Abundance of Secondary Structure in Lodgepole Pine Stands Affected by the Mountain Pine Beetle in the Cariboo-Chilcotin

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ABSTRACT

The extent and abundance of secondary structure was studied in the Cariboo-Chilcotin region of the central interior of British Columbia. Plots were selected from age class four and higher pine stands in the Quesnel, Williams Lake and 100 Mile House Timber Supply Areas. A total of 1,649 plots were obtained of which 1,109 were determined to be pine-leading. Secondary structure is understory and overstory trees that survive the current mountain pine beetle epidemic. All lodgepole pine trees 7.5 cm in diameter or greater were assumed to die in the epidemic. The forest health status of a large dataset of individual trees was also summarized. Secondary structure was abundant in all biogeoclimatic zones of the Cariboo-Chilcotin region and was consistent with results from other regions of British Columbia where pine-leading stands have been examined. The median density of conifer seedlings and saplings in the Cariboo-Chilcotin was 1800 stems per hectare (spa). This varied from a high of 4,700 sph in the ESSF zone to a low of 1019 sph in the SBS zone. Across all ecological units about 70% of sample plots in pine-leading stands exceeded a 1000 sph threshold for understory conifer seedling and sapling density. The species composition of the understory tree layer varied considerably in the individual biogeoclimatic zones. Lodgepole pine was by far the most common understory tree species in the MS and SBPS zones (79 and 74%, respectively). About 34% of all plots had or exceeded 5 m^2 ha^{-1} of secondary structure basal area. This varied from a low of 25% of plots in the SBS to a high of 57% in the ESSF. Substantial amounts of the secondary structure basal were found on non-merchantable stems. The relationship between overstory pine basal area and non-merchantable secondary structure basal area was poor. Assumptions about non-merchantable secondary structure basal area can not be made based on the proportion of overstory pine basal area. There was also little evidence to support a relationship between the average piece size of lodgepole pine and the basal area of non-merchantable secondary structure. Across the different ecological units, between 31 and 68% of pine-leading stands currently have secondary structure equivalent to or better than a 20 year old pine plantation. The forest health status of secondary structure was examined. Damage data is difficult to summarize since not all damage agents are equal. Understory pine trees (seedlings and saplings) averaged 3.3% infection by mistletoe across all ecological units. Fewer than 10% of all understory pine trees had some sort of damage, whereas just fewer than 20% of all understory interior spruce had some sort of damage, but often of a minor nature. Sub-canopy and canopy secondary structure trees (non-pine species) had similar or higher levels of damage than understory trees of the same species. The variable levels of secondary structure found in the Cariboo-Chilcotin region provide considerable management flexibility. The suitability of managing the secondary structure will depend on the value being considered (e.g., timber supply, hydrological recovery period).

Keywords: Mountain pine beetle, timber supply, conservation, stand structure.

INTRODUCTION

The term “secondary structure” was coined as a way to describe the abundance, composition and distribution of trees that will remain alive in stands impacted by the mountain pine beetle (MPB) (*Dendroctonus ponderosae* Hopk.) epidemic (Coates et al. 2006). The epidemic has been killing extensive swaths of lodgepole pine in the interior forests of British Columbia since the late 1990s.

Secondary structure can be broken into two main components – understory and overstory trees. Understory trees include seedlings and saplings and can include smaller lodgepole pine trees that survive the epidemic. Overstory trees that survive the MPB epidemic are typically of non-host species (e.g., interior spruce, subalpine fir, Douglas-fir, or broadleaf species). Overstory pine can, and will, survive through the current epidemic, however, numbers will be highly variable and unpredictable. For the purpose of this report we will take a conservative approach and not include any overstory pine trees (sub-canopy or canopy trees) in abundance of secondary structure calculations.

The magnitude and extent of the current MPB outbreak in British Columbia requires thoughtful planning to recover economic value from the impacted timber while maintaining other resource values. Forest planners and managers are now paying attention to secondary structure as a key consideration in planning for the sustainability of forest resources (timber supply, range management, wildlife management, carbon storage, species diversity, hydrological recovery period, viewscapes, and tourism).

The first study of secondary structure abundance was conducted for the sub-boreal forests of the northern interior (Coates et al. 2006) and focused on how secondary structure might mitigate mid-term timber supply through strategic management decisions on harvest priority. Other similar studies have followed in the Prince George (Pousette, 2009) and Kamloops (Vyse et al. 2009) Timber Supply Units, in the Montane Spruce zone of the southern BC interior (Nigh et al. 2008) and in South Okanagan watersheds (Huggard 2009).

Concurrent to these studies, the Cariboo-Chilcotin region of the central interior was identified as a vast area where limited information was available on the abundance of secondary structure in extensive stands and landscapes dominated by lodgepole pine. This project addresses the shortfall in the current information available for MPB affected stands by compiling existing information on stand structure in pine-leading stand types of the Cariboo-Chilcotin.

PROJECT OBJECTIVES AND METHODS

The key questions addressed by this study include:

1) What are the attributes of secondary structure in pine-leading forest types after the beetle epidemic within the Cariboo-Chilcotin? Is there variability in secondary structure attributes by biogeoclimatic zone? We will examine:
   a) Median density, cumulative abundance (stems per hectare [spa] exceeding density thresholds) and species composition of secondary structure seedlings and saplings for all plots combined and by biogeoclimatic zone.
   b) Cumulative basal area (m^2 ha^{-1}) of secondary structure saplings, sub-canopy and canopy trees for all plots combined and by biogeoclimatic zone.
   c) Basal area of merchantable and non-merchantable secondary structure in comparison to the percentage of overstory pine for all plots and by biogeoclimatic zone.
2) How long would it take a newly established lodgepole pine plantation to reach the current basal area of secondary structure in each plot? This question addresses the concept of clear-cut equivalency (Coates et al. 2006).
3) What is the relationship between merchantable lodgepole pine piece size and secondary structure?
4) What is the forest health status of secondary structure in pine-leading stands?
   a) Summarize incidence of forest health damaging agents and conditions for seedlings and saplings by species for all plots combined and by biogeoclimatic zone.
   b) Summarize incidence of forest health damaging agents and conditions for all sub-canopy and canopy secondary structure for all plots combined and by biogeoclimatic zone.

Methods

Data sources

Data for this project came from mature and older (age class 4 and higher) pine stands in the Quesnel, Williams Lake and 100 Mile House Timber Supply Areas. This encompasses the Quesnel, Central Cariboo, Chilcotin, and 100 Mile House Forest Districts located in the Southern Interior Forest Region (Figs.1 and 2). A total of 1649 plots from pine stands were obtained (Table 1) covering six different biogeoclimatic zones in the Cariboo-Chilcotin (Table 2).

Criteria for plots to be used in the secondary structure dataset

To be considered pine-leading and included in the dataset used in this analysis, individual sample plots needed to contain 50% or more of their overstory basal area (m^2/ha) in lodgepole pine, based on merchantability limits for pine and non-pine species. Of the 1649 total plots, 1109 were pine-leading by these criteria (Tables 1 and 2). The five biogeoclimatic zones that are the focus of this report are the Sub-Boreal Pine Spruce (SBPS), the Engelmann Spruce-Subalpine Fir (ESSF), the Sub-Boreal Spruce (SBS), the

Interior Douglas Fir (IDF), the Montane Spruce (MS) zones. We provide limited information on the Interior Cedar-Hemlock (ICH) zone because of low sample sizes.

The dataset used in our analysis was collated from projects established at different times relative to the mountain pine beetle attack (Table 1). Plots in the dataset were established before the current epidemic hit the Cariboo-Chilcotin region, during the current epidemic, or after the worse of the current epidemic had passed. For example, plots from the Marshal dataset (Table 1) were established shortly after an earlier mountain pine beetle infestation in the early 1980s. For these plots, measurements of dead and fallen overstory pine were used to re-create pre-beetle stand conditions.

In all datasets used in this analysis, sub-canopy and canopy pine trees were not considered to be secondary structure even if they were alive at the time of measurement. The only pine trees that could contribute to secondary structure composition or abundance were seedlings and saplings that were less than 7.5 cm DBH. In reality this may be conservative; some sub-canopy and canopy pine trees will survive mountain pine beetle attack. We use this approach to reduce the risk of over-estimating secondary structure and to provide a clear representation of the non-pine secondary structure present in the Cariboo-Chilcotin region in the sub-canopy and canopy layers.

Data structure and organization

Data structure and study objectives varied between the individual research projects contributing data (Table 1), however, we were able to take data from the individual plots and summarize the information into several tree layers: seedlings, saplings, sub-canopy and canopy trees (Table 3). Seedlings and saplings combined form the understory layer while sub-canopy and canopy trees combined form the overstory layer (Table 3). In British Columbia merchantability limits vary by tree species. We use merchantability limits in various calculations throughout the report. Individual lodgepole pine trees are considered merchantable if they are 12.5 cm DBH or greater; for other conifer species the limit is 17.5 cm DBH or greater. Broadleaf tree species are not considered merchantable tree species in this report.

Tree species names and abbreviations used for each tree species in the figures and tables of the report are found in Table 4.

Secondary structure was identified as pine trees < 7.5 cm DBH and all other non-pine species, including broadleaf species. Merchantable secondary structure was identified as non-pine conifers >= 17.5 cm DBH. Non-merchantable secondary structure was identified as pine < 7.5 cm DBH, other conifers < 17.5 cm DBH and all broadleaf species (Table 3). When we talk about total secondary structure in this report we are referring to all tree layers and are including both conifer and broadleaf species.

Data analysis and summaries

Table 3 provides a description of size class criteria and terms used to describe secondary structure and canopy layers in this report. We summarized the data by all plots and for each biogeoclimatic zone in the followings groupings.

1. The tree species composition of the different tree layers (seedlings, saplings, sub-canopy and canopy) and reporting methods (densities, basal area) by biogeoclimatic zone.

2. The cumulative percentage of plots in pine-leading stands with combined densities of conifer and broadleaf seedlings and saplings exceeding specified density thresholds.

3. Cumulative percent of plots exceeding basal area thresholds by:
   a) total secondary structure
   b) merchantable secondary structure
   c) non-merchantable secondary structure
   d) non-merchantable conifer secondary structure

4. Cumulative percent of plots exceeding basal area thresholds by:
   a) secondary structure >=7.5cm DBH
   b) secondary structure >=17.5 cm DBH
   c) conifer secondary structure >0 cm DBH
   d) conifer secondary structure >=7.5 cm BH
   e) conifer secondary structure >=17.5 cm BH

5. Comparing the basal area of total secondary structure and non-merchantable secondary structure to the percent of basal area of overstory pine. This analysis is to see if the abundance of secondary structure varies with the proportion of overstory pine. It is expected that total secondary structure will be correlated with proportion of overstory pine. How non-merchantable secondary structure varies in response to the proportion of overstory pine is of more interest.

6. Comparing the basal area of secondary structure to the basal area of a clear-cut lodgepole pine stand. We calculated the basal area of all saplings, sub-canopy and canopy trees in each sample plot (live pine trees greater than 7.5 cm DBH were excluded). We then used TIPSY to determine basal area development of an average lodgepole pine plantation in each of the different ecological units (Table 6). We then assigned a clear-cut equivalence age to each sample plot. This allowed secondary structure to be quantified in terms of how long it would take a typical pine plantation to reach basal areas equivalent to those found in pine-leading stands (Table 7).

7. The relationship between average pine piece size and non-merchantable secondary structure. Average piece size was calculated by determining an average DBH for all live and dead pine trees greater than or equal to 12.5 cm DBH in each plot. We used a combination of measured heights from the plot data and species-specific height:DBH equations to estimate height of trees with no height measurement. Volume per tree was based on tree height to a 4-inch top (3m was deducted from estimated height). Piece size was extrapolated and assigned to each plot in our database.

8. Forest health issues are a major concern for the future viability of secondary structure. This is especially the case in the Cariboo-Chilcotin region where understory pine is common and considered especially vulnerable to forest health concerns. We were able to compile an extensive database of individual trees by tree species, canopy layer and ecological units where forest health and damage had been recorded (Tables 8 and 9).

RESULTS AND DISCUSSION

Seedlings and saplings

The composition and abundance of seedlings and saplings in the Cariboo-Chilcotin region was consistent with results from other regions of British Columbia where pine-leading stands have been examined (Coates et al. 2006, Vyse et al. 2009, Huggard 2009). Median density of conifer seedlings and saplings varied by biogeoclimatic zone with highest median densities in the ESSF and IDF zones, approximately 4,700 and 2,900 sph, respectively (Fig. 3). The overall median density of seedlings and saplings across all ecological units in the Cariboo-Chilcotin was 1800 sph. Seedlings and saplings densities were lowest in the SBS zone (1019 sph, Fig 3).

To illustrate the data, we have provided cumulative stocking graphs for seedlings, saplings and seedlings and saplings combined for conifers (Figs. 4-5) and broadleaf (Figs. 6-7) species. Across all ecological units about 70% of sample plots in pine-leading stands exceeded a 1000 sph threshold for understory conifer seedling and sapling density (Fig. 5). In addition, about 12% of sample plots exceeded a 1000 sph threshold for understory broadleaf seedlings and saplings (Fig. 7); however, broadleaf species were highly variable by ecological unit. Broadleaf species were most common in the IDF zone (Fig. 7). Understory broadleaf species were quite rare in the MS zone. Conifer understory species were more uniformly distributed by ecological unit (Fig. 5). Highest numbers were found in the IDF and ESSF zones.

The species composition of the understory tree layer varied considerably in the individual biogeoclimatic zones (Table 5a). Lodgepole pine was by far the most common understory tree species in the MS and SBPS zones (79 and 74%, respectively). Pine composition decreased to 52% in the IDF zone and was lowest at 10% in the ESSF zone (Table 5a). Pine dominated the sapling layer (89%) in the MS zone. Subalpine fir was common only in two zones, the ESSF (75%) and the SBS (28%). Interior spruce was common, but not abundant, in all zones varying from 9 to 26% of the understory tree composition (Table 5a). Douglas-fir was found in the IDF (28%), SBS (9%) and SBPS (2%) zones, but not elsewhere. Black spruce was rare in the Cariboo-Chilcotin. Trembling aspen represented 16 and 10% of understory species in the IDF and SBPS zones, respectively (Table 5a).

Given the dominance of lodgepole pine in the understory of most ecological units, it is clear information on the current health (see below) and projections of future survival and growth of understory pine is needed to access the merit of protecting or managing understory trees after MPB-disturbance in the Cariboo-Chilcotin

Basal area of sapling, sub-canopy and canopy secondary structure

Based on prior work in the northern interior, pine-leading stands with a minimum of 5 m^2 ha^{-1} of secondary structure basal area can potentially contribute to mid-term timber supply (Coates and Hall 2005, Coates et al. 2006). Across all ecological units 34% of total plots met this standard (Fig. 8). Total secondary structure basal area exceeding this threshold varied somewhat by zone from a low of 25% of plots in the SBS to a high of

57% in the ESSF (Fig. 8). Of course, secondary structure can be broken down by various tree layers or merchantability standards (Table 3). We have provided various different breakdowns of secondary structure basal area in figures 9-13. For example, secondary structure basal area of conifers only (Fig. 11) compared to total secondary structure of all tree species (Fig. 8) clearly indicates that the vast majority of secondary structure found in the Cariboo-Chilcotin region comprise conifer species.

