy closure change from <i>moderate</i> to <i>closed</i>		
	Good	Medium	Poor
PI	30	30	40
Se/BI	40	40	50
Fd	30	30	40
Mixed (average)	30	30	40

2.4.3 Number of Canopy Layers

We defined age at which stratification in the canopy layer begins in natural and clear cut stands with a lookup table (Table 4) in order to relate analysis units to the CBD canopy layers variable (*i.e.*, *1 stratum*, *2 or more strata*). Tembec staff estimated these stand ages based on expert opinion. Partial cut analysis units were assigned to the *2 or more strata* class. Where tables assigned *2 or more strata* to analysis units with the Sapling/Pole tree size class, the canopy layer class was changed to *1 stratum* because no structural conditions with *2 or more strata* were defined in the CBD with the Sapling/Pole tree size class.

Table 4 . Year in which stratification in the canopy layer begins, by stand type and site productivity.

Leading species	Year at which stratification begins in the canopy layer, by site productivity		
	Good	Medium	Poor
PI	80	100	80
Se/BI	90	110	80
Fd	130	110	80
Mixed (average)	100	110	80

2.5 HABITAT ELEMENTS MODELLING

2.5.1 Identification of Focal Habitat Elements

In identifying important habitat elements, we used the list of 47 terrestrial vertebrate species *closely associated* with forest structural conditions and considered the habitat elements required by a relatively large percentage of these species (Appendix 2). The resulting focal habitat elements (with proportion of species that require them) were: snags (43%); down wood (40%); shrubs (34%); large, live trees (43%); and bark (21%). One or more of these habitat elements are used by 40 (85%) of the 47 species.

2.5.2 Snags

Modelling snag availability was based on the following assumptions.

1. Snags >30 cm dbh are ecologically functional for most species. That is, larger species (*e.g.*, woodpeckers, some owls, raptors, marten) require trees this size or larger, and smaller species (*e.g.*, chickadees, nuthatches, squirrels) appear to prefer larger trees but will also use smaller trees (*e.g.*, nuthatches; Steeger & Hitchcock 1998). Larger trees are also preferred as foraging sites, especially by woodpeckers foraging for insects in wildfire burns (Hutto 1995). Woodpecker foraging on unburned trees was found to be concentrated in the 20-50 cm dbh class (Quesnel et al. 1997). For the forecast models, we used Utzig and Gaines (1998) snag supply curves (Appendix 3) which were based on snags >30 cm dbh. Others have suggested including snags as small as 20 cm dbh in retention targets. Snags this size are sometimes used by birds for foraging and nesting (Steeger and Machmer 2002).
2. Snag longevity is area specific (Everett et al. 1999). The same is expected for snag recruitment; however, no snag longevity and recruitment data were available for TFL 14. As a result, we based our snag supply estimates on data from Utzig and Gaines (1998) that was derived from the Invermere Enhanced Forest Management Pilot Project (EFMPP) area, which is located near TFL 14. Snag fall-down estimates were based on data from the east slope of the Cascade Range in Washington State (Everett et al. 1999; Appendix 3). Therefore, these estimates should be interpreted with caution.
3. Naturally regenerating stands:
 - (i) The natural disturbance patterns occurring across the TFL reflect “stand-initiating events” (*sensu* Biodiversity Guidebook 1995). Therefore, at time zero (*i.e.*, just after a fire), the density of (burned) snags equals the pre-fire stand density minus live residuals.
4. Clearcut and partially cut stands:
 - (i) The requirement for Wildlife Tree Retention (WTR) in the THLB on TFL 14 is 3.6% of cutblock area (weighted average of the retention percentages for all BEC subzones in the TFL; Robert Ferguson, *pers. comm.*). This average retention percentage is based on the 1999 Landscape Unit Planning Guide of the Forest Practices Code and the provincial Wildlife Tree Policy, February 2000 version (Province of BC 1999, 2000) and includes the 50% reduction in retention requirements for interior forest stands (*i.e.*, 3.6% is the THLB retention percentage while the other 3.6% is to be located in the non-contributing landbase).
 - (ii) The total THLB in TFL 14 is 56,282 ha; therefore, the required WTR area is 2,026 ha (3.6%). The following calculations of how many large-sized snags are likely contained on 2,026 ha are based on (i) the guiding principles of the provincial wildlife tree policy (*e.g.*, the definition of a valuable wildlife tree, accounting for dispersed retention of snags and the contributions of

seed/shelterwood trees; Province of BC 2000) and (ii) the criteria of the wildlife tree course which include the WCB tree hazard regulations (Province of BC 2001). Assuming a functional (but hazardous) snag of 30 cm dbh is at least 25 m in height, the area of a WTP required around this snag is 0.44 ha (square of 1.5 x times the height of the snag x 3.14). Therefore, approximately 0.1 snag/ha can be expected following harvesting. Assuming that some patches are larger and contain more functional snags (*e.g.*, riparian areas or root disease centres), we increased this minimum retention density from 0.1 to 0.5 snags/ha.

5. Following a stand-initiating event (*e.g.*, fire, insects), snag density will decrease over time according to area- and tree species-specific fall rates. Only when new trees grow to ≥ 30 cm dbh and then die will the decline in snag supply change. Based on species-specific growth curves for TFL 14, we estimate that, on sites with good or moderate productivity, Pl and Se/Bl will reach the 30 cm diameter criterion some time in age class 80-120 and 121+, respectively.

Based on these assumptions, the following methods were used to derive snag density data for TFL 14:

1. For naturally regenerated Pl-leading and mixed species stands, we used results from Utzig and Gaines (1998). Snag density values were estimated from snag density curves, using the intermediate site index curves. These curves are based on cruise data from the Invermere EFMP area. Although we modelled “mixed conifer” stands, we used Utzig and Gaines’ (1998) curves for mixed conifer that also included a deciduous (F-PY/C-H/deciduous) component because it was the closest, most realistic approximation.
2. For naturally regenerated Fd-leading stands, we used Utzig and Gaines’ (1998) mixed stand type which was composed primarily of Douglas-fir (Greg Utzig, *pers. comm.*). We then reduced snag densities according to the regression curves provided by Everett et al. (1999) for periods up to and including 81-120 years (Everett’s curves end at 80 years after fire). We derived the value for the last period from Utzig and Gaines (1998).
3. For naturally regenerated Se/Bl stands, we used mensuration data from the provincial ecology program (Province of BC 2001) and took the weighted average of stems/ha and snags/ha > 30 cm dbh of all ESSF subzone variants that occur in the Nelson Forest Region (*i.e.*, 255 stems + 63 snags/ha = 318 initial snag density; assuming all trees were killed by fire that occurred when the stand was mature, or 101-250 years old). By the midpoint of the 0-20 year period after disturbance, 22% of snags have fallen (Everett et al. 1999), leaving 78% of 318, or 248. We then reduced snag densities according to the regression curves (average of Se and Bl) provided by Everett et al. (1999) up to and including the 81-120 year period. The final value was the same as the starting snag density of 63 snags/ha.
4. For clearcut and partial cut scenarios in all stands, we used the snag retention value calculated under Assumption 4b above for time period 0-20 years (*i.e.*, 0.5 snags/ha). For Pl and mixed stands, we reduced the density value for the second period (21-40 years)

according to the regression curves provided by Everett et al. (1999) and then used Utzig and Gaines (1998) for the remaining periods. For Fd-leading stands, we used Everett et al. (1999) for the next three periods and Utzig and Gaines for the last period. For Se/Bl stands, we used Everett et al. (1999) for the next three periods and the natural scenario 81-120 year value of 32 for the last period (assuming recruitment of big snags is slower than under natural conditions).

Based on these methods, we related snag density to stand type, natural disturbance and clearcut/partial cut with four snag retention levels, and stand age (Table 5).

We reported mean snag densities for the entire TFL, by stand type. We also reported the proportion of TFL that met the guidelines for snag density targets adapted from Steeger and Machmer (2002). These targets are: seven snags/ha for lodgepole pine, five snags/ha for Douglas-fir, and 10 snags/ha for spruce-subalpine fir stand types (in addition, we used a seven snags/ha target for the mixed conifer stand types modelled in this project). These snag density targets refer to snags >20 cm dbh and include stand type-specific proportions of snags >50 cm dbh (*i.e.*, Douglas-fir 50%, lodgepole pine 5%, and spruce or subalpine fir 25%, Steeger and Machmer 2002). In this project, we used the 30 cm dbh criterion because the snag longevity information we used from Everett et al. (1999) is from the 23-41 cm diameter class (see Appendix 3), Utzig and Gaines (1998) data are for snags >30 cm, and the closest tree size class limit in the CBD is 25 cm. Also, the BC wildlife tree policy (Province of BC 2001) calls for leaving the largest wildlife trees on any given cutblock; given the tree sizes on TFL 14, we can therefore assume that a significant amount of leave trees would be between 30-50+ cm diameter in size.

Table 5. Snags/ha (>30 cm dbh) by stand type, natural disturbance, and forest harvesting with four alternative snag retention scenarios (a. clearcut without WTPs, b. current clearcut/partial cut with WTPs, c. double current retention, d. Steeger & Machmer [2002] density targets), and stand age.

Stand type	Disturbance	Year				
		0-20	21-40	41-80	81-120	121+
PI	Natural	50	11	7	11	17
PI	Harvesting plus snag retention scenarios	0	0	0	11	17
		0.5	0.1	3	11	17
		1	0.2	6	11	17
		7	1.4	7	11	17
Mixed conifer	Natural	50	14	7	11	17
Mixed conifer	Harvesting plus snag retention scenarios	0	0	0	11	17
		0.5	0.15	0.15	11	17
		1	0.3	0.3	11	17
		7	2.1	7	11	17
Fd	Natural	50	22	10	8	17
Fd	Harvesting plus snag retention scenarios	0	0	0	0.05	17
		0.5	0.1	0.06	0.05	17
		1	0.2	0.12	0.1	17
		5	1	0.6	0.5	17
Se/Bl	Natural	248	134	48	32	63
Se/Bl	Harvesting plus snag retention scenarios	0	0	0	0.05	32
		0.5	0.2	0.1	0.05	32
		1	0.4	0.2	0.1	32
		10	4	2	1	32

2.5.3 Down Wood

Down wood data have been collected on the TFL, although sample sites were established primarily in old growth (K. Stuart-Smith, *pers. comm.*). Down wood volumes vary widely within stand types; therefore, three broad classes of down wood volumes were modelled in habitat forecasts: low: ≤ 50 m³/ha; medium: >50 and ≤ 150 m³/ha; and high: >150 m³/ha. Down wood by volume class was estimated for stand types and ages (Table 6).

Few studies have related down wood volumes to species requirements (Carey and Johnson 1995), although Craig (2002) recommended that at least 80 m³/ha and 300 m³/ha be maintained in IDF and ESSF forests, respectively, in order to provide adequate habitat for small mammals.

