Two decades of long-term silvicultural systems research in wetbelt ICH and ESSF forests: What have we learned?

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What are the effects of different silvicultural systems and harvest patterns on present and future "old-growth" forest and wildlife habitat attributes in inland temperate rainforests and subalpine forests? Can structural and habitat attributes (e.g., arboreal lichens, coarse woody debris, wildlife trees) be maintained in managed or unmanaged stands, and how? What silvicultural systems can we use to allow for some timber extraction while still protecting habitat for threatened or endangered species such as mountain caribou? What are the effects of different silviculture systems and harvest patterns on the productivity of conifer regeneration and the residual stand, including species composition, vigour, growth and yield, and stocking (Jull et al. 2002)?

Finding answers to these and other questions is the primary focus of research being conducted in a network of long-term research study areas centred in the Northern Rockies and Cariboo Mountains east of Prince George, currently funded by FIA–FSP. These study areas were established to examine the ecological, silvicultural, and habitat effects of different silvicultural systems and post-harvest structure retention options in the wet Interior Cedar–Hemlock (ICH) and Engelmann Spruce–Subalpine Fir (ESSF) subzone forests. Sites include study areas at Lucille Mountain, Pinkerton Mountain, and Northern Wetbelt (East Twin, Minnow, Lunate), as well as the Fleet Creek group selection trial. Biogeoclimatic zone, trial establishment date, and harvest treatments applied at each of the study areas are shown in Table 1. All study areas include an uncut control treatment.

Hair lichen and caribou habitat

The many research studies that have been conducted on these trial areas have generated and continue to generate a wealth of information on impacts to arboreal lichens and mountain caribou habitat. They have been instrumental in the development of forest

TABLE 1. Wet-belt silviculture system trials establishment information

Study area	BEC zone	Year initiated	Silvicultural system treatment				
			Clearcut	Group retention	Group selection/ patch cut	Irregular shelterwood	Single tree selection
Lucille Mountain	ESSF	1991	Yes	0.01–0.1 ha	0.2 ha	Yes	Yes
Pinkerton Mountain	ESSF	1998	No	No	0.1–0.3 ha	No	Yes
Northern Wetbelt	ICH	2000–2001	Yes	30% post-harvest retention	70% post-harvest retention	No	No
Fleet Creek	ICH	1994	No	No	0.24 ha	No	No

management recommendations for mountain caribou. This red-listed species requires large areas of suitable habitat, described as having the characteristics of old forests (at least 150 years old), including abundant arboreal lichens (Stevenson et al. 2001).

Key management recommendations from Stevenson et al. (2001) included the use of single tree and group selection silvicultural systems as long as removals (by area, volume, or basal area) are ≤ 30% and entries are infrequent (e.g., once every 80 years). Group selection openings should vary in size (0.1–1.0 ha – mean of ≤ 0.5 ha) and shape to enhance the structural diversity of the stand. When managing stands with clumpy distributions, as often occurs in the ESSF, efforts should be made to maintain the structure by retaining or removing entire clumps.

Regeneration efforts should also focus on maintaining clumped rather than uniform distributions. This will require that traditional regeneration standards for these sites be lowered and spatial planting patterns be modified. Stevenson et al. (2001) also recommended that the species composition of the regenerating stand be as similar as possible to the harvested stand and that retention of undamaged advance regeneration and residual trees should occur where feasible.

Arboreal hair lichen species *Bryoria* spp. and *Alectoria sarmentosa* are a key winter food source for mountain caribou, and this series of research trials has also provided information on how these species respond to partial cutting. Ten-year results from the Pinkerton Mountain study site indicate that there has been no net loss in forage lichens at the tree level, although there has been a shift in genus composition toward more *Bryoria* spp. and less *Alectoria* (Stevenson and Coxson 2009). At the ***stand level***, however, lichen loading within the partially cut areas remains about one-third lower than that in the uncut control.