If secondary structure is calculated to include only merchantable trees then percentages of plots with a minimum of 5 m^2 ha^{-1} of secondary structure basal area decreases substantially in all ecological units (Fig. 14). Substantial amounts of the secondary structure basal area found in the Cariboo-Chilcotin region are on non-merchantable stems (Fig. 15). The high level of secondary structure in non-merchantable size classes provides considerable future management options, that will of course depend on the management value being considered (e.g., timber supply, hydrological recovery period).

The sapling basal area was dominated by pine in all ecological units except the ESSF zone, where subalpine fir (55%) dominated (Table 5b). Pine varied from a high of 90% in the MS zone to a low of 34% of the sapling basal area in the SBS zone. Interior spruce was the next most common species with sapling basal area varying from 4 to 27% across the ecological units (Table 5b). Douglas-fir comprised 33% of the sapling basal area in the IDF zone. Broadleaf species represented less than 7% of the sapling basal area and were absent from the ESSF and MS zones. The most diverse ecological unit, in terms of sapling composition, was the SBS zone where no single species dominated the composition (Table 5b).

Secondary structure in the sub-canopy and canopy tree layers was comprised of non-pine species. Interior spruce was abundant in all ecological units except the IDF zone where Douglas-fir dominated. Spruce basal area represented between 24 and 76% of the basal area of sub-canopy and canopy trees, excluding the IDF zone (Table 5b). Subalpine fir sub-canopy basal area varied from 21 to 36% in the MS, SBS and ESSF zones (Table 5b). Except for the ESSF zone, the percent of basal area represented by subalpine fir decreased in the canopy layer. The percent of Douglas-fir basal area increased from the sapling to the canopy layer in all zones were it was present. Aspen was most common in the canopy layer, varying from 15 to 20% of the basal area in the IDF, SBS and SBPS zones (Table 5b).

Secondary structure and proportion of overstory basal area occupied by pine

Recall that to be included in the dataset the basal area of the merchantable pine had to be 50% or more of the total merchantable basal area (see methods for details). Hence, by definition, components of the overstory basal area of secondary structure have to be correlated with the basal area of pine.

One might expect secondary structure basal area to increase as pine basal area decreases. In general, this is the trend that is observed for total secondary structure basal area (Fig. 16). It is interesting to note, however, that any given level of pine basal area, in any ecological unit, there is a wide range of possible total secondary structure basal areas possible. This suggests generalizations about the total basal area of all secondary structure based solely on the percent of pine basal are crude at best. In reality, the basal area of secondary structure can vary widely at any given level of pine basal area, requiring site specific field data for a precise value.

The relationship between pine basal area and non-merchantable secondary structure basal area was poor (Fig. 17). The data clearly indicate that any level of non-merchantable secondary structure basal area can be found at any level of pine basal area. Assumptions about non-merchantable secondary structure basal area can not be made based on the proportion of overstory pine basal area. Only the SBS zone showed a slight trend of increased non-merchantable secondary structure basal area with decreasing overstory pine basal area (Fig. 17).

The clear-cut equivalence of secondary structure

We used TIPSY to determine the basal area development of average lodgepole pine plantations in the different ecological units of the Cariboo-Chilcotin region. We then compared the basal area development of the pine plantations to current total basal area of all secondary structure (Table 6 and Fig.18). This allows secondary structure to be quantified in terms of how long it would take a typical pine plantation to reach basal areas equivalent to those found in pine-leading stands damaged by the MPB.

The assignment of a clear-cut equivalence age does not imply that future performance of these stands will follow that of a managed pine plantation. It is simple a means to portray, in terms of the amount of time it might take salvaged and planted sites, in the different ecological units, to recoup the existing basal area of the secondary structure. The shape of the clear-cut equivalence curve was similar for all ecological units (Fig. 18).

Across the different ecological units, between 31 and 68% of pine-leading stands currently have secondary structure equivalent to or better than a 20 year old pine plantation (Table 6). When contrasted with a 40 year old pine plantation, value decreased to between 2 and 11%. Clear-cut equivalence was highest in the ESSF zone and lowest in the MS zone (Table 6).

The relationship between average lodgepole pine piece size and non-merchantable secondary structure

Average piece size is a commonly used metric to characterize the value of a stand from a logging and conversion to dimensional lumber perspective. For example, stands with the highest average piece size might be scheduled for logging first, given all else was equal.

There was little evidence to support a relationship between the average piece size of lodgepole pine and the basal area of non-merchantable secondary structure (Fig. 19). If anything, there was a slight trend toward higher non-merchantable secondary structure basal area in stands with lower average pine piece size (see, for example, the SBS zone panel in Fig. 19).

Similar to the relationship between non-merchantable secondary structure basal area and proportion of pine in the overstory, any level of secondary structure basal area can be found at any level of average pine piece size. This suggests attractive stands for salvage (high piece size) can be found with low levels of secondary structure and that stands with high levels of secondary structure could be deferred from logging if secondary structure is expected to perform well in the future. Again, site specific decisions are required and generalization to be avoided.

Forest health status of secondary structure in pine-leading stands

The forest health status of secondary structure is an important issue throughout BC where secondary structure is being considered in management decisions for MPB-disturbed stands and landscapes. The forest health status of secondary structure is probably most important for growth and yield implications of different management strategies (i.e., salvage and planting compared to managing the secondary structure).

We were able to compile an extensive individual tree dataset from the Cariboo-Chilcotin region to examine the extent of forest health issues of secondary structure (Tables 8 and 9). For example, the information on the forest health status of lodgepole pine is based on a sample size of 53,953 trees well balanced across different tree layers (Table 8). Various summary tables are provided by combinations of damage type, tree species, ecological unit, tree layers or category of secondary structure (Tables 10-19).

In consultation with forest health professionals we selected 18 of the most important damaging agents that impact the tree species of the Cariboo-Chilcotin region. Table 10 presents damage incidence by species across all ecological units of the Cariboo-Chilcotin region, whereas the summaries in Tables 11-16 are specific to the individual ecological units of the Cariboo-Chilcotin.

The tree damage data presented here is difficult to summarize since not all damage agents are equal. Because of the importance of lodgepole pine composition in the Cariboo-Chilcotin we will first focus our results on this species, and specifically on the incidence of lodgepole pine dwarf mistletoe on understory pine trees. We provide damage information on all tree layers of pine, but remember that sub-canopy and canopy pine trees that are not considered secondary structure in this report.

Understory secondary structure pine trees (seedlings and saplings) averaged 3.3% infection of mistletoe across all ecological units (Table 17), a lower rate of infection than the overall average for all pine tree layers combined. On average, 5% of all pine trees in the Cariboo-Chilcotin region were infected by mistletoe (Table 10). The overall incidence of mistletoe varied from a low of 1% in the ESSF zone to a high of 6.9% in the IDF zone. Infection rates were higher in sub-canopy pine (4.5%) and canopy pine (6.8%) (Tables 18 and 19).

Fewer than 10% of all understory pine trees had some sort of damage, whereas nearly 20% of all understory interior spruce had some sort of damage (Table 17). In comparison, nearly 8% of Douglas-fir understory trees were damaged, and only around 1% of subalpine fir understory trees were damaged. Sub-canopy secondary structure trees (non-pine species) generally had higher levels of damage than understory trees of the same species (Table 18). Douglas-fir was an exception with slightly less damage. Levels of damage in canopy trees were similar to sub-canopy trees (Table 19).

Caution should be used in translating damage incidence into the percent of trees that are unacceptable in some way for future management consideration. This decision will depend on the specific management value being considered, the tree species, and the specific damage agent. These data do, however, provide a general sense of forest health in the Cariboo-Chilcotin region.

DISSEMINATION OF RESULTS

This report is the main means of dissemination of results for this project. In addition, this project and earlier results have been described at the 2008 Southern Silviculture Committee Summer Workshop, at the 2009 Western Silviculture Contractors Association Annual Meeting, at several workshops/meeting in Victoria and on various field trips with staff from government, forest companies, contractors and universities.

CONTRIBUTION OF RESEARCH GROUP MEMBERS

This project was coordinated by Dave Coates of the Ministry of Forests and Range, Smithers. His two month contribution of time to this project was all in kind. Several other staff of the Ministry of Forests and Range, Southern Interior Forest Region contributed 1-3 days of in kind support. There were no outside cash contributions to the project.

COLLABORATION WITH PARTNERS

There were no contributions provided by collaborators.

PROBLEMS ENCOUNTERED

The project went very smoothly and was completed under budget.

FINANCIAL SUMMARY

This information has been provided under separate cover.

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TABLES

Table 1. Summary of sample plot sources and location of additional information on experimental procedures and sampling. Pine-leading plots contained >50% basal area of pine in the sub-canopy and canopy, based on merchantability limits for pine and non-pine species.

Summary by Source	Total Plots	Pine-Leading Plots	Funding Source and Experimental Details
Marshal	181	160	FSP M075015. http://www.bcfsp.com
UBC Research Forest	49	27	http://www.forestry.ubc.ca/resfor/afrf/index.htm
NIVMA	44	42	http://www.nivma.bc.ca/
Permanent Sample Plots	233	209	http://www.for.gov.bc.ca/hts/vri/ip/psp/
Vegetation Resource Inventory	327	296	http://www.for.gov.bc.ca/hts/vri/
Tolko Cariboo (Lignum Plot Establishment Programs)	114	58	http://www.for.gov.bc.ca/hfd/library/FIA/2004/FIA-04-05-0016.pdf
Forest Analysis and Inventory Branch, BC Ministry of Forest and Range	701	317	Contract 10005-40/FS09SAM007. Matt.Makar@gov.bc.ca
Total	**1649**	**1109**	

Table 2. Summary of sample plots used in the analysis by biogeoclimatic zone.

Plots summarized by Biogeoclimatic Zones	Number of Pine-Leading Plots
Total Plots	**1649**
Total Pine leading Plots	**1109**
Engelmann Spruce-Subalpine Fir (ESSF)	**28**
Interior Cedar-Hemlock (ICH)	**3**
Interior Douglas-Fir (IDF)	**250**
Montane Spruce (MS)	**186**
Sub-Boreal Pine-Spruce (SBPS)	**484**
Sub-Boreal Spruce (SBS)	**158**

Table 3. Description of tree size criteria, tree layers and categories of secondary structure used in the analysis.

Table 3a. Size class criteria.

Size	Secondary structure layer	Canopy layer
10-130 cm height	understory	seedlings
0 - <7.5 cm DBH	understory	saplings
>= 7.5 - <15 cm DBH	overstory	sub-canopy
>=15cm DBH	overstory	canopy

Table 3b. Secondary structure descriptions.

Total secondary structure	all understory saplings and overstory non pine conifers and broadleaf species
Non-merchantable secondary structure	all understory saplings, all overstory broadleaf species, and overstory non pine conifers <17.5 cm DBH
Merchantable secondary structure	all overstory/canopy non pine conifer trees >=17.5cm DBH

Table 4. Tree species names and species codes used in the report.

Conifer species	Scientific name	Species code	Broadleaf species	Scientific name	Species code
lodgepole pine	*Pinus contorta*	Pl	cottonwood	*Populus balsamifera ssp. Trichocarpa*	Act
whitebark pine	*Pinus albicaulis*	Pa	trembling aspen	*Populus tremloides*	At
interior spruce	*Picea glauca x engelmanni*	Sx	paper birch	*Betula payrifera*	Ep
black spruce	*Picea mariana*	Sb			
subalpine fir	*Abies lasiocarpa*	Bl			
Douglas Fir	*Pseudotsuga menziesii*	Fd			

Table 5a. Distribution of understory seedlings and saplings by species and zone of the Cariboo-Chilcotin.

Percent of understory seedlings and saplings combined

Zone	Pl	Pa	Sx	Sb	Bl	Fd	Ep	At	Act
ESSF	10	5	10	0	75	0	0	0	0
IDF	52	0	3	0	0	28	0	16	0
MS	79	0	12	0	8	0	0	0	0
SBPS	74	0	13	0	0	2	0	10	0
SBS	19	0	28	1	28	9	10	4	0

Percent of understory seedlings

Zone	Pl	Pa	Sx	Sb	Bl	Fd	Ep	At	Act
ESSF	7	5	9	0	79	0	0	0	0
IDF	51	0	3	0	0	25	0	21	0
MS	68	0	19	0	13	0	0	1	0
SBPS	73	0	11	0	1	2	0	14	0
SBS	14	0	26	0	34	11	8	6	0

Percent of understory saplings

Zone	Pl	Pa	Sx	Sb	Bl	Fd	Ep	At	Act
ESSF	31	2	23	0	45	0	0	0	0
IDF	53	0	4	0	0	33	0	10	0
MS	89	0	7	0	4	0	0	0	0
SBPS	76	0	15	0	0	2	0	7	0
SBS	25	0	31	1	22	7	12	3	0

Table 5b. Distribution of saplings, sub-canopy and canopy secondary structure trees by species and zone of the Cariboo-Chilcotin.

Percentage of secondary structure by species for the sapling layer

Zone	Pl	Pa	Sx	Sb	Bl	Fd	Ep	At	Act
ESSF	29	1	16	0	55	0	0	0	0
IDF	57	0	4	0	0	33	0	6	0
MS	90	0	6	0	3	0	0	0	0
SBPS	81	0	13	0	0	2	0	3	0
SBS	34	0	27	1	26	8	2	2	0

Percentage of secondary structure by species for the sub-canopy layer

Zone	Pa	Py	Sx	Sb	Bl	Fd	Ep	At	Act
ESSF	31	0	29	3	36	0	0	0	0
IDF	1	0	6	3	0	76	2	11	1
MS	1	0	76	2	21	0	0	0	0
SBPS	8	0	56	15	0	11	0	9	0
SBS	13	3	24	13	23	15	3	5	0

Percentage of secondary structure by species for the canopy layer

Zone	Pa	Sx	Sb	Bl	Fd	Ep	At	Act
ESSF	14	49	0	36	0	0	1	0
IDF	0	9	0	0	75	1	15	0
MS	0	66	3	12	19	0	0	0
SBPS	0	66	0	0	18	0	16	0
SBS	0	38	0	9	29	2	20	2

Table 6. Details of TIPSY pine plantation runs. Site index is based on averages from zone, sub-zone and sites.