Table 6. Down wood volume classes by stand type and stand age (age categories based on research and Stuart-Smith *pers. comm.*). Volume classes were defined as: low: ≤ 50 m³/ha; medium: >50 and ≤ 150 m³/ha; and high: >150 m³/ha

Leading species	Down wood volume class by stand age		
	Natural ≤ 120 years	Natural >120 years	Clear-cut and partial cut stands (all ages)
PI	Medium	Medium	Low
S/B	Medium	Medium	Medium
Fd	Low	High	Low
Mixed (average)	Medium	Medium	Low

2.5.4 Shrubs

No data were available for TFL 14 to relate the abundance of shrub cover to forest age or stand type; therefore, we categorized multi-storey and single-storey stands as *high* and *low* shrub cover, respectively. All shrub/seedling structural conditions were assumed to have *high* shrub cover.

2.5.5 Large Live Trees

We inferred the abundance of large, live trees directly from forest structural conditions with *large trees*. All structural conditions, by CBD definition, include post-disturbance residual cover of $<10\%$; however, residual cover may be higher than 10% on TFL 14 due to partial cutting and wildlife tree retention management practices.

2.5.6 Bark

We considered Douglas-fir stands >100 years old to contain trees with bark thick enough to be functionally useful for a variety of wildlife species (*e.g.*, for brown creeper nest sites or bark-gleaning insectivores). Other thick-barked species occurring in the TFL include western larch, ponderosa pine, and black cottonwood. These species were not modelled because no analysis units were defined with these species leading. As a result, the number of trees with ecologically functional bark was underestimated.

2.6 HABITAT SUPPLY FORECASTING

We used the tables in the above sections to translate analysis units and stand age output from the spatial project to CBD forest structural conditions and habitat elements, at specific reporting

years (0, 20, 70, 100, and 250 years). This provided the ability to project abundance of structural conditions and habitat elements on TFL 14 over the forecast period. Forecasts were based on simple aspatial sums of areas covered by different structural conditions and classes of habitat elements.

2.7 RANGES OF NATURAL VARIABILITY

We used maximum, mean, and minimum seral stage distributions (by BEC subzone variant) from Utzig and Holt (2002) and applied the lookup tables for forest structural conditions and habitat elements to generate ranges of natural variability. We assumed that, within seral stage grouping listed by Utzig and Holt (2002), stands were equally distributed among decades.

Utzig and Holt (2002) used disturbance return intervals (considering maximum ages of trees in a stand) to establish ranges of natural variability; however, the timber supply model considered average rather than maximum age of trees in a stand. Therefore, the ranges of natural variability might report larger proportions of old forest, particularly in natural stands characterized by long return intervals (*e.g.*, wetter subzones in ESSF) where senescence of trees results in average tree ages that are younger than the time since last disturbance.

Maximum and minimum ranges of natural variability were included on figures illustrating forecasted abundance of forest structural conditions and habitat elements. Means were omitted for legibility.

2.8 KEY INDICATOR SPECIES

We assembled a list of indicator species for a wildlife-monitoring program on TFL 14. The purpose of the program would be to track trends in relative abundance of species that are closely associated with focal structural conditions and habitat elements on the TFL. Monitoring practicality must also be considered.

Starting with the list of 47 species (Figure 2), we used the CBD to relate these species to:

- two types of focal structural conditions (large-tree and multi-story); and
- five focal habitat elements (large live trees, snags, down wood, shrubs, and bark).

We then computed the total number of focal habitat associations (*i.e.*, to a maximum of 7, Appendix 4) for each species, as well as the number of structural conditions (*i.e.*, to a maximum of 25, Appendix 1) with which the species are closely associated.

For selection of indicators, we considered only those species that are

- closely associated with ≥ 4 of the seven focal habitat associations (*i.e.*, structural conditions and habitat elements); and
- found in ≤ 5 of the 25 forest structural conditions (*i.e.*, species that were not habitat generalists).

Finally, we filtered out those species we considered impractical for monitoring, using the following criteria:

- species have to be detectable with common survey methods, according to the provincial Resource Inventory Standards Committee (RISC);
- species are expected to be responsive to changes caused by forest management practices; and
- survey methods have to be cost effective.

3.0 RESULTS

3.1 SPECIES

Of the 447 terrestrial vertebrate species potentially occurring in the BC portion of the Columbia River Basin, 349 are related in the CBD to the habitat types that occur on TFL 14. Expert review suggested that 145 of these species are either known to occur on the TFL or are highly probable residents likely responsive to timber harvesting and/or silviculture activities. Final filtering for species closely associated with forest structural conditions that occur or could occur on the TFL resulted in a list of 47 species (Table 7). We cross-referenced the 47 species with forest structural conditions and habitat elements (Appendices 1 and 4). Of the 47 species, two are currently blue-listed by the BC Conservation Data Centre (Flammulated Owl and Northern Long-eared Myotis).

Table 7. Terrestrial vertebrate species closely associated with forest structural conditions on TFL 14. Additional detail is provided in Appendix 1.

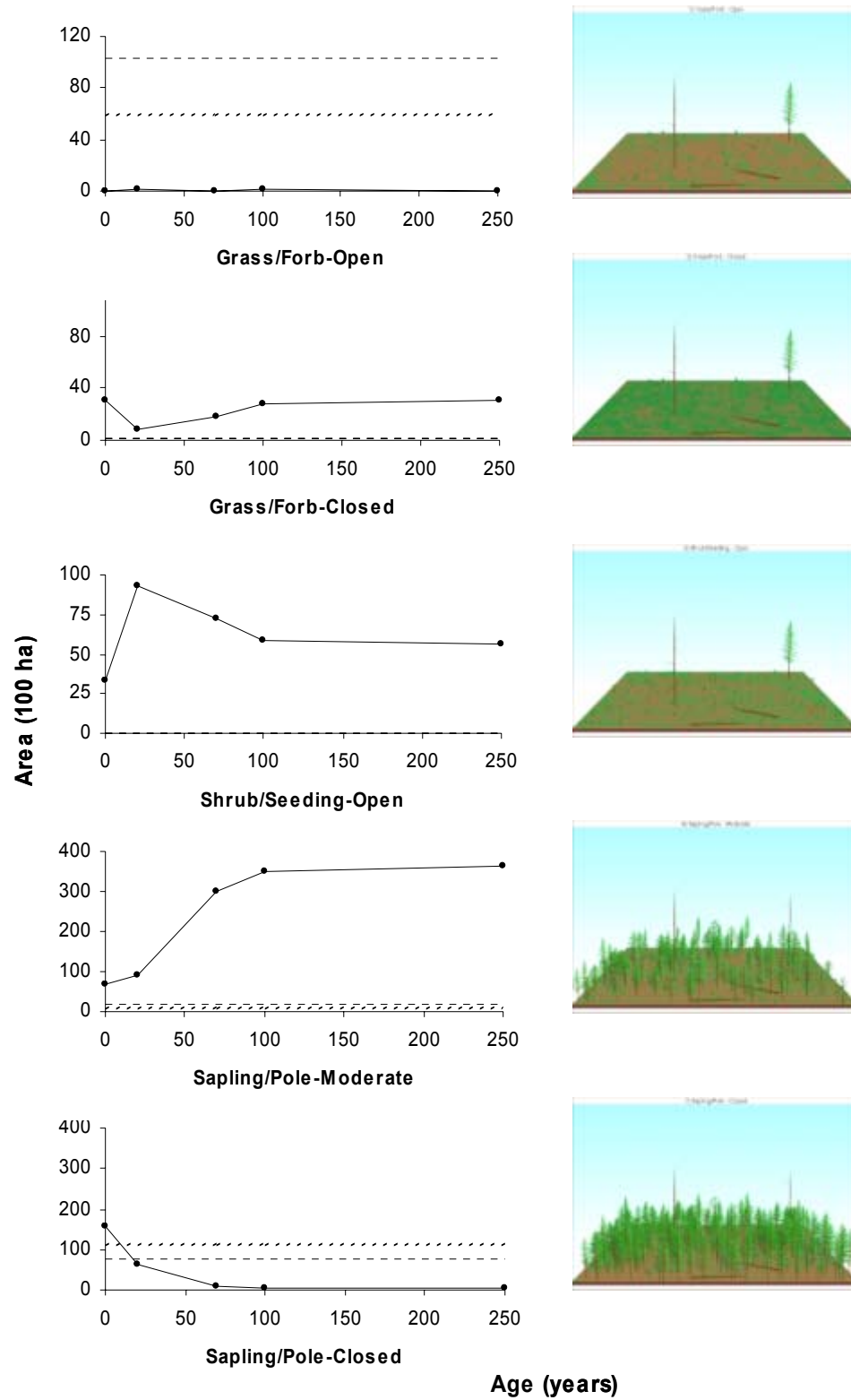
Common Name	Scientific Name
Wood Duck	<i>Aix sponsa</i>
Hooded Merganser	<i>Lophodytes cucullatus</i>
Sharp-shinned Hawk	<i>Accipiter striatus</i>
American Kestrel	<i>Falco sparverius</i>
Ruffed Grouse	<i>Bonasa umbellus</i>
Spruce Grouse	<i>Dendragapus Canadensis</i>
Blue Grouse	<i>Dendragapus obscurus</i>
Flammulated Owl	<i>Otus flammeolus</i>
Northern Pygmy-owl	<i>Glaucidium gnoma</i>
Barred Owl	<i>Strix varia</i>
Great Gray Owl	<i>Strix nebulosa</i>
Boreal Owl	<i>Aegolius funereus</i>
Black-backed Woodpecker	<i>Picoides arcticus</i>
Pileated Woodpecker	<i>Dryocopus pileatus</i>
Olive-sided Flycatcher	<i>Contopus borealis</i>
Cassin's Vireo	<i>Vireo philadelphicus</i>
Red-eyed Vireo	<i>Vireo olivaceus</i>
Steller's Jay	<i>Cyanocitta stelleri</i>
Winter Wren	<i>Troglodytes troglodytes</i>
Golden-crowned Kinglet	<i>Regulus satrapa</i>
Mountain Bluebird	<i>Sialia currucoides</i>

Common Name	Scientific Name
Varied Thrush	<i>Ixoreus naevius</i>
Townsend's Warbler	<i>Dendroica townsendi</i>
Western Tanager	<i>Piranga ludoviciana</i>
Lincoln's Sparrow	<i>Melospiza lincolnii</i>
White-crowned Sparrow	<i>Zonotrichia albicollis</i>
Dark-eyed Junco	<i>Junco hyemalis</i>
Common Shrew	<i>Sorex cinereus</i>
Pygmy Shrew	<i>Sorex hoyi</i>
California Myotis	<i>Myotis californicus</i>
Long-legged Myotis	<i>Myotis volans</i>
Northern Long-eared Myotis	<i>Myotis keenii</i>
Silver-haired Bat	<i>Lasionycteris noctivagans</i>
Big Brown Bat	<i>Eptesicus fuscus</i>
Snowshoe Hare	<i>Lepus americanus</i>
Least Chipmunk	<i>Eutamias minimus</i>
Red-tailed Chipmunk	<i>Eutamias ruficaudus</i>
Red Squirrel	<i>Tamiasciurus hudsonicus</i>
Northern Flying Squirrel	<i>Glaucomys sabrinus</i>
Deer Mouse	<i>Peromyscus maniculatus</i>
Southern Red-backed Vole	<i>Clethrionomys gapperi</i>
Western Jumping Mouse	<i>Zapus princeps</i>
Porcupine	<i>Erethizon dorsatum</i>
Black Bear	<i>Ursus americanus</i>
Grizzly Bear	<i>Ursus arctos</i>
Lynx	<i>Lynx canadensis</i>
Mountain Goat	<i>Oreamnos americanus</i>

3.2 FOREST STRUCTURAL CONDITIONS

The abundance and distribution of forest structural conditions changed considerably over the 250-year forecast (Figures 4 and 5). Eleven CBD structural conditions were represented on TFL, and of those, two covered only a few hectares at time zero and disappeared after the second or third reporting period (*sapling/pole-open* and *medium tree-single-story-closed*, are not shown in Figure 4). In general, the abundance of *small*, and *medium tree* structural conditions declined over time, and there was a large increase in the abundance of the *sapling/pole-moderate*

structural condition, which remained the most abundant structural condition through all reporting periods.



