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# Long-term responses of ecosystem components to stand thinning in young lodgepole pine forest
# III. Growth of crop trees and coniferous stand structure

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**Abstract**

Enhanced growth of crop trees and development of late-seral structural characteristics in second-growth stands in temperate and boreal forest zones could be achieved by silvicultural practices such as pre-commercial thinning (PCT). This study was designed to test the hypotheses that large-scale stand thinning, at a 15-year period after PCT, would enhance: (i) productivity and structural features (crown volume, diameter, height, and volume growth of lodgepole pine (*Pinus contorta*) crop trees); and (ii) coniferous stand structure (abundance, species diversity, and structural diversity of coniferous tree layers). Replicate study areas were located near Penticton, Kamloops, and Prince George in south-central British Columbia, Canada. Each study area had three stands thinned to densities of ~500 stems/ha (low), ~1000 stems/ha (medium), and ~2000 stems/ha (high), with an unthinned young pine and old-growth pine stand for comparison.

An overall analysis of tree growth in thinned stands, across these regional replicates, indicated that lodgepole pine grew significantly faster in mean diameter in the low- than either of the medium- or high-density stands. There was no difference in mean height growth among stand densities over the 15-year period since PCT. Mean tree volume increment was significantly higher in the low-density than in the high-density stands. Mean stand volume increment ($m^3$/ha) was similar in the medium-density (108.53) and high-density (132.51) stands, both of which were significantly higher than the low-density stands (72.88). Mean crown volume of crop trees was significantly greater in the low-density (52.8 $m^3$) and medium-density (42.9 $m^3$) stands than in the high-density (27.8 $m^3$), unthinned (11.7 $m^3$), or old-growth stands (30.9 $m^3$ pine only). This measure of crown size was similar among pine trees in the low-density, medium-density, and all conifers (43.2 $m^3$) in the old-growth stands. Other measurements of crown architecture followed this same pattern. Mean densities of understory trees were similar among stands for height classes up to 3 m. Mean species diversity and structural diversity of coniferous tree layers were highest in the low- and medium-density stands than in other treatment stands. Our results support the hypotheses that PCT enhances productivity (diameter and volume growth, but not height growth) and structural features (crown architecture) of young lodgepole pine, as well as diversity of coniferous tree layers in thinned stands. Accelerated development of some structural features of late-seral forest appeared in our young managed stands.


*Keywords:* Crown architecture; Diameter and height growth; Lodgepole pine; Old-growth attributes; Pre-commercial thinning; Stand volume; Structural diversity

## 1. Introduction

A major objective of enlightened forest management in temperate and boreal ecological zones is acceleration of forest succession to develop late-seral structural characteristics in second-growth stands (McComb et al., 1993; Carey and Curtis, 1996; Hayes et al., 1997; Carey, 2000; Sullivan et al., 2001). Old-growth structural attributes include large dominant trees with substantial crowns, a diverse tree community with smaller shade-tolerant trees, multilayered canopies, snags, an abundance of coarse woody debris, canopy gaps, and understory patchiness with some herb and shrub development (Franklin et al., 1981; Franklin and Spies, 1991; Kneeshaw and Burton, 1998; Wells et al., 1998). This approach is designed to meet the biodiversity goals of a range of successional stages and wildlife diversities across forest landscapes dominated by young

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regenerating stands that have developed after clearcut harvesting and wildfire. Such stands are structurally simple, usually with a single canopy layer, few tree species, sparse understory vegetation, and a variable abundance of standing or fallen dead trees (Carey and Johnson, 1995; Hayes et al., 1997).

As discussed by Koch (1996a) and Sullivan et al. (2001), early seral (1–30 years old) lodgepole pine (*Pinus contorta*) is the dominant coniferous tree species ranging across a vast area (several million hectares) of the inland Pacific Northwest of North America. Lodgepole pine has perhaps the greatest potential to respond to various silvicultural practices designed to diversify structural heterogeneity and growth rates of crop trees within stands (Johnstone, 1985; McComb et al., 1993; Koch, 1996b; Hayes et al., 1997; Cochran and Dahms, 1998). Innovative silvicultural strategies in lodgepole pine and other coniferous tree species include conventional pre-commercial thinning (PCT), sometimes over a range of stand densities (Schmidt and Seidel, 1988; Sullivan et al., 2001; Homyack et al., 2004) and variable-density thinning (Carey and Johnson, 1995; Carey et al., 1999; Sullivan et al., 2002). The goal of these silvicultural interventions in young stands is the development of biocomplexity and late-seral structural features over relatively short time periods (Carey and Wilson, 2001). A critical caveat of this approach is that the affinity of those wildlife species occurring in late-seral forests is more likely attributable to structural (ecological) characteristics than to age of the forest (Thomas et al., 1990; Hayes et al., 1997).