Tipsy Parameter	ESSF	IDF	MS	SBPS	SBS
Site Index	16.5	16.3	18	15	19.7
stems/ha	1600	1600	1600	1600	1600
regen delay	3 years	3 years	3 years	3 years	3 years
OAF 1	85%	85%	85%	85%	85%
OAF 2	95%	95%	95%	95%	95%
merch limit	12.5	12.5	12.5	12.5	12.5
stock height	13 cm	13 cm	13 cm	13 cm	13 cm

Table 7. Cumulative percentage of plots in pine leading stands that have the equivalent basal area to a developing lodgepole pine clear-cut in biogeoclimatic zones of the Cariboo-Chilcotin. Basal area of pine plantations are based on TIPSY runs (Table 5). For example, in the MS zone a 20 year old plantation has 4 m^2/ha. The cumulative percent of plots indicates the percent of total secondary structure basal match or exceed that of the pine plantation.

Zone	Year	BA/ha	cumulative % plots
ESSF	20	3	68
ESSF	30	12	18
ESSF	40	21	11
ESSF	50	28	7
IDF	20	3	57
IDF	30	12	17
IDF	40	20	3
IDF	50	28	0
MS	20	4	31
MS	30	15	7
MS	40	25	2
MS	50	32	1
SBPS	20	2	49
SBPS	30	9	14
SBPS	40	17	3
SBPS	50	24	1
SBS	20	6	47
SBS	30	18	15
SBS	40	29	3
SBS	50	36	1

Table 8. Forest health sample size by species and canopy layer used to access damage types.

Canopy layer	Act	At	Bl	Cw	Ep	Fd	Pa	Pl	Py	Sb	Sx
Saplings	8	207	152	0	11	1777	0	12407	0	144	1660
Sub-canopy	21	485	162	3	26	1025	3	22503	1	169	1636
Canopy	11	355	99	3	34	693	14	19043	0	34	916
Total	40	1047	413	6	71	3495	17	53953	1	347	4212

Table 9. Forest health sample size by species from each biogeoclimatic zone.

Zone	Act	At	Bl	Cw	Ep	Fd	Pa	Pl	Py	Sb	Sx
ESSF	0	4	79	0	0	1	17	514	0	0	115
ICH	0	3	0	5	4	40	0	75	0	0	3
IDF	2	353	0	0	9	1968	0	13919	1	9	508
MS	0	0	32	0	0	19	0	2594	0	13	75
SBPS	0	311	5	0	6	836	0	28973	0	101	1884
SBS	38	376	297	1	52	631	0	7878	0	224	1627
Total	40	1047	413	6	71	3495	17	53953	1	347	4212

Table 10. The percentage of each tree species with forest health issues. Percentage from the total number of trees for each species. All biogeoclimatic zones combined.

Damages	At	Bl	Ep	Fd	Pl	Sb	Sx
Anything abiotic such as fire or drought	3.63	1.21	0	1.09	3.15	0.29	1.42
Broom rusts	0	0.24	0	0	0	0.86	1.04
Other foliage diseases	0	0.24	0	1.69	0.09	0	1.12
Pine needle cast	0	0	0	0	0.60	0	0
Lodgepole pine dwarf mistletoe	0	0	0	0	5.04	0	0
Other stem rusts	0.57	0	0	1.72	0.66	0	6.48
Atropellis canker	0	0	0	0	1.86	0	0
Comandra blister rust	0	0	0	0	0.15	0	0.02
Western gall rust	0.10	0	0	0	2.69	0	0.07
Orange stalictiform blister rust	0	0	0	0	0.46	0	0
Cooley spruce adelgid	0	0	0	0.03	0.01	0	4.30
Other bark beetles	0	0	0	0.03	0.13	0	0
Mountain pine beetle	0.10	0	0	0	1.75	0.58	0
Defoliators	0	0	0	1.23	0.01	0	0.02
Lodgepole pine terminal weevil	0	0	0	0	0.09	0	0
Physical damages (eg lean, sweep,borken stem)	1.43	5.57	11.27	0.83	0.97	0.86	0.62
Vegatative competition	0.10	0.24	0	0.11	0.18	0	0.74
Wildlife damage	3.15	0	0	0.20	0.41	0	0.02

Table 11. The percentage of trees in the ESSF zone with forest health issues. Percentage from the total number of trees for each species.

Damages	At	Bl	Pl	Sx
Anything abiotic such as fire or drought	0	2.53	5.45	2.61
Broom rusts	0	0	0	0
Other foliage diseases	0	0	0	0
Pine needle cast	0	0	0	0
Lodgepole pine dwarf mistletoe	0	0	0.97	0
Other stem rusts	0	0	0.19	0
Atropellis canker	0	0	0	0
Comandra blister rust	0	0	0	0
Western gall rust	0	0	0	0
Orange stalictiform blister rust	0	0	0	0
Cooley spruce adelgid	0	0	0	0
Other bark beetles	0	0	0	0
Mountain pine beetle	0	0	0.39	0
Defoliators	0	0	0	0
Lodgepole pine terminal weevil	0	0	0	0
Physical damages (eg lean, sweep, broken stem)	25.00	5.06	7.39	3.48
Vegetative competition		1.27	0.78	0
Wildlife damage	25.00	0	0	0

Table 12. The percentage of trees in the ICH zone with forest health issues. Percentage from the total number of trees for each species.

Damages	At	Ep	Fd	Pl
Anything abiotic such as fire or drought	33.33	0	2.50	5.33
Broom rusts	0	0	0	0
Other foliage diseases	0	0	0	0
Pine needle cast	0	0	0	0
Lodgepole pine dwarf mistletoe	0	0	0	0
Other stem rusts	0	0	2.50	0
Atropellis canker	0	0	0	0
Comandra blister rust	0	0	0	0
Western gall rust	0	0	0	1.33
Orange stalictiform blister rust	0	0	0	0
Cooley spruce adelgid	0	0	0	0
Other bark beetles	0	0	0	0
Mountain pine beetle	0	0	0	1.33
Defoliators	0	0	0	0
Lodgepole pine terminal weevil	0	0	0	0
Physical damages, (eg lean, sweep, broken stem)	0	50.00	10.00	14.67
Vegetative competition	0	0	0	2.67

Wildlife damage	0	0	0	0

Table 13. The percentage of trees in the IDF zone with forest health issues. Percentage from the total number of trees for each species.

Damages	At	Fd	Pl	Sx
Anything abiotic such as fire or drought	3.97	1.07	3.13	0.40
Broom rusts	0	0	0	0
Other foliage diseases	0	2.18	0.14	0
Pine needle cast	0	0	1.04	0
Lodgepole pine dwarf mistletoe	0	0	6.89	0
Other stem rusts	0	2.08	0.97	3.98
Atropellis canker	0	0	0.68	0
Comandra blister rust	0	0	0.19	0
Western gall rust	0	0	2.64	0
Orange stalictiform blister rust	0	0	0.74	0
Cooley spruce adelgid	0	0.05	0.02	7.16
Other bark beetles	0	0.05	0.07	0
Mountain pine beetle	0.28	0	1.86	0
Defoliators	0	2.18	0.01	0
Lodgepole pine terminal weevil	0	0	0.25	0
Physical damages (eg lean, sweep, broken stem)	1.70	0.51	0.76	0.40
Vegetative competition		0.10	0.08	0.20
Wildlife damage	1.13	0.25	0.60	00

Table 14. The percentage of trees in the MS zone with forest health issues. Percentage from the total number of trees for each species.

Damages	Fd	Pl	Sb	Sx
Anything abiotic such as fire or drought	5.26	2.58	7.69	4.00
Broom rusts	0	0	0	0
Other foliage diseases	0	0	0	0
Pine needle cast	0	2.16	0	0
Lodgepole pine dwarf mistletoe	0	5.24	0	0
Other stem rusts	5.26	0.19	0	0
Atropellis canker	0	0.08	0	0
Comandra blister rust	0	0	0	0
Western gall rust	0	0.69	0	0
Orange stalictiform blister rust	0	0	0	0
Cooley spruce adelgid	0	0	0	4.00
Other bark beetles	0	0.27	0	0
Mountain pine beetle	0	0.35	0	0
Defoliators	0	0	0	0
Lodgepole pine terminal weevil	0	0	0	0
Physical damages (eg lean, sweep, broken stem)	0	0.31	7.69	0
Vegetative competition	0	0	0	0
Wildlife damage	0	0	0	0

Table 15. The percentage of trees in the SBPS zone with forest health issues. Percentage from the total number of trees for each species.

Damages	At	Fd	Pl	Sb	Sx
Anything abiotic such as fire or drought	3.86	0.96	3.38	0	1.91
Broom rusts	0	0	0	2.97	1.86
Other foliage diseases	0	1.91	0.04	0	2.49
Pine needle cast	0	0	0.40	0	0
Lodgepole pine dwarf mistletoe	0	0	5.12	0	0
Other stem rusts	1.61	1.56	0.70	0	13.27
Atropellis canker	0	0	2.81	0	0
Comandra blister rust	0	0	0.09	0	0.05
Western gall rust	0.32	0	3.11	0	0.11
Orange stalictiform blister rust	0	0	0.45	0	0
Cooley spruce adelgid	0	0	0	0	6.42
Other bark beetles	0	0	0.15	0	0
Mountain pine beetle	0	0	1.99	1.98	0
Defoliators	0	0	0.01	0	0
Lodgepole pine terminal weevil	0	0	0.04	0	0
Physical damages (eg lean, sweep,borken stem)	0.96	0.12	0.74	0	1.49
Vegatative competition		0.12	0.21	0	0.05
Wildlife damage	8.36	0.24	0.47	0	0.27

Table 16. The percentage of trees in the SBS zone with forest health issues. Percentage from the total number of trees for each species.

Damages	At	Bl	Ep	Fd	Pl	Sb	Sx
Anything abiotic such as fire or drought	28.95	1.01	0	1.11	2.37	0	1.00
Broom rusts	0	0.34	0	0	0	0	0.56
Other foliage diseases	0	0.34	0	0	0.20	0	0
Pine needle cast	0	0	0	0	0.06	0	0
Lodgepole pine dwarf mistletoe	0	0	0	0	1.73	0	0
Other stem rusts	2.63	0	0	0.63	0.15	0	0.19
Atropellis canker	0	0	0	0	1.22	0	0
Comandra blister rust	0	0	0	0	0.36	0	0
Western gall rust	0	0	0	0	2.06	0	0.06
Orange stalictiform blister rust	0	0	0	0	0.20	0	0
Cooley spruce adelgid	0	0	0	0	0	0	1.31
Other bark beetles	0	0	0	0	0.13	0	0
Mountain pine beetle	0	0	0	0	1.22	0	0
Defoliators	0	0	0	0	0	0	0.06
Lodgepole pine terminal weevil	0	0	0	0	0	0	0
Physical damages (eg lean, sweep, broken stem)	13.16	6.40	11.54	2.22	1.85	0.89	0.94
Vegetative competition	2.63	0	0	0.16	0.25	0	0.12

Wildlife damage	5.26	0	0	0	0.03	0	0

Table 17. The percentage of understory trees with forest health concerns. Trees 0-7.5cm DBH. All biogeoclimatic zones.

Damages	**At**	**Bl**	**Fd**	**Pl**	**Sb**	**Sx**
Anything abiotic such as fire or drought	0.48	0	0.90	0.59	0	1.03
Broom rusts	0	0	0	0	1.39	0.54
Other foliage diseases	0	0.66	2.08	0.09	0	1.27
Pine needle cast	0	0	0	1.43	0	0
Lodgepole pine dwarf mistletoe	0	0	0	3.30	0	0
Other stem rusts	0.48	0	2.31	0.20	0	9.43
Atropellis canker	0	0	0	0.85	0	0
Comandra blister rust	0	0	0	0.09	0	0.06
Western gall rust	0.48	0	0	1.68	0	0
Orange stalictiform blister rust	0	0	0	0.02	0	0
Cooley spruce adelgid	0	0	0.06	0.02	0	5.50
Other bark beetles	0	0	0	0.01	0	0
Mountain pine beetle	0	0	0	0.19	0.69	0
Defoliators	0	0	1.97	0.02	0	0
Lodgepole pine terminal weevil	0	0	0	0.21	0	0
Vegetative competition	0	0	0	0.10	0	0.97
Wildlife damage	3.86	0	0.28	0.70	0	0
Total hideous damages	5.31	0.66	7.60	9.49	2.08	18.80

Table 18. The percentage of sub-canopy trees with forest health issues. Trees >= 7.5 to <15 cm DBH. All biogeoclimatic zones.

Damages	At	Bl	Ep	Fd	Pl	Sb	Sx
Anything abiotic such as fire or drought	3.09	0.62	0	0.68	2.15	0.59	1.65
Broom rusts	0	0	0	0	0	0.59	1.34
Other foliage diseases	0	0	0	1.56	0.04	0	0.98
Pine needle cast	0	0	0	0	0.27	0	0
Lodgepole pine dwarf mistletoe	0	0	0	0	4.49	0	0
Other stem rusts	0.21	0	0	1.66	0.63	0	6.67
Atropellis canker	0	0	0	0	1.37	0	0
Comandra blister rust	0	0	0	0	0.15	0	0
Western gall rust	0	0	0	0	3.10	0	0.12
Orange stalictiform blister rust	0	0	0	0	0.45	0	0
Cooley spruce adelgid	0	0	0	0	0	0	3.55
Other bark beetles	0	0	0	0	0.08	0	0
Mountain pine beetle	0	0	0	0	1.13	0.59	0
Defoliators	0	0	0	0.49	0.00	0	0.06
Lodgepole pine terminal weevil	0	0	0	0	0.08	0	0
Physical damages (eg lean, sweep,borken stem)	1.44	9.88	11.54	0.88	0.86	0.59	0.10
Vegatative competition	0.21	0.62	0	0.39	0.26	0	0.49
Wildlife damage	2.06	0	0	0	0.31	0	0

Total hideous damages	7.01	11.11	11.54	5.66	15.38	2.37	14.97

Table 19. The percentage of canopy trees with forest health concerns. Trees >=15 cm DBH. All biogeoclimatic zones.