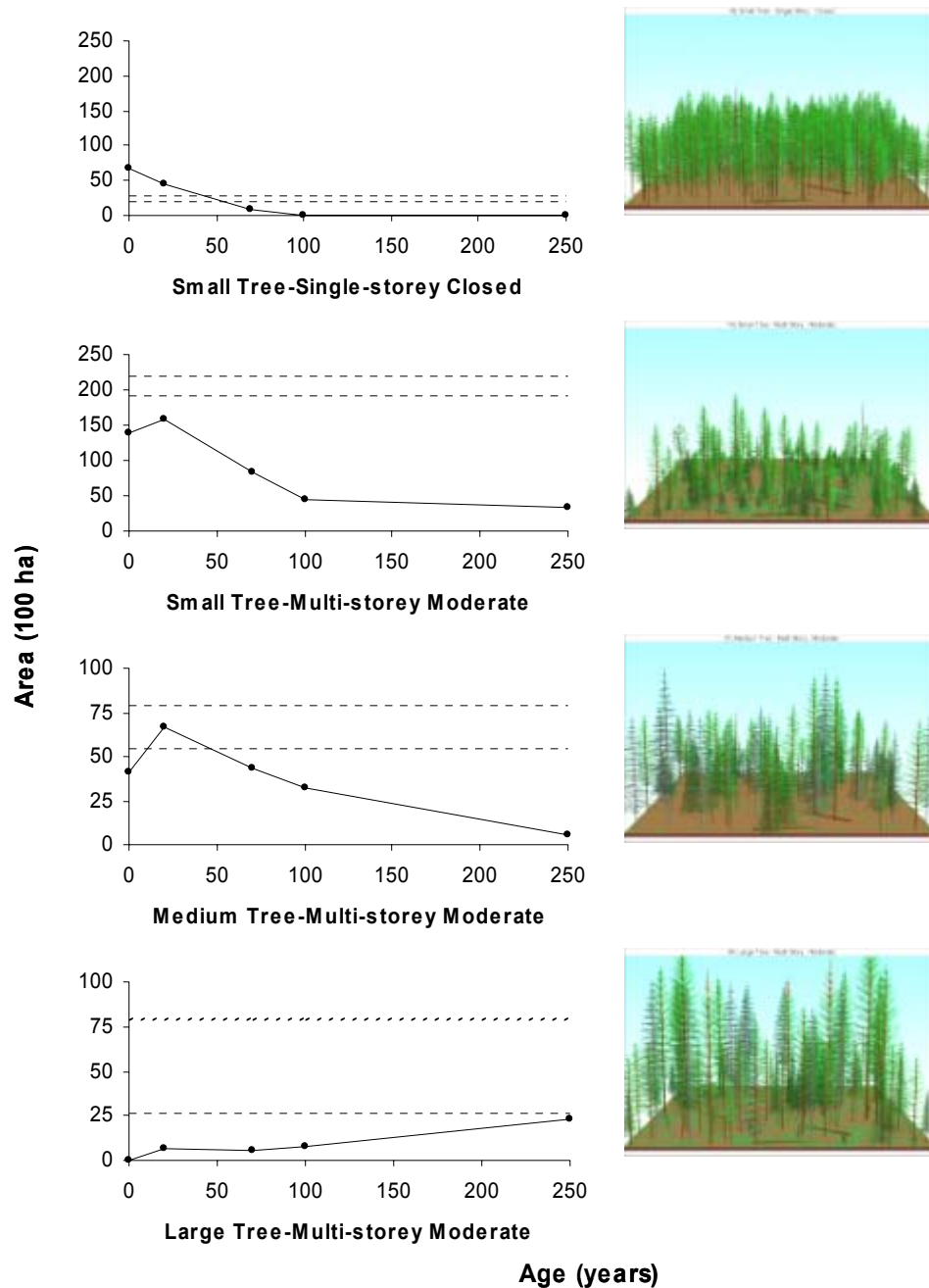


Figure 4. Forecasted areas of forested structural conditions, based on the spatial project's base case (Timberline 2001). Depictions of structural conditions are reproduced from Johnson and O'Neil (2001). Dashed lines indicate maximum and minimum ranges of variability, based on Utzig and Holt (2002).

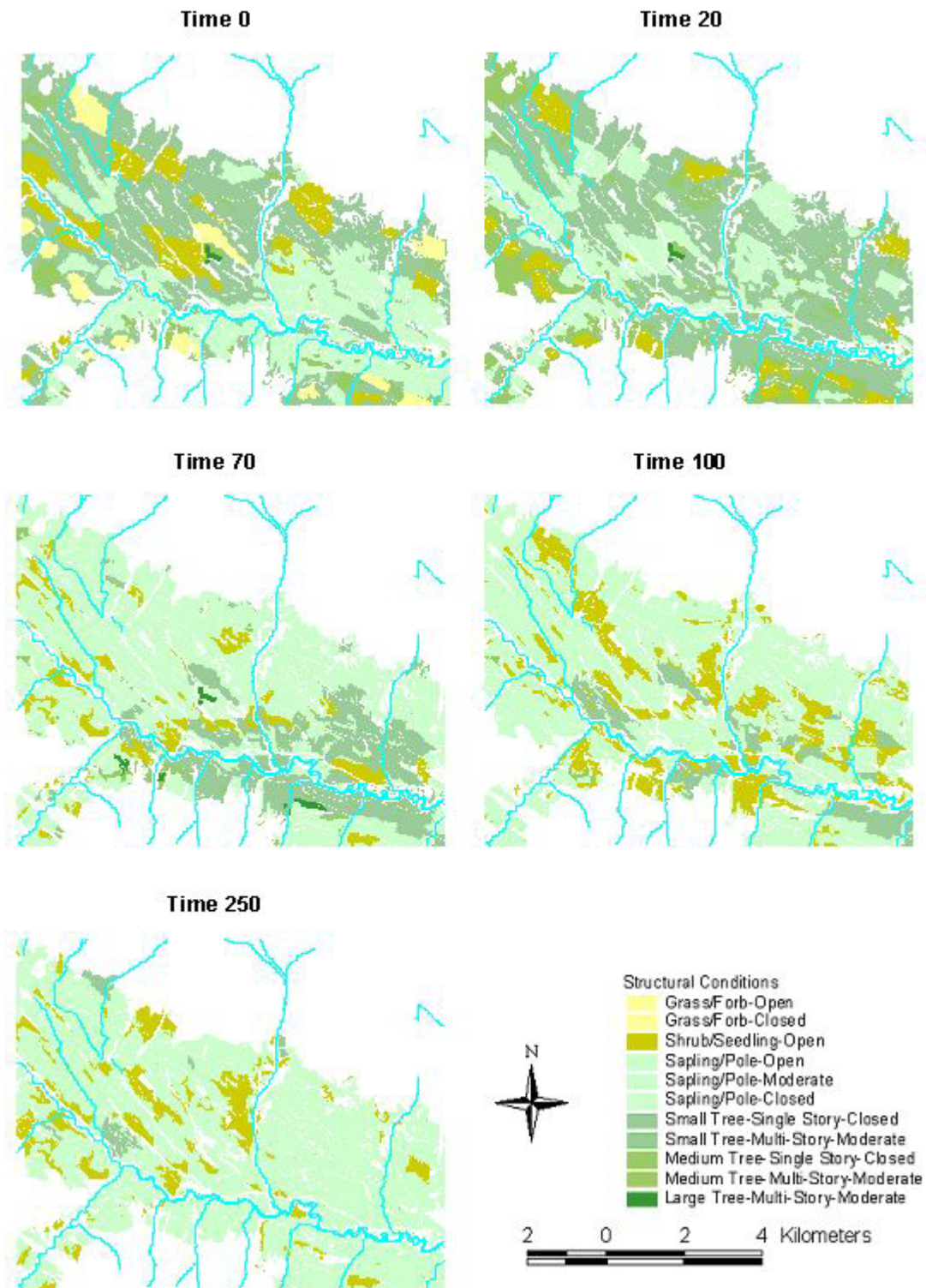


Figure 5. Forecasts of forest structural conditions on a portion of TFL #14, illustrating predicted distribution and abundance of structural conditions currently and at 20, 70, 100, and 250 years into the future.

3.3 HABITAT ELEMENTS

3.3.1 Snags

The abundance of snags in all stand types and for nearly all management scenarios declined with time in the forecast (Figure 6). The decline was most dramatic in the Spruce-Subalpine fir stand type, where the mean density of snags declines >50% in the first 70 years of the simulation. Averaged over the entire THLB (*i.e.*, aspatially), snag densities remained above targets for all scenarios in the Douglas-fir stand type, but fell below targets by year 250 in all scenarios in lodgepole pine and spruce-subalpine fir stands. Only the Steeger and Machmer (2002; Scenario d) retention levels maintained snags near target densities in mixed conifer stands.

The proportion of the THLB that met snag density targets fell in each reporting period for nearly all stand types (Figure 7) and was the same for Snag Retention Scenarios a, b, and c. Only where Steeger and Machmer's (2002; Scenario d) recommendations were modelled did the proportion of the THLB meeting targets increase.