The researchers expect this shift in lichen genus to continue until such time as the regenerating trees are large enough to reduce the effects of solar and wind exposure on *Alectoria* lichen. They conclude that stand level lichen levels will remain lower than in the unharvested forest until the regenerating trees grow large enough to accumulate substantial biomass of lichens. These findings were corroborated in other research from the study areas in this trial as well as other trials in British Columbia and the United States (Stevenson and Coxson 2006).

Other lichen species

Research has also been conducted on the response of other species of lichen to partial and clearcut harvesting. *Lobaria pulmonaria*, a species of foliose cyanolichen, showed little difference in growth rates within an old-growth ICH forest at a distance of 7.5 m from clearcut edges (hard edges) compared to the same distance from partially harvested blocks (soft edges) (Coxson and Stevenson 2007). However, these researchers noted some differences in growth rates between large, established thalli of this lichen compared to that of small thalli immediately adjacent to hard edges.

In contrast, another foliose cyanolichen, *Lobaria retigera,* a sensitive old-growth forest indicator, exhibited high mortality rates and loss of biomass in forests adjacent to clearcut harvest blocks, whereas mortality rates and biomass loss were much lower in forests adjacent to partially harvested areas (Stevenson and Coxson 2008). The authors suggest that the impact of forest harvesting on canopy lichen biodiversity can potentially be reduced by using a partial-harvest system in which a substantial number of residual trees are retained along cutblock edges.

Coarse woody debris and wildlife trees

Other research at the ICH study sites looked at the effects of partial cutting on coarse woody debris and wildlife trees. Stevenson et al. (2006) found that although forest harvesting had little effect on the volume of coarse woody debris found on the site, it did affect the decay class distribution. Piece length and the proportion of pieces exhibiting structural habitat attributes were also reduced. They concluded that partial cutting may mitigate the anticipated deficits in large wildlife trees and logs in managed stands, but only if stands are managed on longer rotations than those planned for timber production alone.

Conifer regeneration, growth, vegetation succession, and windthrow

Other studies at these sites have looked at the response of conifer regeneration (natural and planted) to the partial-cutting treatments as well as the response of competing vegetation, and the incidence of windthrow. Eastham and Jull (1999) studied the factors affecting the natural regeneration of Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) at the Lucille Mountain study area and found that seed availability was the leading factor for seedling establishment in clearcuts.

In the partially harvested areas, seed availability and mineral soil exposure were key factors for spruce, and the presence of disturbed forest floor seedbeds was the key factor for subalpine fir.

In a follow-up study, Eastham and Jull (2003) found that 9-year seedling growth for natural regeneration of both species was significantly less in selectively harvested areas compared to the clearcuts and patch cuts. However, they also noted that although the growth was better in the clearcut and partial-cut treatments, growth rates were still low and, based on their projections, would not meet the minimum height requirements to achieve free-growing status within the required 20-year period for the clearcut treatment. They also noted that free-growing density targets within the clearcut treatment would not likely be achieved.

Eastham and Jull (2003) also measured the growth of the residual mature trees. Although they reported that increases in growth were being offset by losses to windthrow, they noted that it was too early in the rotation to predict if or how this would affect timber production. For the Northern Wetbelt study sites, Eastham and Jull (2008) found that natural regeneration was highly variable regardless of silvicultural system. It depended on seed production and dispersal, predation, suitable seedbed, and growing season weather. Further work is planned to determine survival rates for the newly established natural seedlings.

Scientists have also studied the effects of different silvicultural systems on planted seedlings. Lajzerowicz et al. (2006) reported on the survival and growth of planted seedlings after six growing seasons for the Lucille Mountain study area and two other silvicultural system trials in the southern interior of the province (Sicamous Creek and Quesnel Highlands). They found that seedling survival was good across all sites and was sufficient to meet free-growing requirements in all but the smallest openings. Growth rates were good in large openings but were reduced as opening size decreased and canopy retention increased. They concluded that the regeneration of clearcuts and group selection silvicultural systems with opening sizes greater than 0.1 ha by planting is likely to be successful whereas the conditions for survival and growth of planted seedlings are not provided by group selection systems with opening sizes less than 0.1 ha and individual tree selection systems.