Damages	At	Bl	Ep	Fd	Pl	Sb	Sx
Anything abiotic such as fire or drought	6.20	4.04	0	2.16	6.01	0	1.75
Broom rusts	0	1.01	0	0	0	0	1.42
Other foliage diseases	0	0	0	0.87	0.15	0	1.09
Pine needle cast	0	0	0	0	0.45	0	0
Lodgepole pine dwarf mistletoe	0	0	0	0	6.82	0	0
Other stem rusts	1.13	0	0	0.29	0.99	0	0.87
Atropellis canker	0	0	0	0	3.10	0	0
Comandra blister rust	0	0	0	0	0.19	0	0
Western gall rust	0	0	0	0	2.86	0	0.11
Orange stalictiform blister rust	0	0	0	0	0.76	0	0
Cooley spruce adelgid	0	0	0	0	0.01	0	3.60
Other bark beetles	0	0	0	0.14	0.27	0	0
Mountain pine beetle	0.28	0	0	0	3.50	0	0
Defoliators	0	0	0	0.43	0.01	0	0
Lodgepole pine terminal weevil	0	0	0	0	0.01	0	0
Physical damages (eg lean, sweep,borken stem)	2.25	7.07	14.71	2.89	1.74	5.88	0.87
Vegatative competition					0.15		0.55
Wildlife damage	4.23			0.29	0.33		0.11
Total hideous damages	14.08	12.12	14.71	7.07	27.33	5.88	10.37

FIGURES

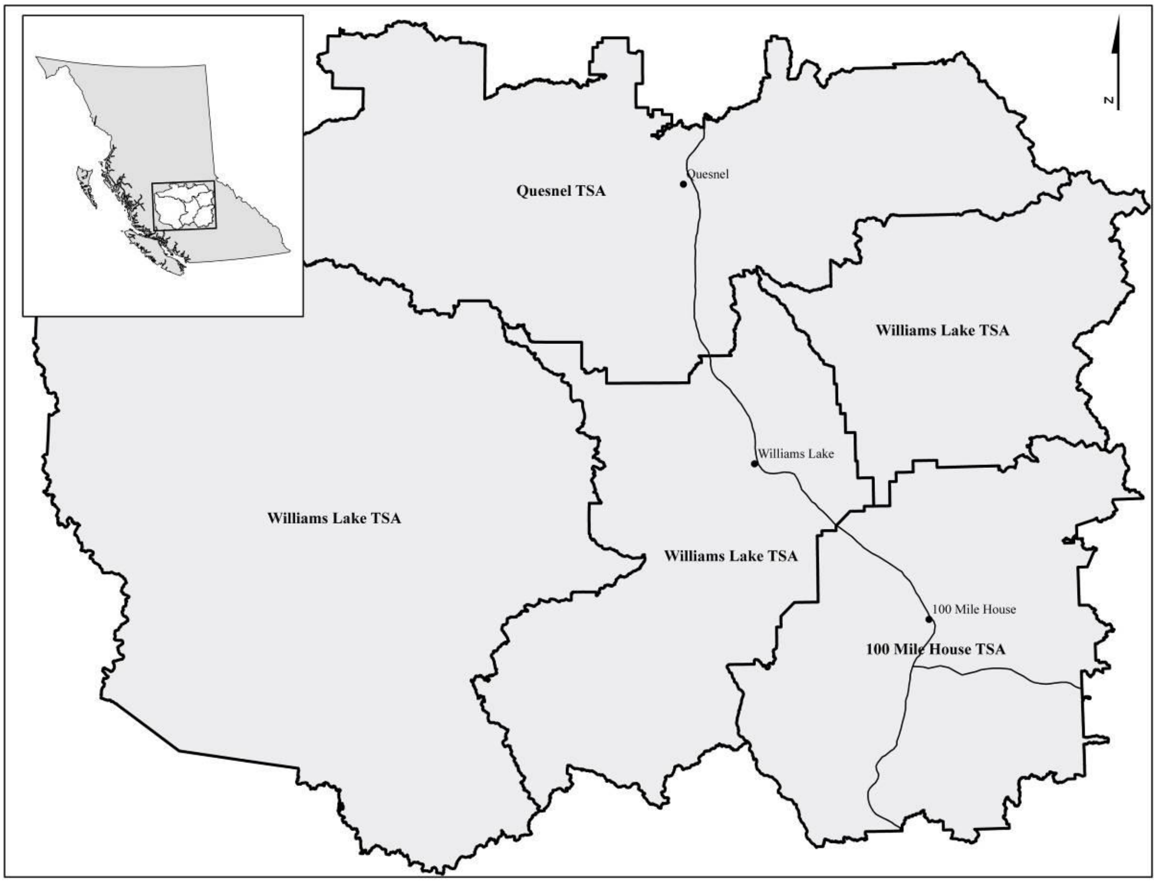

Figure 1. Study area showing the Quesnel, Williams Lake, and 100 Mile House Timber Supply Units in the Southern Interior Forest Region.

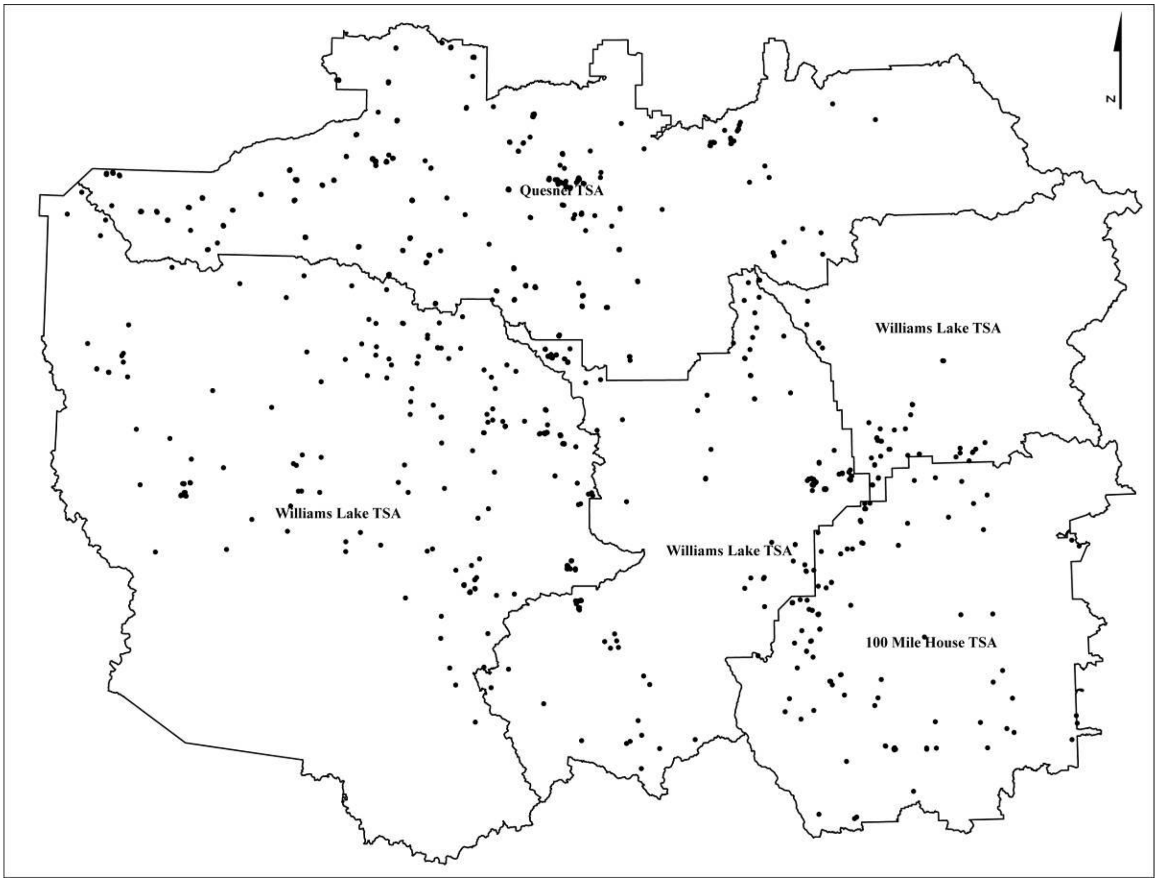

Figure 2. Distribution of sample plots throughout the Quesnel, Williams Lake, and 100 Mile House Timber Supply Units.

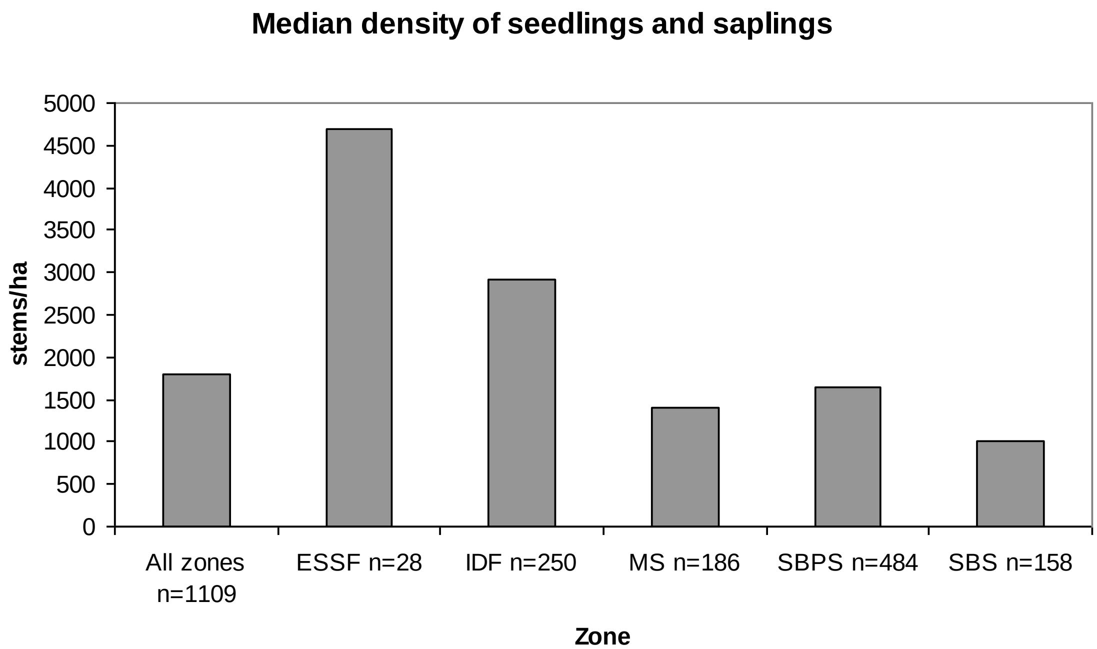

Figure 3. Median density of conifer seedlings and saplings in pine-leading stands by biogeoclimatic unit. The median represents the middle number in the distribution of densities from the sample plots. For example, in the IDF, the median was approximately 2900 stems/ha, meaning that 50% of pine leading stands in the IDF zone had more than 2900 stems/ha while the other half had lower densities.

Median conifer densities: All zones = 1799; ESSF = 4700; IDF = 2917; MS = 1400; SBPS = 1651; SBS = 1019

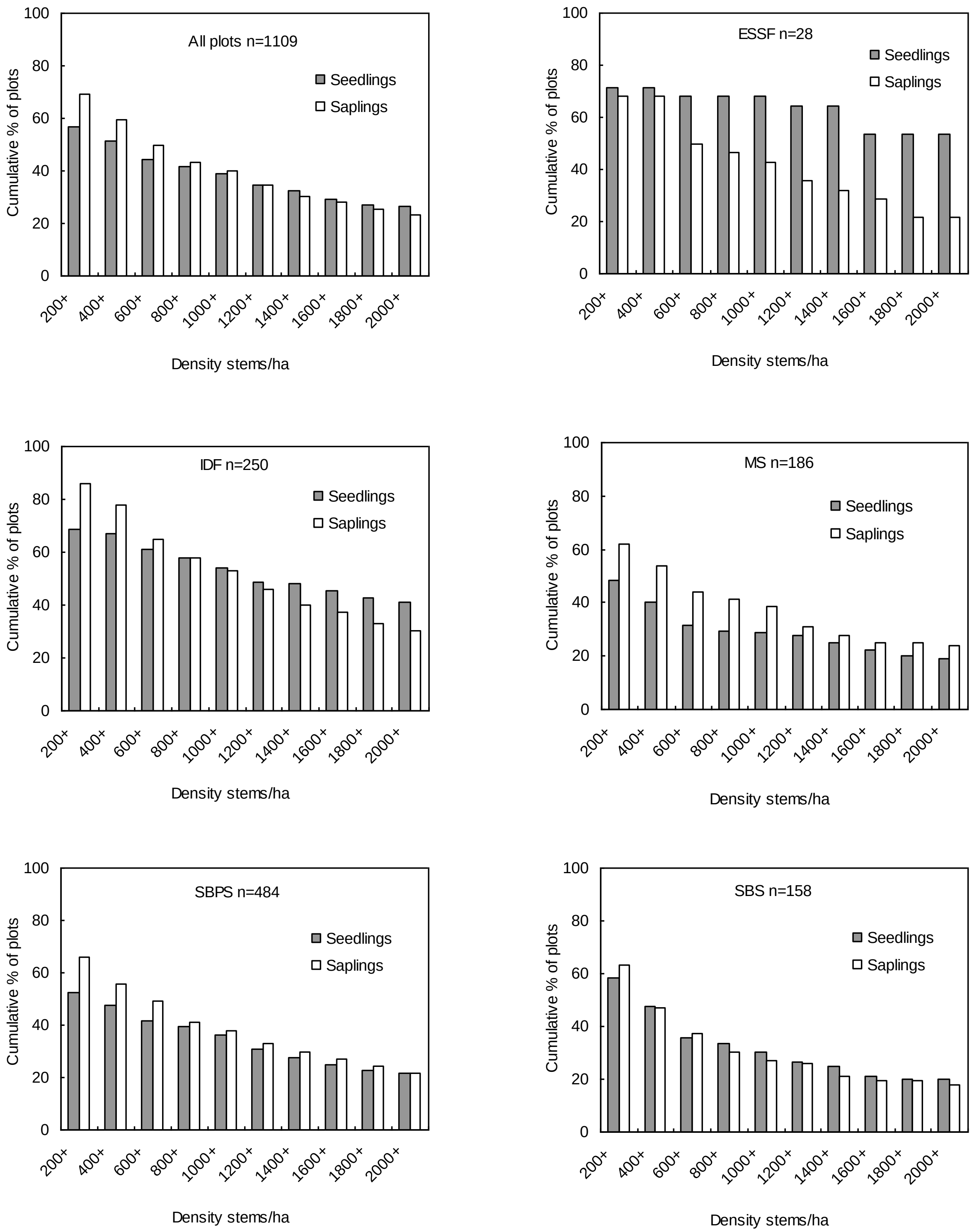

Figure 4. Cumulative percentage of plots in pine-leading stands in the Cariboo-Chilcotin in central BC with densities (stems per hectare) of conifer seedlings (> 0.1 m and <1.3 m tall) and saplings (≥ 1.3 m tall and < 7.5 cm DBH) above specified density thresholds.