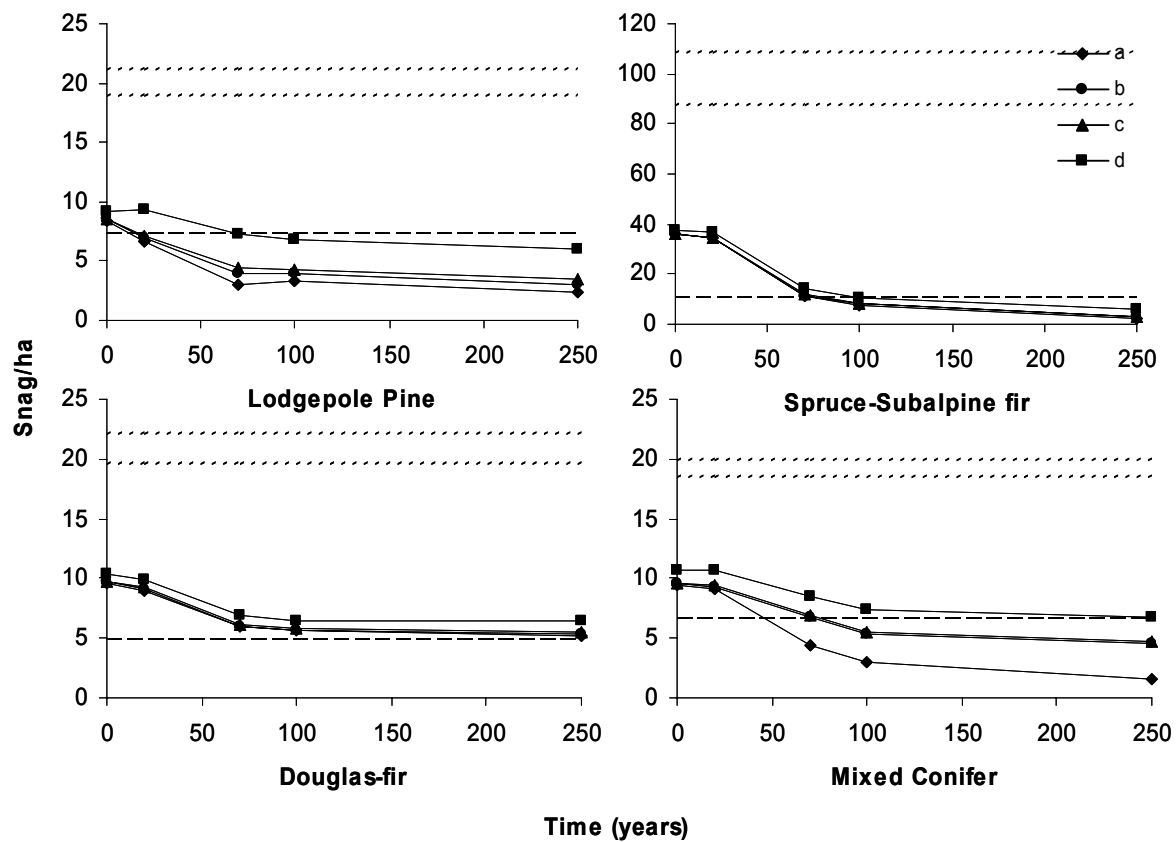


Figure 6. Density of snags (>30 cm dbh)/ha by forecast age, initial snag retention level (a. clearcut without WTPs, b. current clearcut/partial cut with WTPs, c. double current WTP retention, d. Steeger and Machmer [2002] density targets), and stand type. Dashed line indicates Steeger and Machmer (2002) targets and dotted lines indicate maximum and minimum ranges of variability, based on Utzig and Holt (2002).

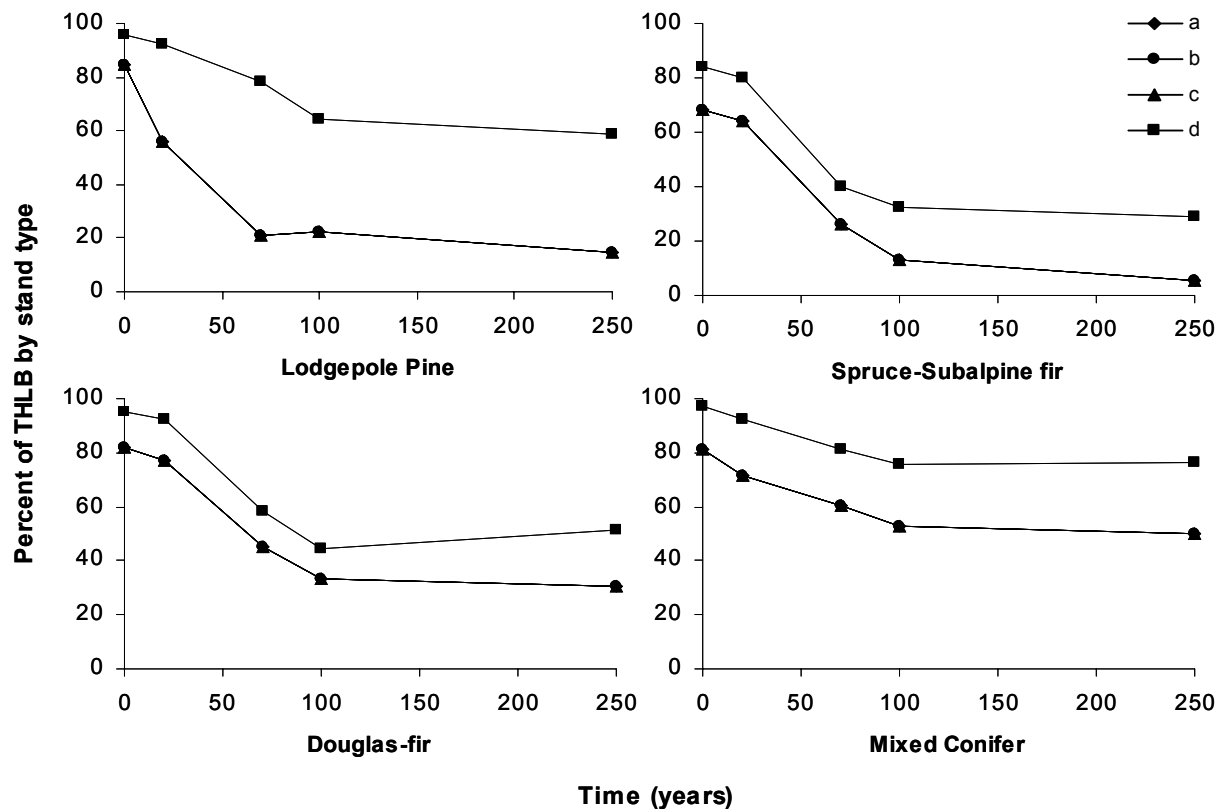


Figure 7. Proportion of area covered by different stand types meeting snag density targets (≥ 20 cm dbh; ≥ 7 snags/ha for PI and mixed conifer stands, ≥ 5 snags/ha for Fd, and ≥ 10 for Se/BI). Initial snag retention level (a. clearcut without WTPs, b. current clearcut/partial cut with WTPs, c. double current WTP retention, d. Steeger and Machmer [2002] density targets), and stand type. Dashed line indicates Steeger and Machmer (2002) targets and dotted lines indicate maximum and minimum ranges of variability, based on Utzig and Holt (2002).

3.3.2 Down Wood

High volumes of down wood ($>150 \text{ m}^3/\text{ha}$) were rare (1.9-3.7% of the THLB) and remained low throughout the forecast (Figure 8). The area covered by medium volumes of down wood declined with each reporting period.

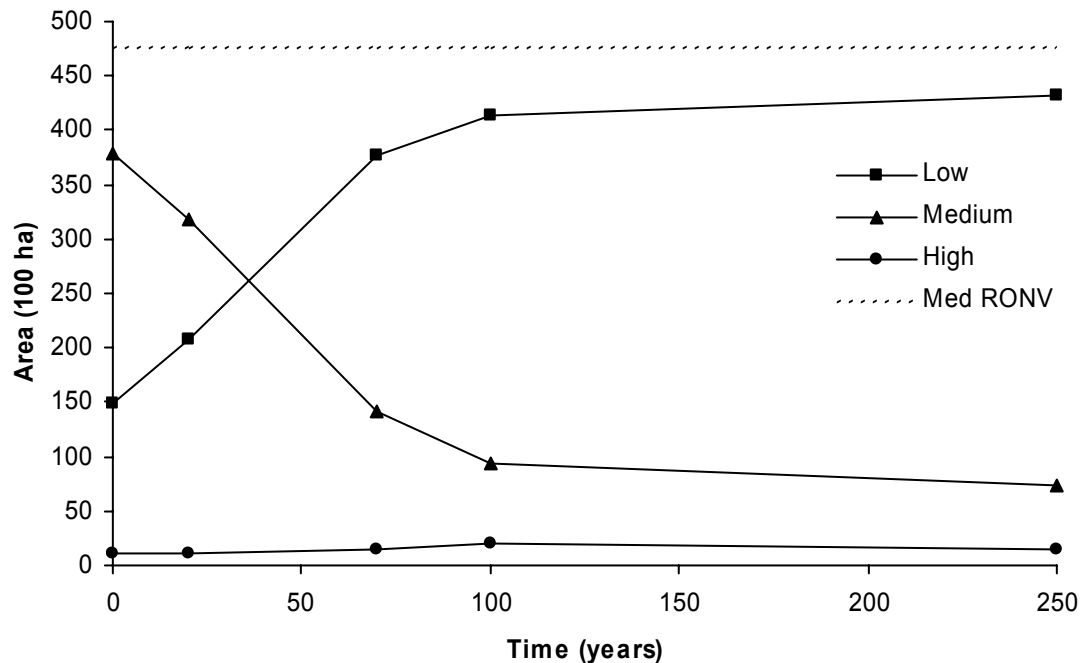


Figure 8. Down wood classes by area (low: $\leq 50 \text{ m}^3/\text{ha}$, medium: >50 and $\leq 150 \text{ m}^3/\text{ha}$, high: $>150 \text{ m}^3/\text{ha}$) and by reporting year. The dashed line represents the area of the THLB covered by stands dominated by medium volumes of downed wood averaged over 250 year period, as estimated by the range of natural variability max = min. (see Table 6).

3.3.3 Shrubs

Both lodgepole pine and mixed conifer stand types had peaks in *high* shrub abundance at year 20 (Figure 9). Abundance of shrubs was relatively constant in all stand types from year 100 onward.