The influence of PCT on the development of habitat attributes such as understory composition, abundance, and structural diversity has tended to dominate in much of the forest-wildlife and biodiversity literature. However, it is the responses of crop trees to PCT, in terms of diameter and height growth, as well as crown architecture that are driving these habitat attributes. PCT increases stem diameters (Harrington and Reukema, 1983; Cochran and Barrett, 1993; Cochran and Dahms, 1998; Brissette et al., 1999; Ffolliott et al., 2000; Sullivan et al., 2001; Pothier, 2002; Homyack et al., 2004). PCT alone, or in combination with vegetation management treatments, increases crown volume or size (McCormack and Lemin, 1998; Schmidt and Seidel, 1988; Brissette et al., 1999; Lindgren and Sullivan, 2001; Sullivan et al., 2001; Homyack et al., 2004). Crowns are the production factory of a tree, and hence they reflect the degree of vigor and growth (Schmidt and Seidel, 1988). The structural attributes of crown architecture have considerable relevance to the nesting, foraging, and cover (both hiding and thermal) requirements of a wide variety of wildlife species (Hayes et al., 1997; Spies, 1998; Suzuki and Hayes, 2003).

A range of thinning densities or regimes is conducive to producing a range of wood products (Koch, 1996b; Barbour et al., 1997; Lippke and Fretwell, 1997; Sullivan et al., 2001). Appropriately managed coniferous stands, particularly lodgepole pine and Douglas-fir (*Pseudotsuga menziesii*), could be managed for both structural diversity and a range of wood products. For example, heavily thinned stands may have reduced total wood volume, but can produce large-diameter timber and quality products (Jozsa and Middleton, 1994; Barbour et al., 1997). Higher density stands will produce much wood volume for the construction lumber market (Jozsa and Middleton, 1994).

A major question is: at what point in time, or successional development, do younger managed stands provide sufficient ‘‘structural complexity’’ and the consequent ecological functions of late-seral forests? Few, if any, studies have investigated the growth responses of crop trees and coniferous stand structure to PCT in young lodgepole pine forests at a spatial scale relevant to wildlife and over a relatively long-term (15 years since treatment) temporal scale. Thus, this study was designed to test the hypotheses that large-scale stand thinning to a wide range of densities, at a 15-year period after PCT, would enhance: (i) productivity and structural features (crown volume and dimensions, diameter, and height growth of crop trees (those dominant trees destined for harvest)); and (ii) coniferous stand structure (abundance, species diversity, and structural diversity of coniferous tree layers). This paper is one of several periodic publications reporting on long-term responses of understory vegetation (Lindgren et al., 2006), northern flying squirrels (*Glaucomys sabrinus*) and red squirrels (*Tamiasciurus hudsonicus*) (Ransome et al., 2004), forest floor small mammals (Sullivan et al., 2005), and large mammalian herbivores (Sullivan et al., 2006) to these treatments.

## 2. Materials and methods

### 2.1. Study areas

There were five lodgepole pine stands located at each of three replicate study areas in south-central British Columbia, Canada: Penticton Creek, Kamloops, and Prince George. These areas were selected on the basis of having several thousand hectares of young lodgepole pine forest. Stands within these tracts of young forest had relatively uniform tree cover and comparable diameter, height, and density of lodgepole pine trees prior to PCT. Each replicate had four second-growth lodgepole pine stands (age range of 17–27 years); three of which were PCT to low (~500 stems/ha), medium (~1000 stems/ha) or high (~2000 stems/ha) density. The fourth stand was left unthinned. The second-growth stands had very few remnant trees and snags remaining from previous stands. There was also an old-growth lodgepole pine stand (age range 160–250 years) as part of the set of treatment stands at each study area.

The Penticton Creek study area was located 15 km northeast of Penticton (49°34′N; 119°27′W). All stands were located in the Interior Douglas-fir ($IDF_{dk}$) biogeoclimatic zone (Meidinger and Pojar, 1991). Elevation of stands ranged from 1340 to 1500 m. Topography in the area is hilly with sandy loam soil, southeast aspect, and an average slope of 10%. This area (several thousand ha) was burned by wildfire in 1970, salvage logged in 1971, and planted with lodgepole pine in 1972. Density of pine from natural regeneration ranged from 18,500 to 30,000 stems/ha. Dominant coniferous species in these stands included lodgepole pine with a minor component of Douglas-fir, Engelmann spruce (*Picea engelmannii*), and