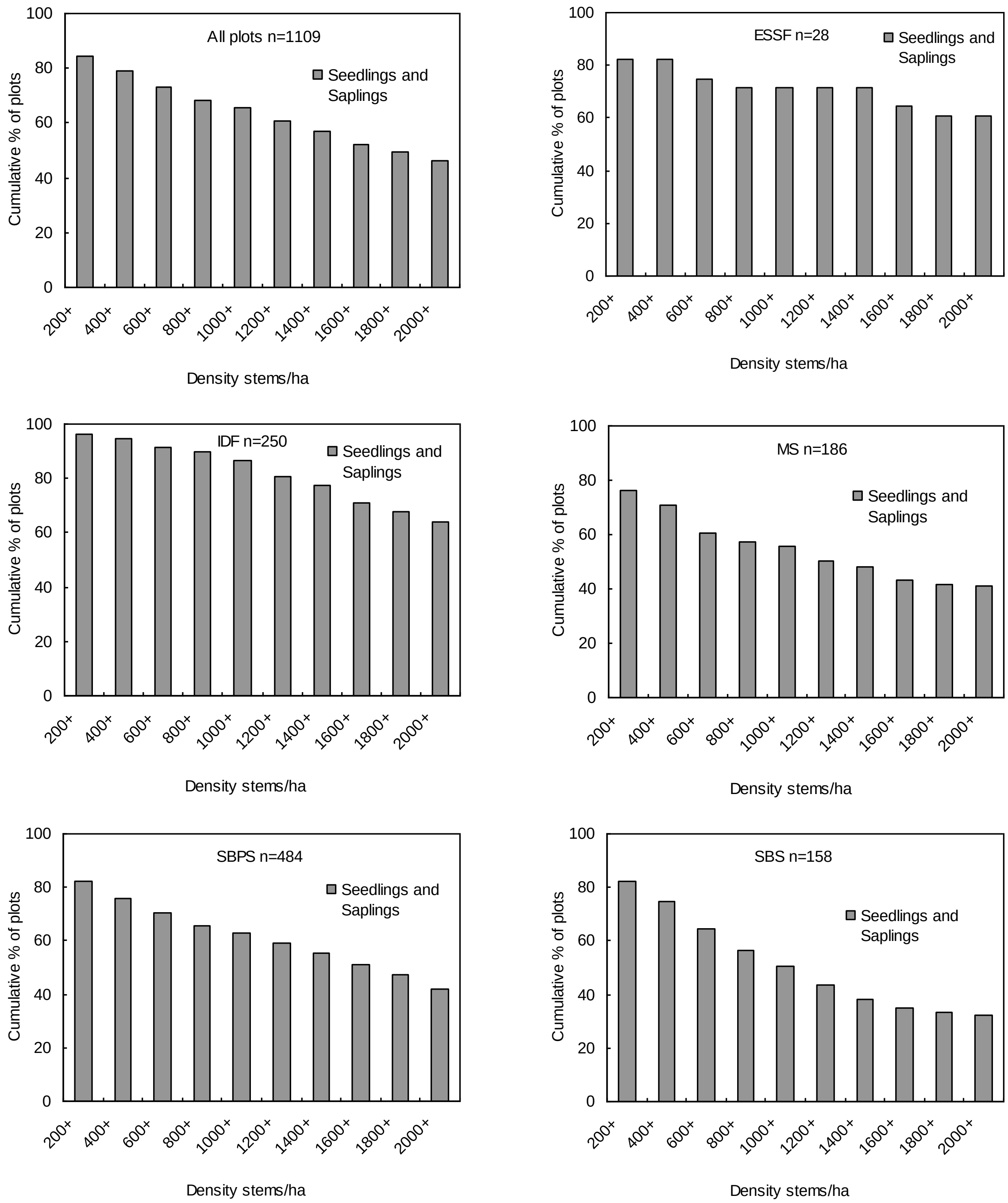

Figure 5. Cumulative percentage of plots in pine-leading stands in the Cariboo-Chilcotin in central BC with combined densities (stems per hectare) of conifer seedlings (> 0.1 m and <1.3 m tall) and saplings (≥ 1.3 m tall and < 7.5 cm DBH) above specified density thresholds.

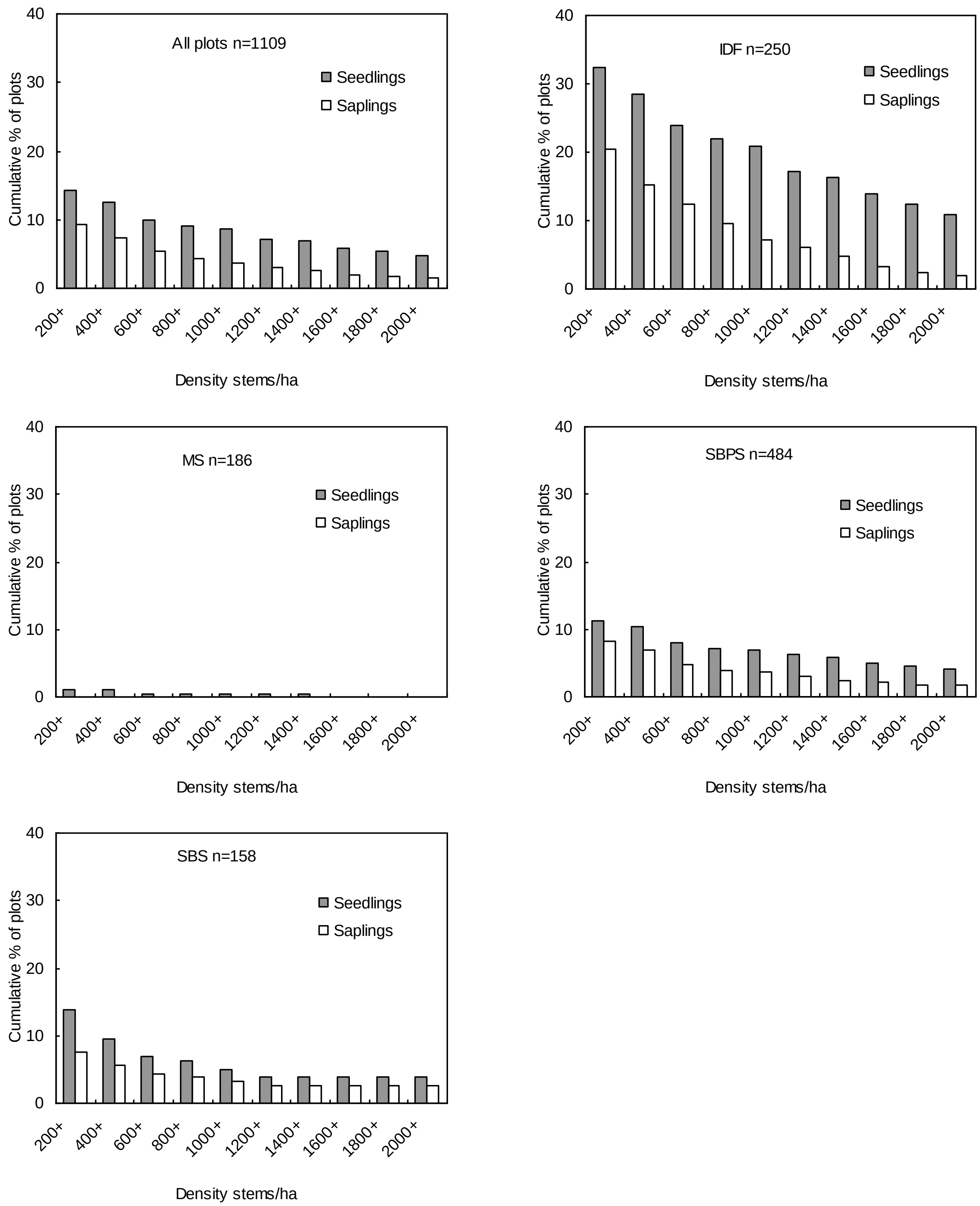

Figure 6. Cumulative percentage of plots in pine-leading stands in the Cariboo-Chilcotin in central BC with densities (stems per hectare) of broadleaf seedlings (> 0.1 m and <1.3 m tall) and saplings (≥ 1.3 m tall and < 7.5 cm DBH) above specified density thresholds.

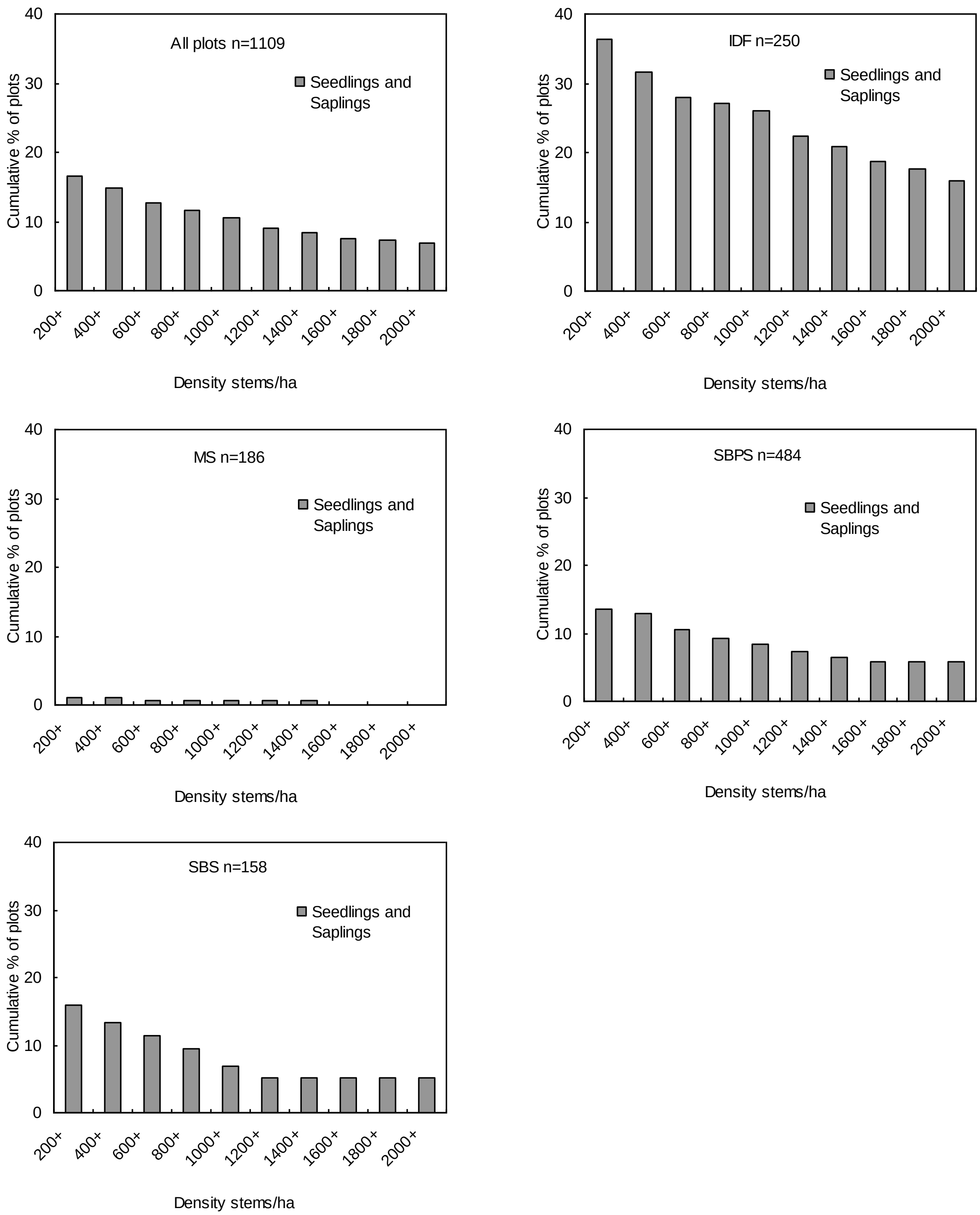

Figure 7. Cumulative percentage of plots in pine-leading stands in the Cariboo-Chilcotin in central BC with combined densities (stems per hectare) of broadleaf seedlings (> 0.1 m and <1.3 m tall) and saplings (≥ 1.3 m tall and < 7.5 cm DBH) above specified density thresholds.

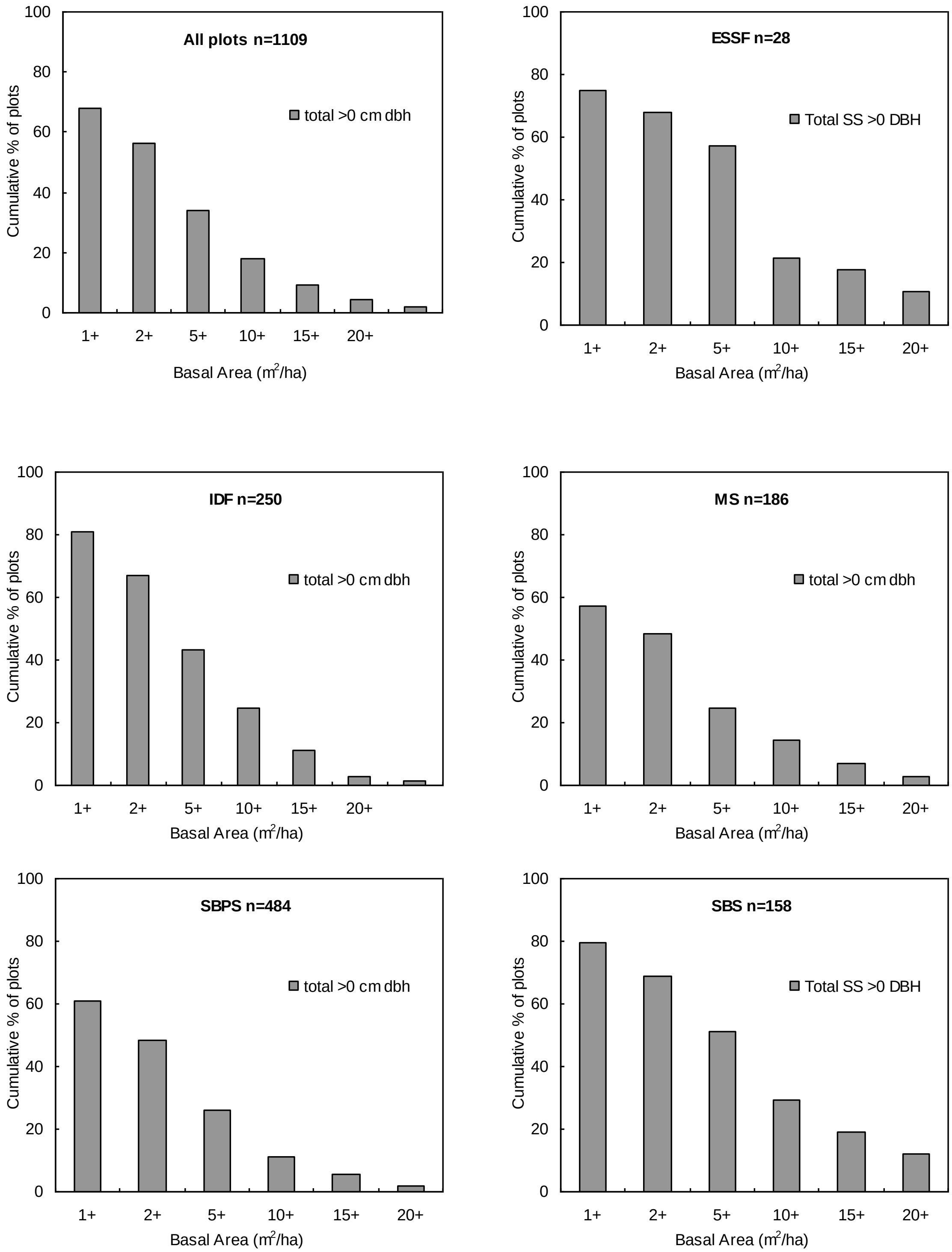

Figure 8. Cumulative percentage of plots in pine-leading stands above specified basal area thresholds by biogeoclimatic zone in the Cariboo-Chilcotin. Data are for total secondary structure - all Pl <7.5cm DBH, all other conifers and broadleaf species.