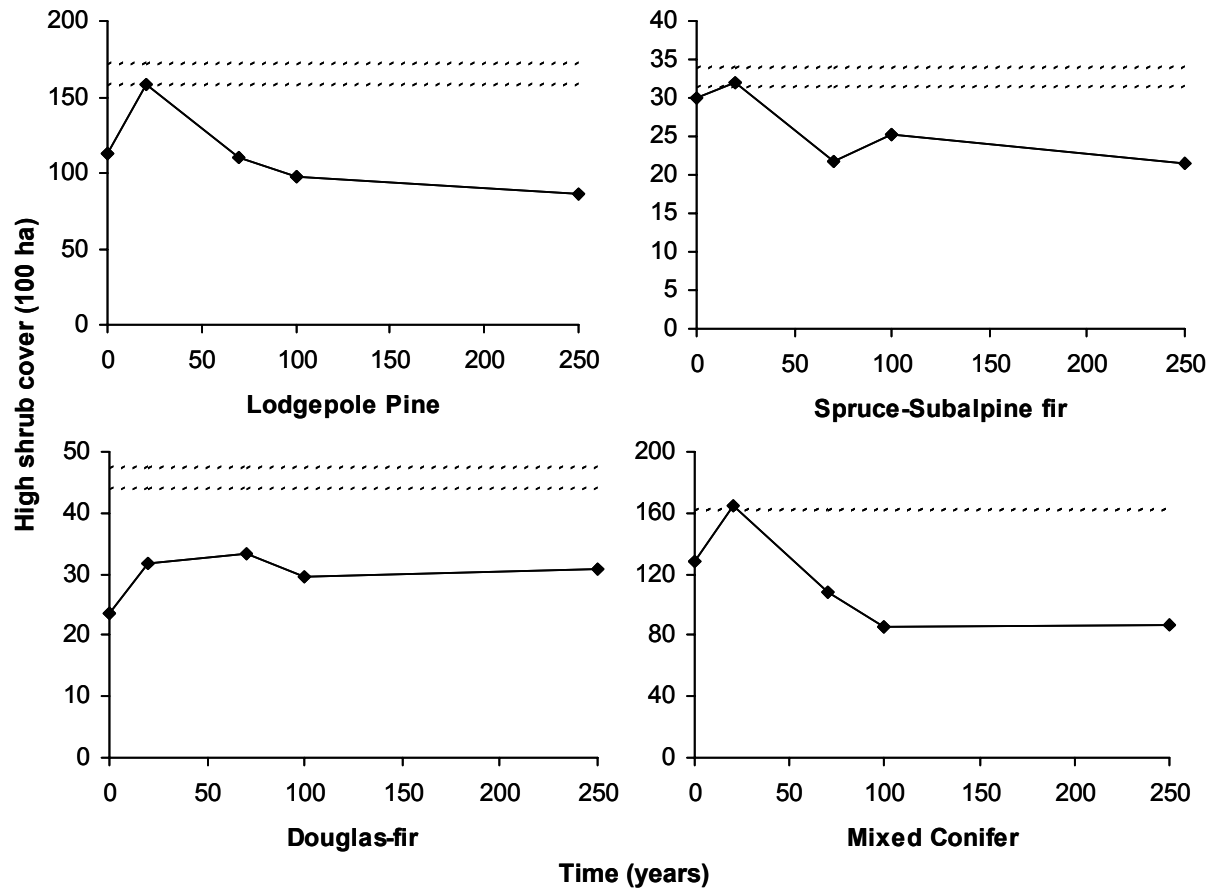


Figure 9. Area covered by high shrub cover, by stand type and forecast year. Dashed lines indicate maximum and minimum ranges of variability, based on Utzig and Holt (2002).

3.3.4 Large Live Trees

The area covered by stands dominated by large trees generally increased with time through the forecasting period, although the area remained a small proportion (0.07-4.4%) of the THLB. This habitat element was represented by the *Large tree-multi-story-moderate* structural condition (Figure 4).

3.3.5 Bark

The area covered by stands dominated by trees with thick bark initially increased and then decreased during the forecast period. Overall, the area covered by stands dominated by trees with thick bark accounted for only 2.7-4.9% of the THLB (Figure 10).

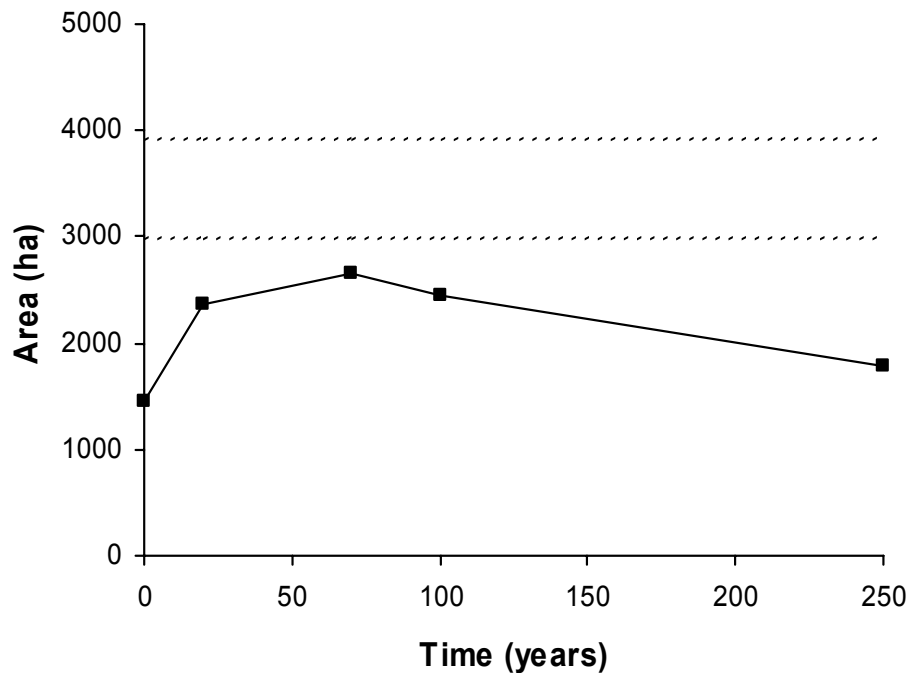


Figure 10. Abundance of stands dominated by trees with ecologically functional thick bark Defined as Douglas-fir trees >100 years old. Dashed lines indicate maximum and minimum ranges of variability, based on Utzig and Holt (2002).

3.4 INDICATOR SPECIES

Thirteen species were closely associated with ≥ 4 focal structural conditions and habitat elements and ≤ 5 forest structural conditions (Table 8). We consider nine species as practical for inclusion in a habitat supply monitoring program (*i.e.*, met selection criteria). These practical indicator species covered all focal structural conditions and habitat elements, and 80% of the key ecological functions associated for the 47 focal species.

Table 8. Indicator species and relationships with forest structural conditions, habitat elements, and key ecological functions.

Common name	Focal structural conditions (of 2)	Focal habitat elements (of 5)	Closely associated forest structural conditions	Key ecological functions	Practical to census?	Comments
Wood Duck	2	2	3	16	Yes	Rare
Hooded Merganser	2	2	3	18	Yes	Rare
Flammulated Owl	2	2	4	9	No	Rare
Northern Pygmy Owl	2	2	5	6	Yes	
Pileated Woodpecker	2	4	5	10	Yes	
Winter Wren	2	3	5	7	Yes	
California Myotis	2	3	2	9	No	Vocalizations cannot be distinguished from other Myotis species
Northern Long-eared Myotis	2	2	2	6	No	Vocalizations cannot be distinguished from other Myotis species
Big Brown Bat	2	3	2	11	Yes	Primarily presence-absence
Red-tailed Chipmunk	2	2	4	16	No	Rare
Northern Flying Squirrel	2	3	2	16	Yes	Labour intensive to sample
Southern Red-backed Vole	2	2	2	13	Yes	Labour intensive to sample
Black Bear	0	4	2	33	Yes	Simple indices inexpensive. Might not respond strongly to management changes.

4.0 DISCUSSION

4.1 HABITAT SUPPLY ON TFL 14

This project illustrated the utility of the CBD for identifying forest structural conditions and key habitat elements for habitat supply modelling on TFL 14. While the CBD provided the knowledge base for relating species to various habitat attributes and ecological functions, expert knowledge of local occurrence of species and habitat attributes made the analysis more realistic. The CBD allowed us first to identify important forest structural conditions and habitat elements associated with a large number of wildlife species, and second to develop a list of indicator species (Section 4.2) that can be used to monitor key habitat features on TFL 14.

We chose the forest structural conditions and key habitat elements to track in the habitat supply analysis by examining the list of 47 closely associated species and selecting the structural conditions and habitat elements that were associated with the largest number of species. The resulting list included mostly indicators of old seral forests: large tree and multi-storey structural conditions, large live trees, medium and large snags, down wood and thick bark. The only partial exception was shrubs, which were considered abundant in both young and old stands. Although many species are known to use early seral habitats, in general they were not classified as “closely associated” by the CBD.

We relied on the spatial timber supply analysis to provide us with information on future forest conditions. Much of our effort in this project was directed to translating the information provided in the spatial analysis to information we required for projecting the abundance of different structural conditions and habitat elements. Output of the spatial project was volume-based with broad information related to leading species and productivity. Inferring stand structure from this information was difficult. In addition, the spatial project was limited to harvest scheduling within the current THLB, which meant that habitat supply was not forecasted over 65% of the area of TFL 14.

4.1.1 Forest Structural Conditions

The process of cross-walking the spatial project output to the CBD resulted in the mapping of 11 of 25 possible forest structural conditions on TFL 14. The other 14 did not occur on the THLB because of the parameters used in the lookup tables. For example, the *small tree-single story-open* structural condition did not appear because we assumed that any stand with trees that size would have a relatively closed canopy. Silviculture options to influence canopy closure, such as thinning, pruning, or stocking density, were not part of the spatial analysis and therefore could not be modelled in our analysis.

The lookup tables we developed to infer forest structural conditions were relatively simple. We simplified the spatial project’s analysis units to a matrix of four stand types and three site productivities. This was done for practical reasons but it limited our ability to capture much of the variation among stands. The dynamics of canopy closure and canopy layer differentiation were developed with no empirical information. Tree size was calculated directly from growth

and yield curves from the spatial project and assumptions used to develop those curves were inherent to our habitat supply analysis.

As the forecast progressed, the number of different forest structural conditions declined. This occurred because regenerated stands were generally less diverse, and were harvested as second-rotation stands before adequate time had elapsed to regenerate rarer structural conditions. Some structural features, such as forest canopies considered *closed* (i.e., >70%), all but disappeared as the TFL became dominated by regenerated stands.

Another clear result from the forecast was that the THLB was increasingly dominated by the *Sapling/Pole-moderate* structural condition in later decades. This was the most abundant structural condition at time zero because of TFL 14's current forest age structure. In addition, the harvesting schedule generated by the spatial analysis resulted in a large increase in mid-seral forest.

4.1.2 Snags

Modelling the abundance of snags on TFL 14 was based on empirical information regarding snag abundance (although these data were not collected on TFL 14), and on current provincial snag retention guidelines; however, there is no standardized way for snag data collection. Snag abundance is often stratified by BEC unit (e.g., Ministry of Forests 2001), and dbh classes do not correspond well to tree sizes used in the CBD. For example, trees ≥ 30 cm dbh are often considered large enough to create ecologically functional snags; however, the closest tree size class limit in the CBD is 25 cm.

Post-harvest snag abundance was considered a function of management practices and rates of decay and recruitment in the four stand types. The density of snags on the THLB declined throughout the forecast period in all four stand types under all four snag retention scenarios. This was not surprising because retention rates were drastically lower in all scenarios than the abundance of snags in naturally regenerating stands. In addition, second and third rotation harvests usually occurred before significant snag recruitment but after retained snags were lost to decay, leading to very low densities in mid and mature stands.

Although overall snag densities on the THLB remained near recommended targets during the forecast (Steege and Machmer 2002), the area of the THLB meeting snag density targets provided a better measure of suitable habitat provided for snag-dependent wildlife. Again, the areas meeting these targets declined for nearly all stand types and snag retention scenarios throughout the forecast period, with the greatest declines during the first 100 years. This suggested that habitat isolation will increase on the THLB under current management practices. This has serious consequences for snag-dependent wildlife species, most of which are territorial and therefore cannot be expected to be abundant in relatively small patches of suitable habitat.

Our analysis suggested that the rate of cut and rotation age will have a greater impact on the future abundance of snags than practical changes in rates of snag retention. The abundance of snags post-harvest is extremely low relative to post-disturbance natural stands. Partial cutting is unlikely to improve the situation because Worker's Compensation Board hazard tree regulations require the removal of most snags.

Because there was no distinction in either the spatial analysis or in our lookup tables between stands that have already been harvested and those that will be harvested, snag densities under the four retention scenarios were retroactively applied to second growth stands. This tended to over estimate the abundance of snags, particularly in early reporting periods of the forecast.