At the Northern Wetbelt ICH study areas, sixth-year survival for planted hybrid spruce and western redcedar seedlings was found to be high for all silvicultural system treatments (Eastham and Jull 2008). Preliminary data analysis of seedling performance at the Lunate Creek site shows that the greatest seedling growth and vigour was found for planted spruce in the group retention treatment, followed by the clearcut treatment. Further data analysis for the other sites in this study is ongoing. At the Fleet Creek study site, fourth-year survival for planted western redcedar, hybrid spruce, and Douglas-fir seedlings was high. All species exhibited good growth rates on these sites, which allowed them to keep pace with the growth of the vigorous understorey vegetation (Jull et al. 1999).

Assessment of vegetation succession for the Lucille Mountain study area indicated that treatments exposing mineral soil resulted in the greatest change in vegetation. Within 8 years of harvest, shrubs and herbs were recovering toward the pre-disturbance condition for all silvicultural system treatments (Jull and Stevenson 2001). Changes in the species composition of the understorey vegetation were noted at the Fleet Creek site 4 years post-harvest, with a shift to more pioneer species for herbs and shrubs (Jull et al. 1999).

Loss of residual trees to windthrow was also monitored at these study areas. Windthrow damage for the Lucille Mountain site was reported by Jull and Stevenson (2001) and for the Fleet Creek site by Jull et al. (1999). The Lucille Mountain site has high topographic wind exposure and also experienced two major winter wind events 4 years after harvest. These two wind events, in which peak gusts ranged from 90 to 105 km/h, caused the majority of the damage that occurred at the site. Damage ranged from 6% in the group retention treatment to 14.7% along the south- and west-facing edges of the clearcut treatment. At the Fleet Creek site, wind damage along the edges of the group selection treatments was similar to that in the unharvested control area and was very light (0.33%). Monitoring of losses to wind is continuing at all of the study areas, including the two reported on here.

Ongoing and future research

Work is continuing at these study sites. Stand-, tree-, and site-level response variables, including vegetation, are being assessed in a network of permanent plots and coarse woody debris transects. These are being monitored on a ±5-year interval. This long-term monitoring focusses on changes in the following variables over time:

- growth and dynamics of regeneration and the residual stand (including mortality)

- recruitment and development of structural attributes in wildlife trees and coarse woody debris
- arboreal lichen abundance and species shifts
- changes in understorey vegetation composition and structure
- contributing processes, including windthrow and tree-falls, and biotic and abiotic damage agents

These sites are also being maintained as demonstration areas for foresters, decision makers, and the public, and have been included as stops on several recent field tours. They also provide further research opportunities for those interested in assessing the long-term ecological and silvicultural effects of different silvicultural systems in these wetbelt forest types.

A new research project has recently been initiated at the Northern Wetbelt study area to study carbon dynamics and forest floor carbon levels in the inland rainforest. This study will draw on the existing stand structure and climate data from these sites. It illustrates how baseline data from a replicated, multidisciplinary field project can be useful in ways that were not anticipated when the field project was started (S. Stevenson, pers. comm. April 2010).

An additional study site, Isaiah Creek, near Quesnel Lake, was established in 2006 to gain further operational experience with partial cutting in cedar-hemlock stands and to monitor the response of key environmental variables to partial cutting in a different biogeoclimatic variant. For more information on this trial and to view additional publications from the research studies conducted at these sites and others, visit: ***http://web.unbc.ca/~wetbelt/summaries-ssproject.htm*** and ***http://wetbelt.unbc.ca***.

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Citation –
Wiensczyk, A. 2011. *LINK News*: Two decades of long-term silvicultural systems research in wetbelt ICH and ESSF forests: What have we learned? *BC Journal of Ecosystems and Management* 11(3):xi–xv. ***http://jem.forrex.org/index.php/jem/article/view/84/48***