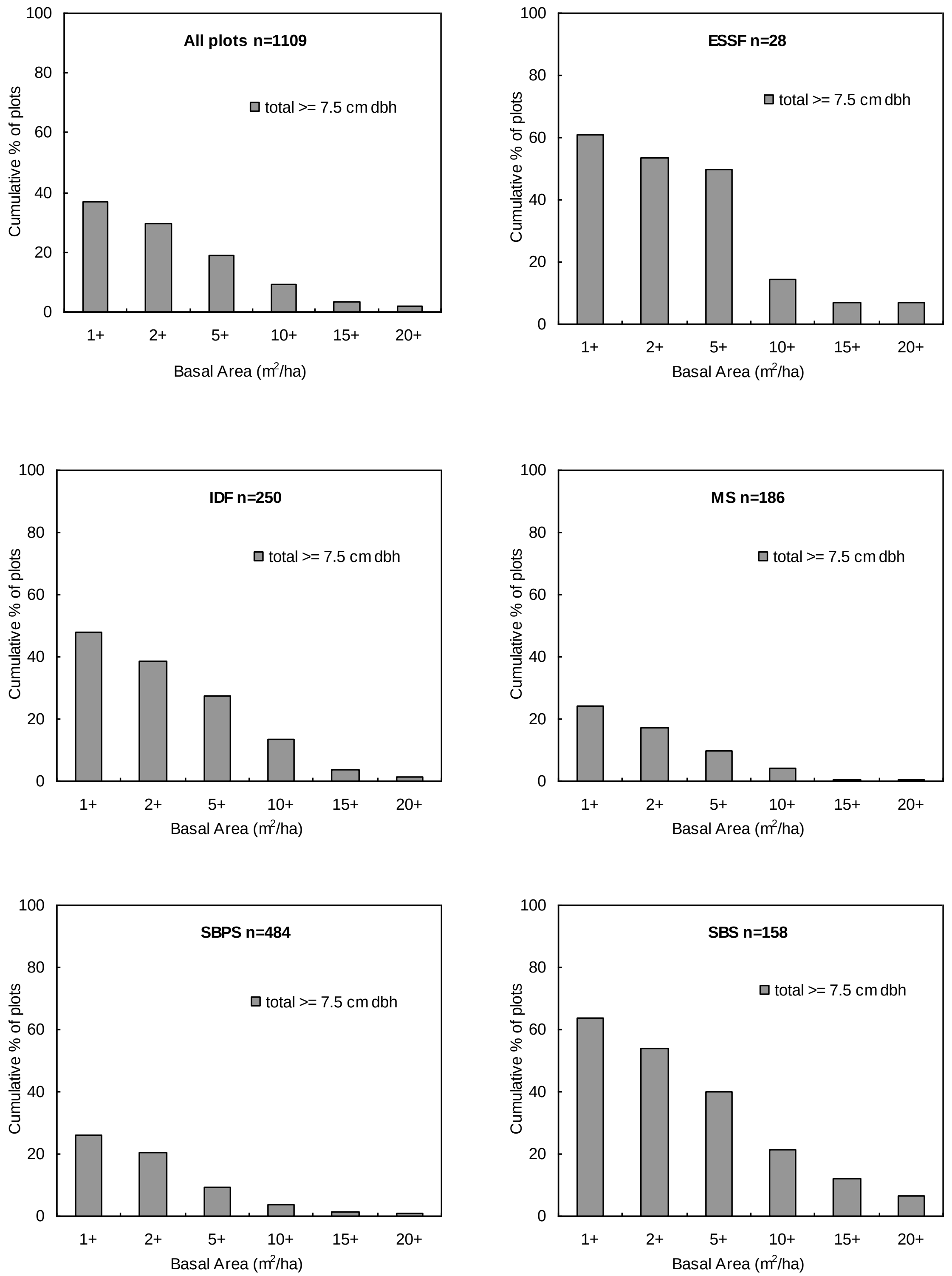

Figure 9. Cumulative percentage of plots in pine-leading stands above specified basal area thresholds by biogeoclimatic zone in the Cariboo-Chilcotin. Data are for secondary structure with a DBH >= 7.5cm including non-pine conifers and broadleaf species.

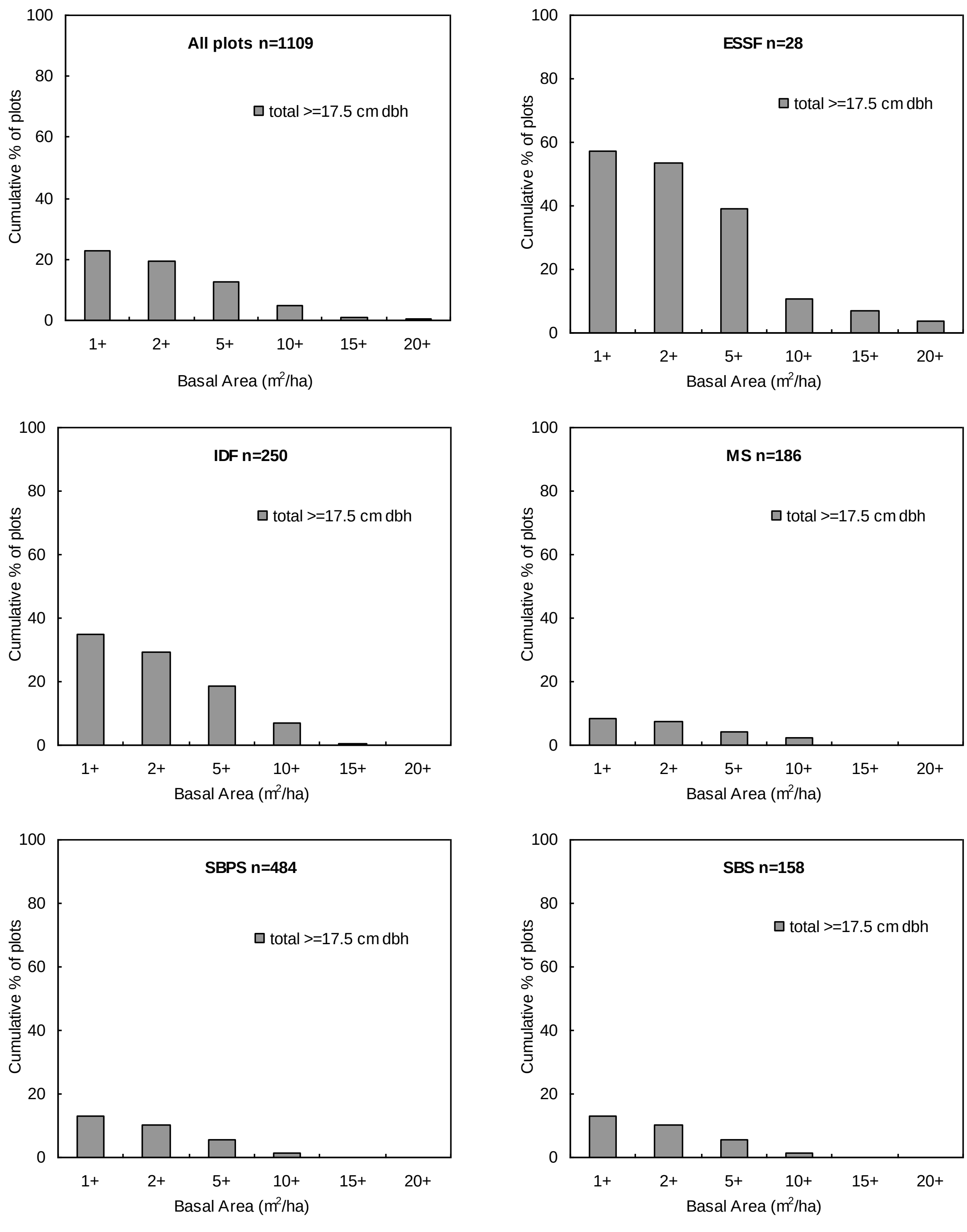

Figure 10. Cumulative percentage of plots in pine-leading stands above specified basal area thresholds by biogeoclimatic zone in the Cariboo-Chilcotin. Data are for secondary structure with a DBH >= 17.5cm including non-pine conifers and broadleaf species.

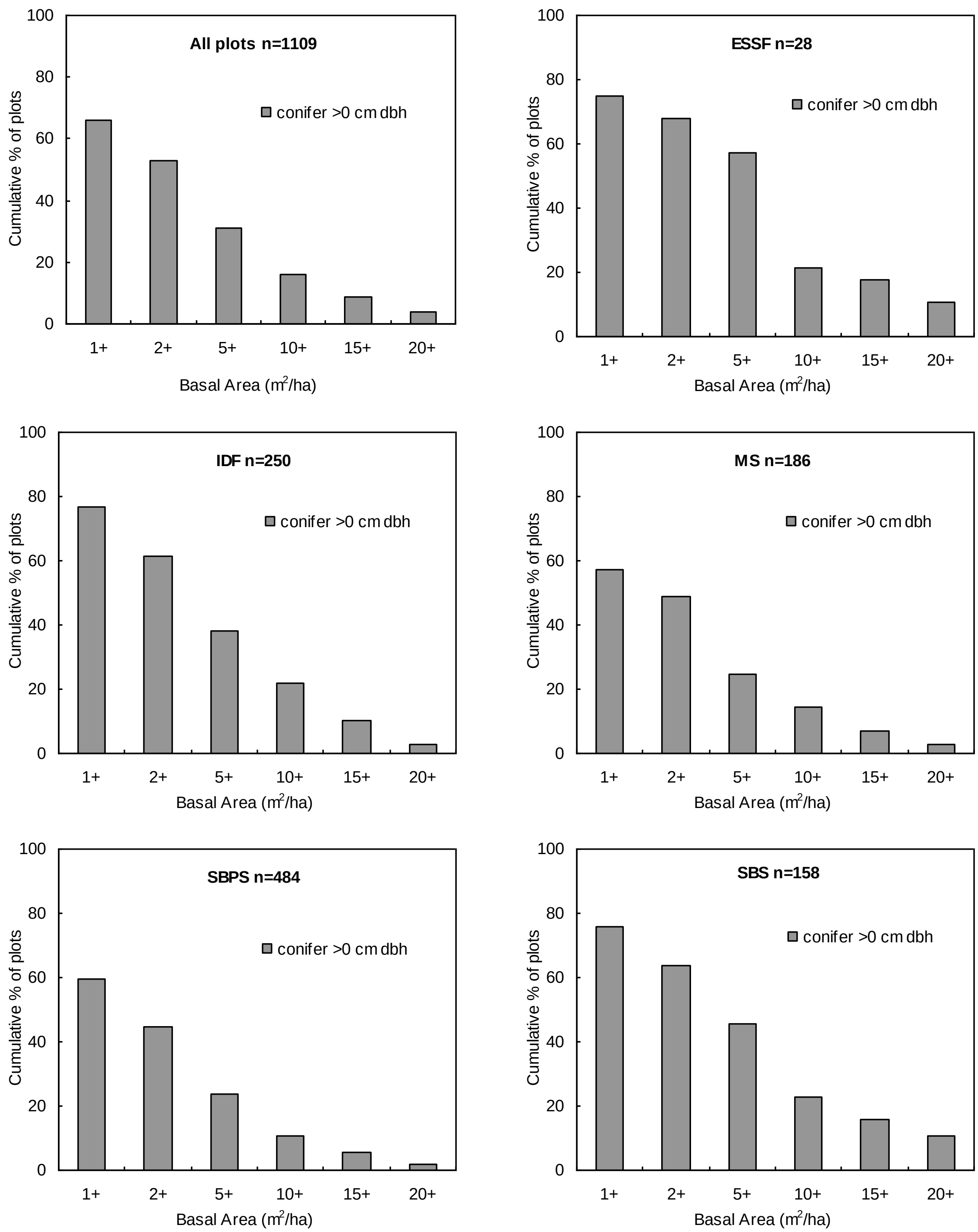

Figure 11. Cumulative percentage of plots in pine-leading stands above specified basal area thresholds by biogeoclimatic zone in the Cariboo-Chilcotin. Data are for conifer secondary structure with a DBH >0 cm. This includes Pl <7.5cm DBH and all other non-pine conifers >0 cm DBH and excludes all broadleaf species.

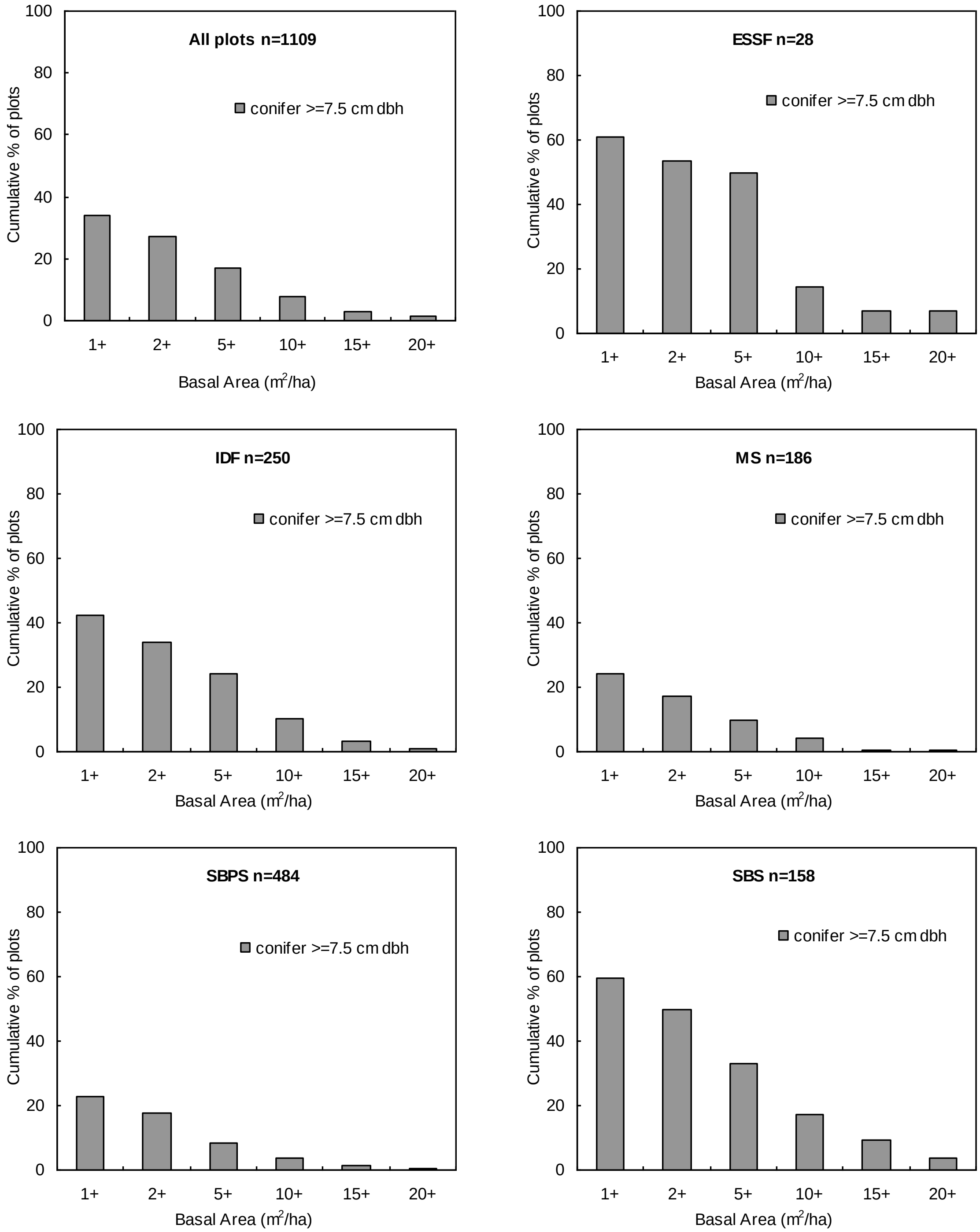

Figure 12. Cumulative percentage of plots in pine-leading stands above specified basal area thresholds by biogeoclimatic zone in the Cariboo-Chilcotin. Data are for conifer secondary structure with a DBH >=7.5cm. Data excludes all broadleaf species.