4.1.3 Down Wood

The abundance of down wood is highly variable on TFL 14 and is poorly characterized in second-growth stands. As a result, we limited our analysis to broad down wood categories. In addition, there are few studies that have established threshold levels of down wood necessary to maintain wildlife populations, although some guidelines are available (Craig 2002). In our analysis, stands with moderate down wood volumes declined during the forecast. Stands with high down wood volumes were uncommon but increased slightly during the forecast. Assuming that volumes $\leq 50 \text{ m}^3/\text{ha}$ are inadequate to maintain population of down wood-dependent species, suitable down wood habitat is likely to decrease and become increasingly fragmented as harvesting continues on TFL 14.

Like snags, down wood volume is a function of management practices as well as decay and recruitment. Alternative forest and silviculture strategies can be used to increase volumes of down wood and this can be tracked in the habitat supply analysis, as it is currently structured.

4.1.4 Shrubs

Despite its importance to a large number of wildlife species, the dynamics of shrub cover in forests is poorly understood. Stands in shrub-seedling structural conditions comprised approximately 10% of the THLB through most of the latter decades of the forecast. No data were available to parameterize the abundance of shrub cover in older structural conditions on TFL 14 and we made simple assumptions about the effects of forest management on the shrub layer in forested stands. There are few data available to relate the abundance and characteristics of forest shrubs to the abundance of shrub-dependent species; therefore, the consequences of even well parameterized forecasts are difficult to interpret.

4.1.5 Large Live Trees

We based our forecast of the abundance of large live trees on a single structural condition: *Large tree-multi-story-moderate*. This captured the abundance of stands dominated by large trees but ignored the abundance of single large trees or small patches dominated by large trees. This resulted in the underreporting of large live trees on the THLB throughout the forecast. In the CBD, all forest structural conditions are assumed to have up to 10% residual cover.

The failure to capture single large trees and small patches of large trees was a result of the output generated by the spatial timber supply analysis. Partial cutting and stand structure was accommodated by the analysis, but only from a growth and yield perspective. Partial cutting in the spatial analysis contributed to our tracking of large live trees only where subsequent growth of partial cut stands resulted in the *Large tree-multi-storey moderate* structural condition. This likely occurred rarely, if at all.

As a result, the estimated area of the THLB covered by stands of large live trees was small, although it generally increased during the forecast. Tracking large live trees under alternative silviculture scenarios is a function that needs to be further explored. Stand structure is better represented in standard forest cover databases as veteran, dominant and sub-dominant canopy layers.

4.1.6 Bark

Thick furrowed bark is important foraging substrate for bark-foraging birds (Machmer and Steeger 1995), nesting substrate for brown creepers (Steeger and Dulisse, in press), and roosting substrate for bats (Nagorsen and Brigham 1993). We faced many of the same problems forecasting the abundance of trees with ecologically functional bark as we faced with forecasting large live trees. Our analysis was restricted to stands dominated by trees with functional bark and we were unable to track the contribution of residual cover. In addition, we were unable to track the contribution of sub-dominant tree species because they were not provided in the analysis units defined by the spatial timber supply analysis. Bark condition (thick and furrowed) is a habitat feature that can be modelled more easily using tree species and age from derived from standard forest cover databases.

4.1.7 Ranges of Natural Variability

Developing ranges of natural variability for important forest structural conditions and habitat elements is a useful way to establish benchmarks for management. The concept has a sound theoretical basis; however, it is based on a number of assumptions (Utzig and Holt 2002).

The forecasted abundance of many habitat elements was far below the minimum natural ranges of variability throughout the planning horizon. The most probable reason for this is that much of the THLB burned <100 years ago (due to fires related to the railway and other human-caused activities), creating a seral stage distribution at time zero that is considerably different from the calculated return intervals from natural disturbance (Utzig and Holt 2002).

Some differences between ranges of natural variability and the habitat supply forecasts were expected because timber supply modelling is based on the average age of trees in stands, while ranges of natural variability are based on return intervals since last disturbance. As a result, timber supply models underestimate the abundance of old forest, relative to estimates based on disturbance intervals. Differences will be greatest for habitat elements common in older forest stand types characterized by long return intervals.

4.2 MONITORING HABITAT SUPPLY WITH INDICATOR SPECIES

Our filtering process of the CBD species list (Figure 2) generated a short list of species (Table 8) that can be used to track changes in key habitat attributes over time. Further fine-tuning of this list may be necessary during development of a work plan for habitat supply monitoring on TFL 14. For example, it is unclear at this time how abundant species such as wood duck and hooded merganser are on TFL 14 and how much they are affected by forest management practices. The cost effectiveness of sampling for red-backed voles is also questionable. The development of a monitoring plan should therefore include initial presence or abundance surveys before a list of indicator species is finalized.

While the selected indicator species are related to all focal structural conditions and habitat elements and are complementary with respect to covering a broad range of vertebrate taxa (*i.e.*, waterfowl, owls, woodpeckers, bats, passerines, small mammals, and large carnivores), some taxa such as neotropical songbirds are not included. Hence, further additions to the list could be considered. For example, the western tanager⁵ is associated with the two focal structural conditions and one focal habitat element and is restricted to one structural condition (Appendix 4). As a result, this species narrowly missed one of the criteria (≥ 4 focal structural conditions and habitat elements) for inclusion in the indicator list. It is important to note that the criteria we used for assembling the list of indicator species was somewhat arbitrary and could be adjusted.

Three of the selected focal habitat elements (snags, large live trees, and bark) are attributes of wildlife trees and the supply of down wood is closely related to the retention of trees in managed forests. Wildlife tree retention is currently the primary management tool to preserve stand structure and stand level biodiversity in British Columbia (Province of BC 1999, 2000). With the exception of the southern red-backed vole and winter wren, all indicator species selected for TFL 14 are wildlife tree users, and six (wood duck, hooded merganser, flammulated owl, northern pygmy-owl, pileated woodpecker, and northern flying squirrel) are classed as highly dependent on wildlife trees for reproduction (Province of BC 2001).

Two species currently blue-listed by the BC Conservation Data Centre (flammulated owl and northern long-eared myotis) were included in the candidate indicator list but were not considered practical to monitor (Section 2.8 and Table 8). However, habitat management focused on the seven selected focal habitat associations will likely maintain habitat for these listed species on TFL 14.

The key ecological functions of the CBD provided another opportunity to check the appropriateness of the list of indicator species generated by the filtering process. Key ecological functions enabled us to obtain a measure of functional diversity associated with the set of selected species. The indicator species are related to 80% of the key ecological functions performed by the 47 species closely associated with forest structural conditions on TFL 14. Note that the black bear fulfills more than twice the number of ecological functions compared to most other indicator species; therefore, we included this species in the final indicator list, although it might not respond strongly to specific changes in forest management practices.

Filtering on the basis of the CBD represents one possible strategy for assembling a list of indicator species to monitor biodiversity impacts of industrial forestry. Other strategies are likely to generate alternative lists that might be just as appropriate, although we would expect some overlap.

⁵ The apparent inconsistency of the western tanager's association with 1 versus 2 structural conditions is due to "double counting"; that is, the single structural condition the tanager is closely associated with is *Large tree-multi-story-open*, which is included under both focal structural conditions (Appendix 4).

4.3 KEY ASSUMPTIONS AND LIMITATIONS

- The analysis considered only the THLB portion of TFL 14 (*i.e.*, where timber harvesting was modelled). The spatial project assigned analysis units to forested stands outside the THLB; however, no growth data were associated with these analysis units. This limited the analysis to approximately 35% of the area of the TFL.
- Time zero was defined as current conditions; therefore, any changes in forest structural conditions that have resulted from forest harvesting in the past were not considered.
- Riparian areas were not considered because these areas are not part of the contributing area of the THLB, and were therefore excluded from the timber supply analyses. A number of terrestrial vertebrate species are associated with riparian ecosystems and are likely affected for forest management and practices.
- Characterization of structural conditions and habitat elements in partial cut stands was governed primarily by the post-harvest age assignment and “flat-line” dbh curves assigned by the spatial project. These parameters are more useful for TFL-scale stand accounting than for inferring stand structure.
- Determining the distribution of structural conditions and habitat elements depended completely on four general stand types, dbh curves (for natural, clearcut, and partial cut stands) and stand age. This was an obvious simplification of the landscape. In addition, relationships with stand-level structural attributes were based on simple lookup tables that were based on incomplete or limited data, data not specific to TFL or expert opinion.
- There were conflicts between some of the spatial project’s dbh curves and look-up tables. For example, in some instances the lookup tables defined closed canopies before the spatial analysis timber forecast “grew” trees of adequate size to meet the definition of closed canopy.
- Ranges of natural variability estimates were based on disturbance return intervals while stand ages in spatial forecasts were based on average age of trees in stands.

5.0 RECOMMENDATIONS

Our habitat supply analysis provides the basis for implementing and extending the explicit consideration of wildlife habitat in forest planning. For TFL 14, the next step would be to develop a detailed habitat supply modelling workplan to include

- linkage of CBD species-habitat relationships, spatial timber forecasts, Type 2 analyses, and the habitat supply modelling results of this pilot project to specific criteria and indicators in support of sustainable forest management planning;
- additional data requirements (see below) to fill data gaps, better parameterize model inputs/outputs and periodic model refinement;
- habitat supply and indicator species monitoring (include presence and relative abundance surveys of indicator species) as well as operational efficiency and effectiveness monitoring for adaptive management purposes; and
- site-specific harvesting and silviculture trials that address the recommendations for management of key structural conditions and habitat elements (see below).

5.1 FOREST STRUCTURAL CONDITIONS

5.1.1 Management Recommendations

Forest planning should include measures to increase the abundance of stands dominated by medium and large-sized trees. For example, multi-storey canopies could be encouraged through growth management or partial cutting. Deferral of harvest of some blocks could also be considered.

5.1.2 Rationale

The abundance of the *Pole/Sapling-moderate* structural condition increased nearly fourfold in the first 100 years of the forecast while the combined abundance of medium and large tree structural conditions declined. This trend also applied to single-storey *versus* multi-storey stands.

5.1.3 Data Needs

Partial cutting and retention strategies were not adequately captured by the habitat supply analysis. This was a result of stand structure accounting from the spatial project. Resetting stand ages based on the volume of timber removed did not adequately account for changes in stand structure following partial cutting. From a wildlife habitat perspective, partially-cut old forest stands may not be functionally equivalent to mid-seral forest stands.

Methods need to be developed to track residual cover explicitly in timber supply forecasts. That is, the abundance of important habitat elements such as snags, down wood, shrubs and large live trees need to be quantified and modelled throughout the forest rotation in both natural and regenerated stands.

5.2 SNAGS

5.2.1 Management Recommendations

Snags should be managed to meet density targets (*e.g.*, Steeger and Machmer 2001) over a large proportion of the THLB. This will require relatively large WTPs (>1 ha) and single-tree retention, as well as longer stand rotations. Adequate spatial distribution of WTPs to avoid isolation of patches is important. A suitable spatial scale for identification, assessment and layout of WTPs and single-tree retention is 100-1000 ha (*i.e.*, whole or contiguous parts of cutting permits).

5.2.2 Rationale

In comparison to natural disturbance, snag abundance is strongly affected by forest harvesting and silviculture. The area of the THLB that meets snag targets falls to very low levels over the first two forecast periods (50 years and 100 years) for most stand types and snag retention scenarios. Only large increases in snag retention rates altered this trend in some stand types. Due to the territorial behaviour of most snag-dependent species, populations of such species are best maintained when snag habitat is widely distributed rather than concentrated in relatively small areas.

5.2.3 Data Needs

TFL14-specific information on natural snag abundance, snag retention levels in managed stands, and snag recruitment and longevity is required to parameterize the habitat supply models. Data should be collected in both the THLB and non-contributing forest land base.

5.3 DOWN WOOD

5.3.1 Management Recommendations

Stands should be managed to retain >50 m³/ha of down wood post-harvest, where possible. Higher volumes should be retained in spruce-subalpine fir stands.

5.3.2 Rationale

Data from TFL 14 suggest that all stand types have >50 m³/ha of down wood at ≥120 years old and studies elsewhere suggest that down wood is more abundant and more important in higher elevations stands for species such as small mammals (Craig 2002).

5.3.3 Data Needs

Additional TFL 14-specific data are required to parameterize the habitat supply model, particularly for second growth stands.

5.4 SHRUBS

5.4.1 Management Recommendations

We have no basis for management recommendations related to shrub cover in forested stands.

5.4.2 Rationale

There was no empirical basis for the shrub abundance estimates in the habitat supply forecast, with the exception of shrub-seedling structural conditions.

5.4.3 Data Needs

TFL-specific data on the dynamics of shrub cover in natural and managed stands are required to parameterize the habitat supply model.

5.5 LARGE LIVE TREES

5.5.1 Management Recommendations

Management recommendations related to forest structural conditions are relevant to the management of large live trees (Section 5.1.1). Throughout the THLB, some trees should be designated as “full-cycle trees”. This would not only result in increased amounts of large live trees but subsequently of large snags and, potentially, large-sized down wood.

5.5.2 Rationale

The abundance of large live trees is affected directly by 1) management prescriptions aimed at increasing the abundance of medium and large tree structural conditions and 2) individual large tree retention during harvest and silviculture operations.

5.5.3 Data Needs

TFL-specific data on contribution of residual cover and partial cutting to abundance of large live trees is required. Methods need to be developed to track residual cover explicitly in timber supply forecasts.

5.5 BARK

5.5.1 Management Recommendations

Management recommendations related to forest structural conditions and large live trees are relevant to management for ecologically functional bark in Douglas-fir stands (Section 5.1.1). Other species with functional bark (*e.g.*, western larch, ponderosa pine, and black cottonwood) should be retained, where possible.

5.5.2 Rationale

Douglas-fir trees >100 years old provide ecologically functional bark for wildlife. Stands dominated by these trees increase early in the forecast and then decline moderately. Other species with functional bark were not captured in the forecast.

5.5.3 Data Needs

Methods need to be developed to track the abundance of large-sized Douglas-fir, ponderosa pine, larch and cottonwood residual cover and other tree species to model bark habitat in timber supply forecasts.

5.6 SUMMARY OF DATA NEEDS

Table 9 summarizes data needs listed above, as well as general data requirements highlighted elsewhere in the report. The proposed timeframe and two levels of difficulty are intended to facilitate planning for a long-term monitoring and adaptive management system.

Table 9. Summary of data needs for habitat supply modelling and management on TFL 14.

Timeframe	Easy	Difficult
Short term (<3 years)	<p>Initiate investigations to fill data gaps to better parameterize models. Immediate emphasis should be placed on habitat contribution of non-THLB which makes up 65% of the area of TFL 14</p> <p>Parameterize habitat lookup tables using TFL-specific data (e.g., TEM and TEM field databases for down wood, shrubs, snags, large trees)</p> <p>Expand habitat supply modelling to include Type 2 analyses</p>	<p>Expand the spatial timber supply analysis to accommodate the area of TFL 14 outside the THLB</p> <p>Expand the spatial timber supply analysis to explicitly track key habitat elements (snags, down wood, shrubs, large live trees) where data are available</p> <p>Develop better methods to track residual cover explicitly</p>
Medium term (3-10 years)	<p>Retrospective field studies of the dynamics of key habitat elements in managed stands on TFL 14</p> <p>Conduct field studies of contribution of non-THLB in terms of forest structural conditions and key habitat elements</p>	<p>Conduct research regarding threshold levels of key habitat attributes for indicator wildlife species</p> <p>Fill data gaps for focal habitat elements and key ecological functions</p> <p>Establish population baseline levels of indicator species</p>
Long term (>10 years)	<p>Track the abundance of key habitat elements in experimental forest harvesting and silviculture trials</p>	<p>Track population trends of indicator species</p>

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7.0 APPENDICES

APPENDIX 1. SPECIES CLOSELY ASSOCIATED WITH FOREST STRUCTURAL CONDITIONS POTENTIALLY FOUND ON TFL 14.

Common name	1.01 Grass/Forb-Open	1.02 Grass/Forb-Closed	1.03 Shrub/Seedling-Open	1.04 Shrub/Seedling-Closed	1.05 Sapling/Pole-Open	1.06 Sapling/Pole-Moderate	1.07 Sapling/Pole-Closed	1.08 Small Tree-Single Story-Open	1.09 Small Tree-Single Story-Moderate	1.10 Small Tree-Single Story-Closed	1.11 Medium Tree-Single Story-Open	1.12 Medium Tree-Single Story-Moderate	1.13 Medium Tree-Single Story-Closed	1.14 Large Tree-Single Story-Open	1.15 Large Tree-Single Story-Moderate	1.16 Large Tree-Single Story-Closed	1.17 Small Tree-Multi-story-Open	1.18 Small Tree-Multi-story-Moderate	1.19 Small Tree-Multi-story-Closed	1.20 Medium Tree-Multi-story-Open	1.21 Medium Tree-Multi-story-Moderate	1.22 Medium Tree-Multi-story-Closed	1.23 Large Tree-Multi-story-Open	1.24 Large Tree-Multi-story-Moderate	1.25 Large Tree-Multi-story-Closed	Total
Wood Duck																							X	X	X	3
Hooded Merganser																							X	X	X	3
Sharp-shinned Hawk									X									X	X	X	X					5
American Kestrel	X	X																								2
Ruffed Grouse				X	X	X	X	X	X	X	X						X									9
Spruce Grouse	X	X	X		X	X	X	X	X	X	X						X	X	X	X	X	X	X	X	X	19
Blue Grouse	X	X	X		X			X			X			X	X	X	X						X	X		12
Flammulated Owl																					X	X		X	X	4
Northern Pygmy-owl																					X	X	X	X	X	5
Barred Owl															X	X					X	X		X	X	6
Great Gray Owl	X	X			X																X		X	X		6
Boreal Owl													X		X	X										3

Common name	1.01 Grass/Forb-Open	1.02 Grass/Forb-Closed	1.03 Shrub/Seedling-Open	1.04 Shrub/Seedling-Closed	1.05 Sapling/Pole-Open	1.06 Sapling/Pole-Moderate	1.07 Sapling/Pole-Closed	1.08 Small Tree-Single Story-Open	1.09 Small Tree-Single Story-Moderate	1.10 Small Tree-Single Story-Closed	1.11 Medium Tree-Single Story-Open	1.12 Medium Tree-Single Story-Moderate	1.13 Medium Tree-Single Story-Closed	1.14 Large Tree-Single Story-Open	1.15 Large Tree-Single Story-Moderate	1.16 Large Tree-Single Story-Closed	1.17 Small Tree-Multi-story-Open	1.18 Small Tree-Multi-story-Moderate	1.19 Small Tree-Multi-story-Closed	1.20 Medium Tree-Multi-story-Open	1.21 Medium Tree-Multi-story-Moderate	1.22 Medium Tree-Multi-story-Closed	1.23 Large Tree-Multi-story-Open	1.24 Large Tree-Multi-story-Moderate	1.25 Large Tree-Multi-story-Closed	Total
Black-backed Woodpecker	X	X																								2
Pileated Woodpecker														X	X	X								X	X	5
Olive-sided Flycatcher					X			X			X			X												4
Cassin's Vireo																	X				X			X		3
Red-eyed Vireo																X						X	X	X	X	5
Steller's Jay																					X	X	X	X	X	5
Winter Wren																					X	X	X	X	X	5
Golden-crowned Kinglet													X			X			X	X		X			X	6
Mountain Bluebird	X	X	X	X																						4
Varied Thrush																					X	X		X	X	4
Townsend's Warbler																					X					1
Western Tanager																							X			1
Lincoln's Sparrow		X	X																							2
White-crowned Sparrow			X		X	X	X																			4
Dark-eyed Junco			X		X			X			X			X			X			X			X			8
Common Shrew									X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	16
Pygmy Shrew	X	X	X	X	X	X	X																			7

Common name	1.01 Grass/Forb-Open	1.02 Grass/Forb-Closed	1.03 Shrub/Seedling-Open	1.04 Shrub/Seedling-Closed	1.05 Sapling/Pole-Open	1.06 Sapling/Pole-Moderate	1.07 Sapling/Pole-Closed	1.08 Small Tree-Single Story-Open	1.09 Small Tree-Single Story-Moderate	1.10 Small Tree-Single Story-Closed	1.11 Medium Tree-Single Story-Open	1.12 Medium Tree-Single Story-Moderate	1.13 Medium Tree-Single Story-Closed	1.14 Large Tree-Single Story-Open	1.15 Large Tree-Single Story-Moderate	1.16 Large Tree-Single Story-Closed	1.17 Small Tree-Multi-story-Open	1.18 Small Tree-Multi-story-Moderate	1.19 Small Tree-Multi-story-Closed	1.20 Medium Tree-Multi-story-Open	1.21 Medium Tree-Multi-story-Moderate	1.22 Medium Tree-Multi-story-Closed	1.23 Large Tree-Multi-story-Open	1.24 Large Tree-Multi-story-Moderate	1.25 Large Tree-Multi-story-Closed	Total
California Myotis																							X	X		2
Long-legged Myotis					X																					1
Northern Long-eared Myotis																								X	X	2
Silver-haired Bat											X	X		X	X								X	X		6
Big Brown Bat																							X	X		2
Snowshoe Hare	X	X	X	X	X	X	X											X	X	X	X	X	X	X	X	15
Least Chipmunk					X			X			X			X			X			X						6
Red-tailed Chipmunk																					X	X		X	X	4
Red Squirrel																					X	X	X	X	X	5
Northern Flying Squirrel																								X	X	2
Deer Mouse	X	X	X	X	X	X																				6
Southern Red-backed Vole																							X	X		2
Western Jumping Mouse	X	X																								2
Porcupine					X	X	X	X	X		X	X		X	X		X	X			X		X	X		14
Black Bear					X	X																				2
Grizzly Bear	X	X																								2