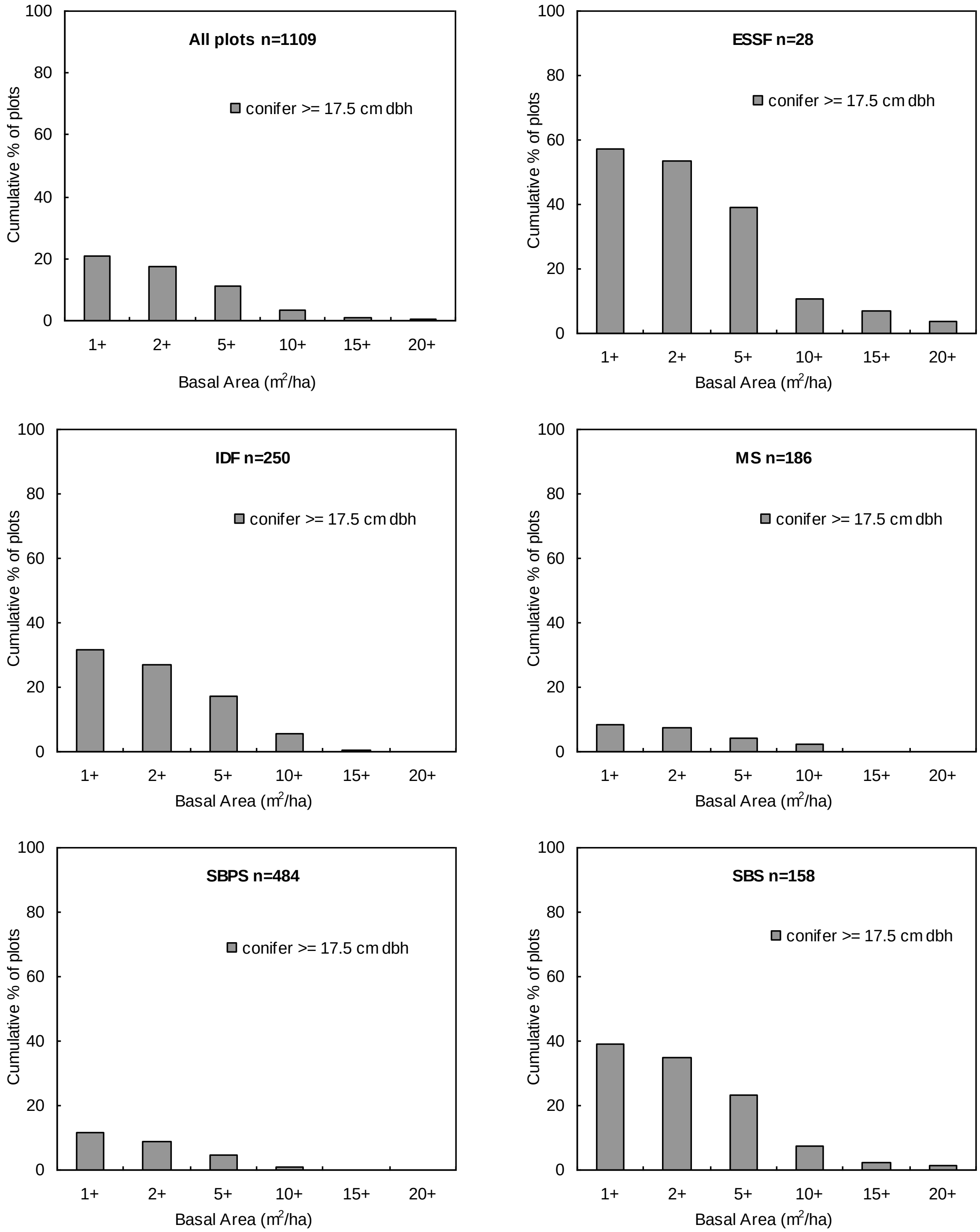

Figure 13. Cumulative percentage of plots in pine-leading stands above specified basal area thresholds by biogeoclimatic zone in the Cariboo-Chilcotin. Data are for conifer secondary structure with a DBH >=17.5cm. This data represents merchantable conifer secondary structure and excludes all broadleaf species.

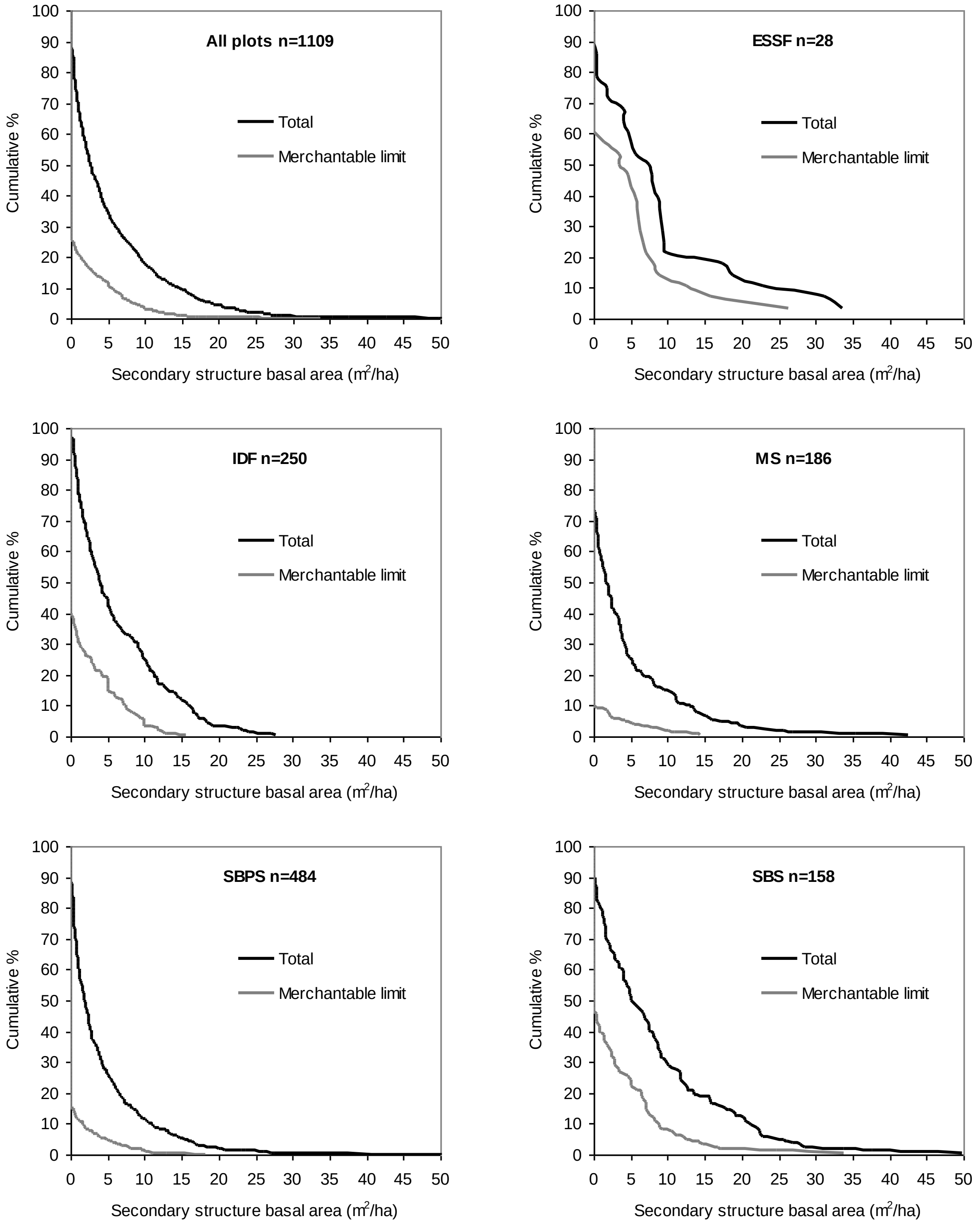

Figure 14. Cumulative frequency of basal area of secondary structure by biogeoclimatic zones. Total is all conifer and broadleaf secondary structure > 0 cm DBH; merchantable limit is conifers >=17.5 cm DBH (see Table 3 for details).

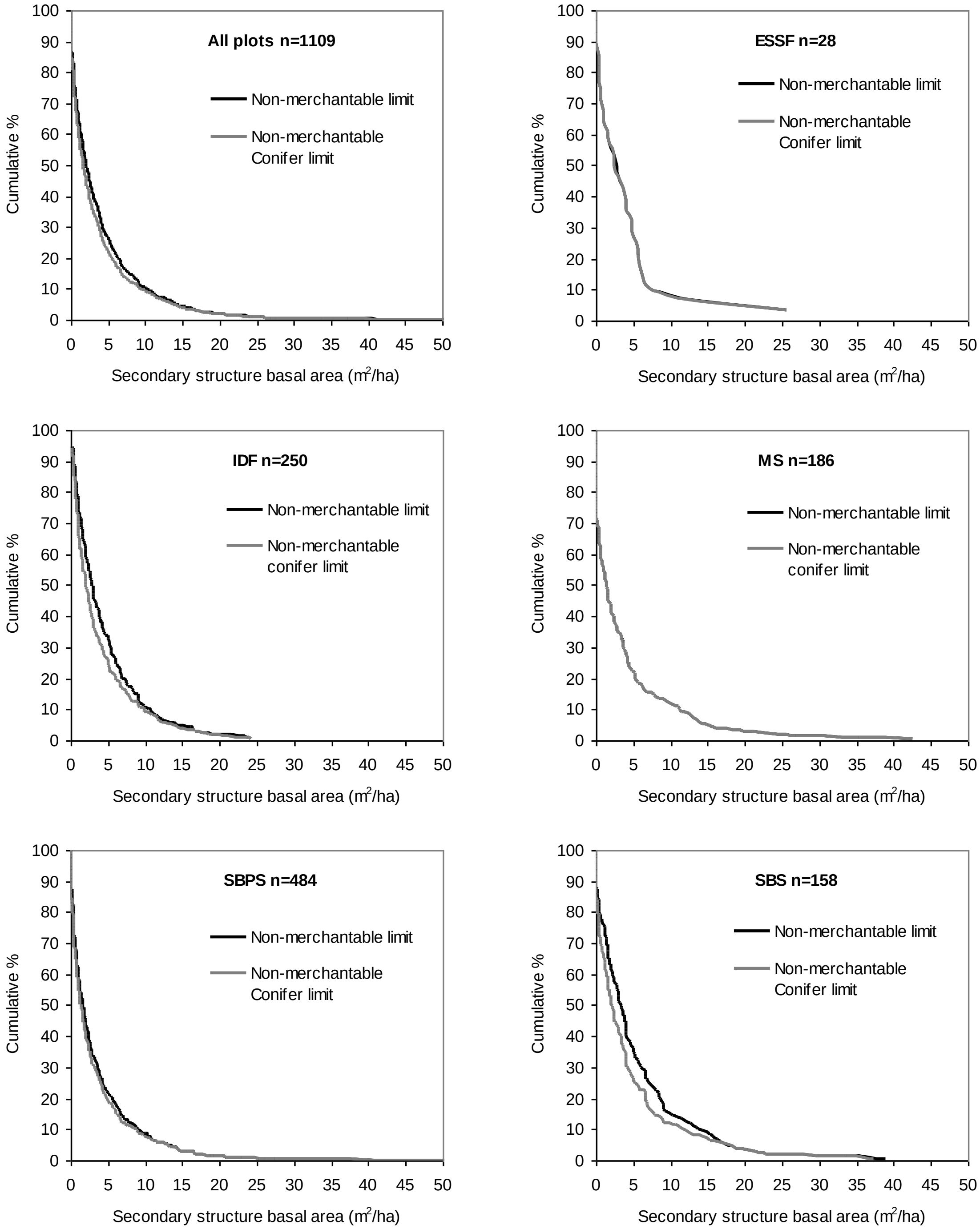

Figure 15. Cumulative frequency of basal area of secondary structure by biogeoclimatic zones. Non-merchantable secondary structure is Pl <7.5 cm DBH, other conifers <17.5 cm DBH and all broadleaf species.