Common name	1.01 Grass/Forb-Open	1.02 Grass/Forb-Closed	1.03 Shrub/Seedling-Open	1.04 Shrub/Seedling-Closed	1.05 Sapling/Pole-Open	1.06 Sapling/Pole-Moderate	1.07 Sapling/Pole-Closed	1.08 Small Tree-Single Story-Open	1.09 Small Tree-Single Story-Moderate	1.10 Small Tree-Single Story-Closed	1.11 Medium Tree-Single Story-Open	1.12 Medium Tree-Single Story-Moderate	1.13 Medium Tree-Single Story-Closed	1.14 Large Tree-Single Story-Open	1.15 Large Tree-Single Story-Moderate	1.16 Large Tree-Single Story-Closed	1.17 Small Tree-Multi-story-Open	1.18 Small Tree-Multi-story-Moderate	1.19 Small Tree-Multi-story-Closed	1.20 Medium Tree-Multi-story-Open	1.21 Medium Tree-Multi-story-Moderate	1.22 Medium Tree-Multi-story-Closed	1.23 Large Tree-Multi-story-Open	1.24 Large Tree-Multi-story-Moderate	1.25 Large Tree-Multi-story-Closed	Total
Lynx						X	X		X	X																4
Mountain Goat	X	X																								2
Total	12	13	9	5	14	9	7	7	5	5	8	3	3	8	7	7	7	5	5	7	16	14	19	25	18	238

**APPENDIX 2. SUMMARY OF HABITAT ELEMENTS REQUIRED BY SPECIES
CLOSELY ASSOCIATED WITH FOREST STRUCTURAL CONDITIONS POTENTIALLY FOUND ON TFL 14.**

CBD Reference	Habitat Element Description	Species (n)	%
1.1	forest/woodland vegetative elements or substrates	43	91.5
1.1.1	down wood	19	40.4
1.1.1.1	down wood decay class	4	8.5
1.1.1.1.1	hard down wood	2	4.3
1.1.1.1.2	moderate down wood	2	4.3
1.1.1.1.3	soft down wood	1	2.1
1.1.1.2	down wood in riparian areas	4	8.5
1.1.1.3	down wood in upland areas	6	12.8
1.1.2	litter	7	14.9
1.1.3	duff	2	4.3
1.1.4	shrub layer	16	34.0
1.1.4.1	shrub size	6	12.8
1.1.4.2	percent shrub canopy cover	7	14.9
1.1.4.3	shrub canopy layers	2	4.3
1.1.5	moss	4	8.5
1.1.6	flowers	3	6.4
1.1.7	lichens	5	10.6
1.1.8	forbs	12	25.5
1.1.10	fungi	8	17.0
1.1.11	roots, tubers, underground plant parts	5	10.6
1.1.12	ferns	4	8.5
1.1.13	herbaceous layer	13	27.7
1.1.14	trees	40	85.1
1.1.14.1	snags	20	42.6
1.1.14.1.1	snag decay class	8	17.0
1.1.14.1.1.1	hard snags	6	12.8
1.1.14.1.1.2	moderate snags	5	10.6
1.1.14.1.1.3	soft snags	1	2.1
1.1.14.2	snag size (dbh)	17	36.2
1.1.14.2.3	small snag 10-14" dbh	6	12.8
1.1.14.2.4	medium snag 15-19" dbh	13	27.7
1.1.14.2.5	large snag 20-29" dbh	16	34.0
1.1.14.2.6	giant snag ≥ 30 " dbh	16	34.0
1.1.14.3	live tree size (dbh)	27	57.4
1.1.14.3.1	seedling <1 " dbh	4	8.5
1.1.14.3.2	sapling/pole 1-9" dbh	6	12.8
1.1.14.3.3	small tree 10-14" dbh	12	25.5
1.1.14.3.4	medium tree 15-19" dbh	20	42.6
1.1.14.3.5	large tree 20-29" dbh	20	42.6
1.1.14.3.6	giant tree ≥ 30 " dbh	20	42.6

CBD Reference	Habitat Element Description	Species (n)	%
1.1.14.4	mistletoe brooms/witches brooms	7	14.9
1.1.14.5	dead parts of live tree	7	14.9
1.1.14.6	hollow living trees (chimney trees)	11	23.4
1.1.14.7	tree cavities	17	36.2
1.1.14.8	bark (includes crevices/fissures, loose or exfoliating bark)	11	23.4
1.1.14.9	live remnant/legacy trees	11	23.4
1.1.14.10	large live tree branches	3	6.4
1.1.14.11	tree canopy layer	12	25.5
1.1.14.11.1	sub-canopy	8	17.0
1.1.14.11.2	above canopy	1	2.1
1.1.14.11.3	tree bole	3	6.4
1.1.14.11.4	canopy	7	14.9
1.1.15	fruits/seeds/nuts	17	36.2
1.1.16	edges	26	55.3

APPENDIX 3. REGRESSIONS FOR SNAG LONGEVITY

(EVERETT ET AL. 1999) AND SNAG SUPPLY CURVES (UTZIG AND GAINES 1998) USED IN THE SNAG SUPPLY MODELLING FOR TFL 14.

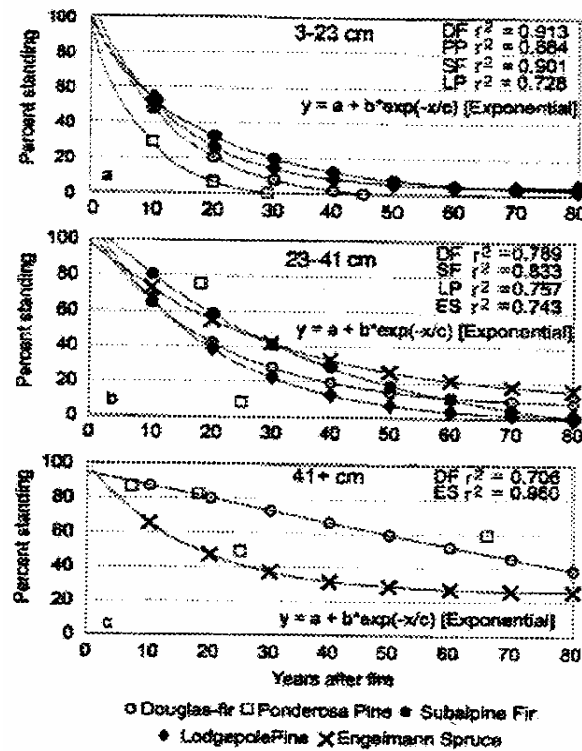
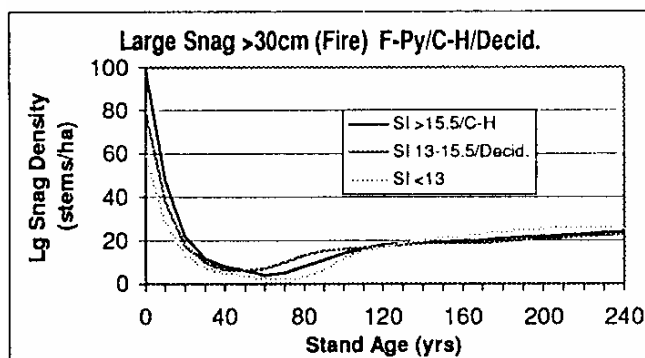
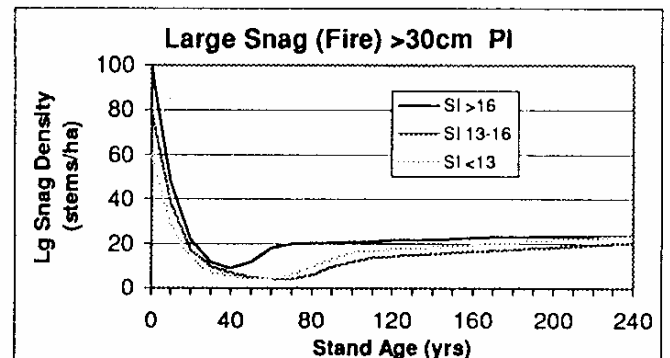


Figure 3. Snag longevity of thick (Douglas-fir) and thin (Engelmann spruce, lodgepole pine and subalpine fir) barked species of (a) 3–23 cm dbh, (b) 23–41 cm dbh and (c) > 41 cm dbh size classes. There was insufficient data for regression of ponderosa pine > 23 cm dbh, but observed values are provided for reader information.



APPENDIX 4. SPECIES CLOSELY ASSOCIATED WITH FOCAL STRUCTURAL CONDITIONS AND HABITAT ELEMENTS ON TFL 14.

	Focal Structural Conditions		Focal Habitat Elements					Total (Focal Habitat Associations)	Number of structural conditions with which species are closely associated (Appendix 1)
	Large tree structural conditions	Multi-storey structural conditions	Large live trees (> 50 cm dbh)	Snags (small, medium, and large; i.e., > 25 cm)	Down wood	Shrubs	Bark		
Common name									
Wood Duck	X	X	X	X				4	3
Hooded Merganser	X	X	X	X				4	3
Sharp-shinned Hawk		X						1	5
American Kestrel			X	X				2	2
Ruffed Grouse		X			X	X		3	9
Spruce Grouse	X	X			X	X		4	19
Blue Grouse	X	X	X		X			4	12
Flammulated Owl	X	X	X	X				4	4
Northern Pygmy-owl	X	X	X	X				4	5
Barred Owl	X	X	X	X				4	6
Great Gray Owl	X	X	X	X				4	6
Boreal Owl			X	X				2	3
Black-backed Woodpecker				X			X	2	2
Pileated Woodpecker	X	X	X	X	X		X	6	5
Olive-sided Flycatcher	X							1	4
Cassin's Vireo	X	X						2	3
Red-eyed Vireo	X	X						2	5
Steller's Jay	X	X						2	5
Winter Wren	X	X			X	X	X	5	5
Golden-crowned Kinglet	X	X						2	6
Mountain Bluebird			X	X				2	4
Varied Thrush	X	X				X		3	4
Townsend's Warbler		X	X					2	1
Western Tanager	X	X	X					3	1
Lincoln's Sparrow								0	2

	Focal Structural Conditions		Focal Habitat Elements					Total (Focal Habitat Associations)	Number of structural conditions with which species are closely associated (Appendix 1)
	Large tree structural conditions	Multi-storey structural conditions	Large live trees (> 50 cm dbh)	Snags (small, medium, and large; i.e., > 25 cm)	Down wood	Shrubs	Bark		
Common name									
White-crowned Sparrow						X		1	4
Dark-eyed Junco	X	X	X		X	X		5	8
Common Shrew	X	X			X			3	16
Pygmy Shrew					X	X		2	7
California Myotis	X	X	X	X			X	5	2
Long-legged Myotis			X	X			X	3	1
Northern Long-eared Myotis	X	X		X			X	4	2
Silver-haired Bat	X	X	X	X			X	5	6
Big Brown Bat	X	X	X	X			X	5	2
Snowshoe Hare	X	X				X		3	15
Least Chipmunk	X	X			X	X		4	6
Red-tailed Chipmunk	X	X			X	X		4	4
Red Squirrel	X	X			X			3	5
Northern Flying Squirrel	X	X	X	X	X			5	2
Deer Mouse					X		X	2	6
Southern Red-backed Vole	X	X	X		X			4	2
Western Jumping Mouse					X			1	2
Porcupine	X	X			X	X		4	14
Black Bear				X	X	X	X	4	2
Grizzly Bear					X	X	X	3	2
Lynx					X	X		2	4
Mountain Goat								0	2
Total	30	32	20	18	19	14	11	-	-