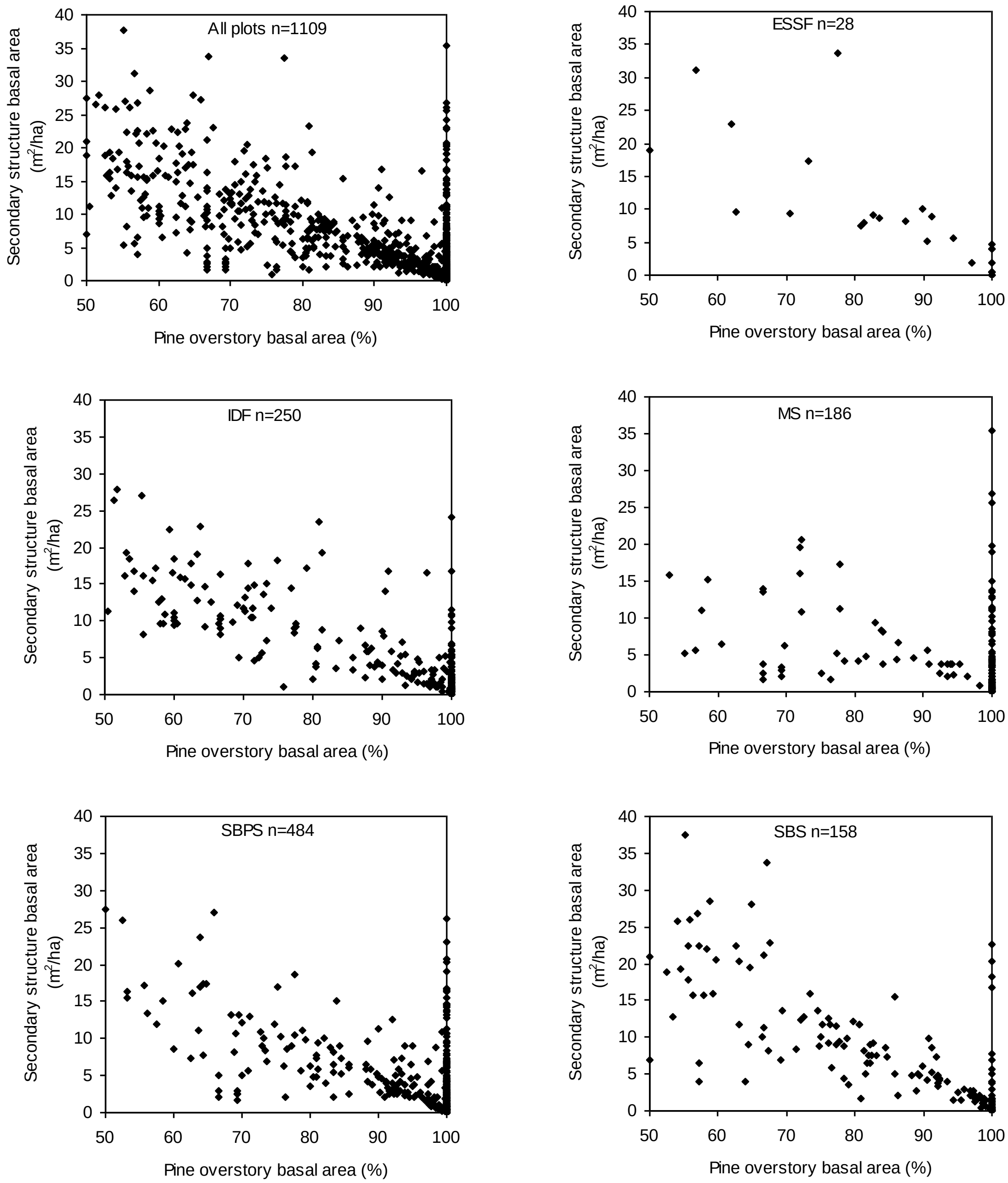

Figure 16. Basal area of secondary structure compared to the percentage of total overstory basal area (m^2/ha) occupied by pine for all plots in pine-leading stands in the Cariboo-Chilcotin. Total secondary structure is the sum of Pl <7.5cm DBH and all other conifers and broadleaf trees >0 cm DBH.

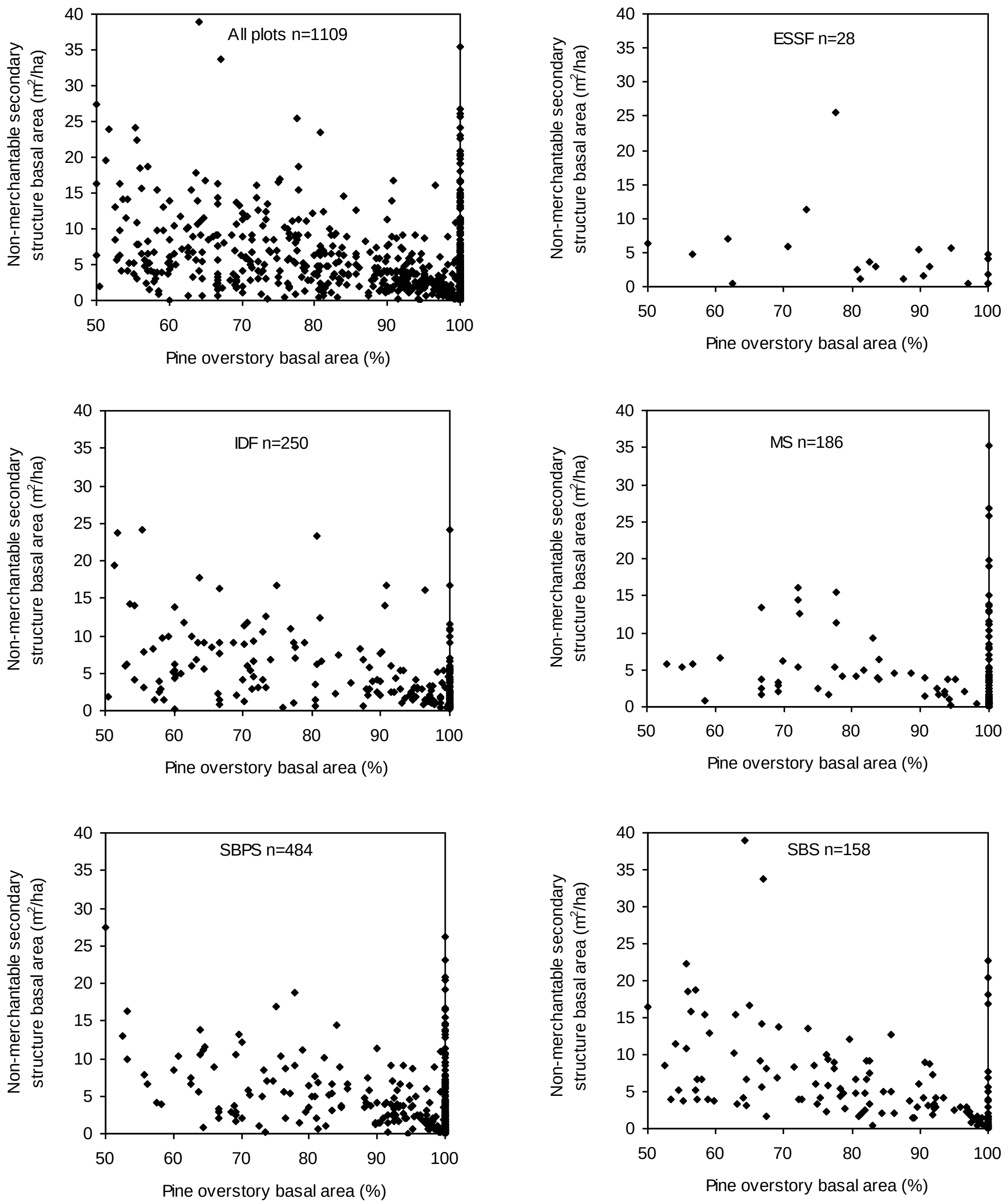

Figure 17. Basal area of non-merchantable secondary structure compared to the percentage of total overstorey basal area (m^2/ha) occupied by pine by zone. Non-merchantability limits are Pl <7.5cm DBH, other conifers <17.5cm DBH and all broadleaf >0 cm DBH.

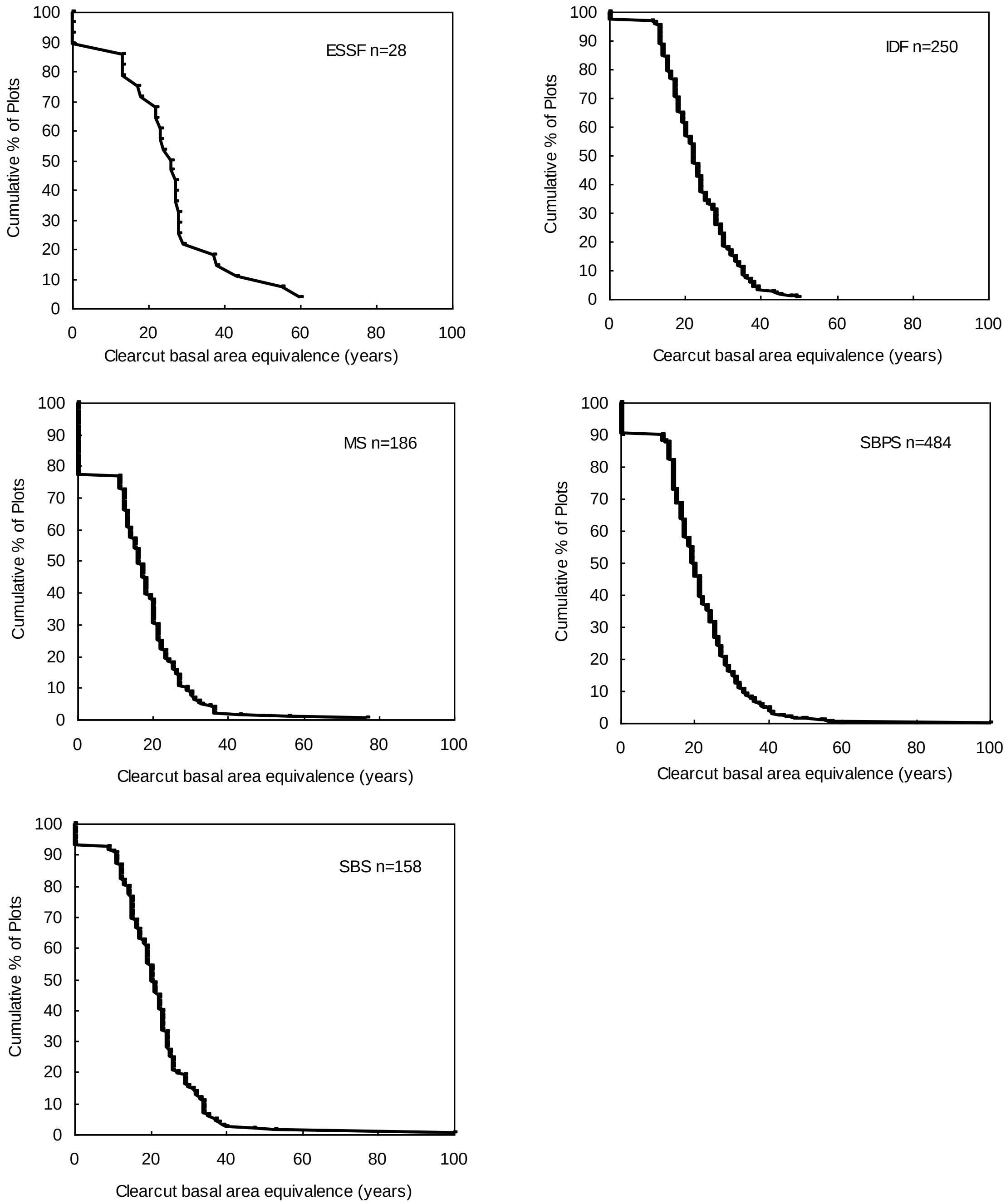

Figure 18. Cumulative percentage of plots in pine leading stands that have the equivalent basal area to a developing lodgepole pine clear-cut (1600 stems/ha) in biogeoclimatic zones in southern BC (see Table 6). The basal area of secondary structure in each plot was assigned the number of years it would take a pine clear-cut to reach that basal area (Table 7).

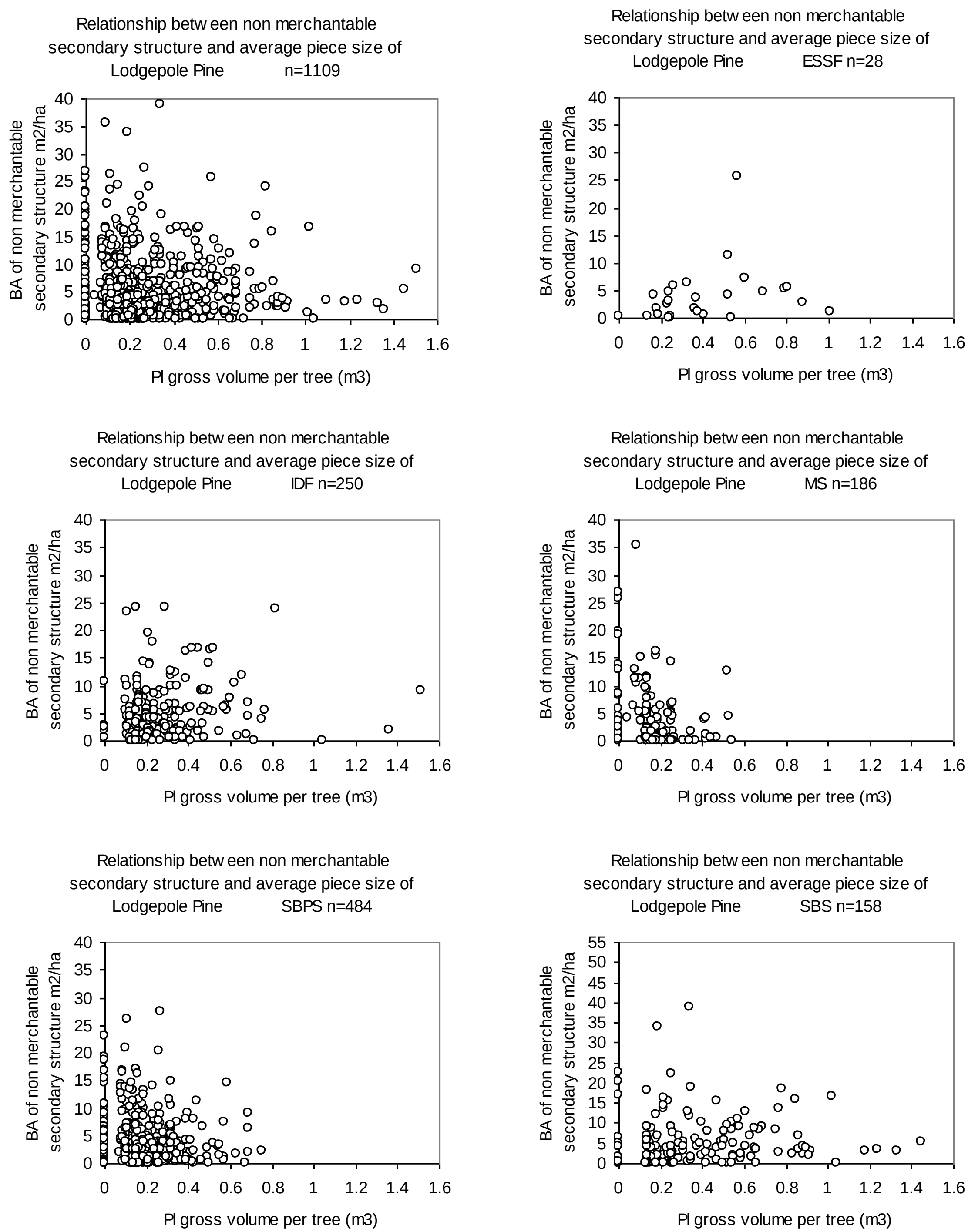

Figure 19. The relationship between the amount of non-merchantable secondary structure and average piece size of merchantable lodgepole pine. Average piece size was calculated by determining the average DBH for all live and dead pine trees >= 12.5 cm DBH in each of the plots (merchantable pine).Volume per tree was based on tree height to a 4 inch top (3m was deducted from the average height of the trees).