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Ten-year regeneration responses to varying levels of overstory retention in two productive southern British Columbia ecosystems

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ABSTRACT

We investigated survival and growth responses of planted and advance natural regeneration species of varying shade tolerance to partial retention harvesting in moist warm Interior Cedar-Hemlock (ICHmw2) and dry cool Montane Spruce (MSdk) ecosystems of southeastern British Columbia, Canada. Treatments included three levels of overstory basal area retention (none, light (~25%), or heavy (~50%)) installed by two harvest methods (handfelled or a pushover falling technique being tested for its ability to control the spread of root disease). After 10 years, growth of both planted and natural regeneration species of varying shade tolerance tended to increase with decreasing overstory retention and associated increases in light availability. In contrast, significant survival responses to retention level were lacking except in the case of shade-intolerant western larch. Harvest method had a variable effect on regeneration survival and growth. Where significant responses did occur, they were generally attributed to harvesting effects on the characteristics of planting microsites rather than root disease spread. Natural regeneration densities at the ICHmw2 site were high at all retention levels, whereas stocking was less consistent at the MSdk site. We concluded that moderately shade-tolerant to shade-tolerant interior spruce and western redcedar can, under conditions similar to those of our study sites, be successfully established under overstories of up to approximately 25 m^2/ha basal area, but that growth performance is likely to be significantly lower than in clearcuts. Despite early survival issues, conclusions regarding Douglas-fir were similar. Poorer survival and vigour of shade-intolerant western larch suggested this species is not suitable for regeneration in partial retention systems where timber production is the primary objective. Where non-timber objectives predominate, survival and acceptable growth of even a small proportion of larch could add to the diversity of the regenerating stand.

1. Introduction

Alternatives to traditional clearcut harvesting are of global interest (Pommerening, 2006) due to a recognized need to manage forests for objectives beyond timber production. The current forest management paradigm is also shifting towards approaches that approximate natural processes (Seymour and Hunter, 1999; Haeussler and Kneeshaw, 2003). The mixed forest types that occur in temperate southern regions of British Columbia, Canada are of particular interest because, in addition to being highly diverse and productive, they typically occur in valley bottom to mid-elevation locations where the majority of human settlement and activity are found. As a result, visual quality (e.g., Yelle et al., 2008), recreational values, and maintaining a positive public image are high priority management objectives for these forests.

Productive ecosystems such as the Interior Cedar-Hemlock (ICH) and Montane Spruce (MS) biogeoclimatic zones (Meidinger and Pojar, 1991) that occur in southern and west-central British Columbia are often characterized by variable disturbance patterns (Vyse and DeLong, 1994). The resulting forests are diverse mixtures of shade-tolerant and -intolerant tree species with complex stand structure, where up to 10 coniferous and broadleaf species can be present on a single site (Meidinger and Pojar, 1991). Such characteristics make these ecosystems suitable, but highly complex, candidates for alternative management approaches such as

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partial retention or shelterwood silvicultural systems (e.g., Smith et al., 1997).

In order to successfully apply continuous cover silvicultural systems, a new suite of management and operational expertise is required across the full range of harvesting and silvicultural activities (Pommerening, 2006). The majority of current guidelines for forest management in British Columbia were developed for clearcut harvesting, and at present, less research is available for alternative systems. Classical approaches to continuous cover forestry feature natural rather than planted regeneration (e.g., Smith et al., 1997), but practical, ecosystem-specific information is required to compare the performance and reliability of these methods. In British Columbia, the need for information to guide regeneration practices under partial canopies has been further amplified by the diverse stand conditions created by the recent mountain pine beetle (*Dendroctonus ponderosae*) epidemic and salvage harvesting (e.g., Hawkes et al., 2004). There is also a limited amount of information relating to the establishment and performance of natural regeneration in partial retention systems or in small clearcuts. In the ICH and MS zones, root disease management (Morrison et al., 1991) adds a further level of complexity to the consideration of continuous cover systems.

Natural forest regeneration occurs through the release of existing advance stems following canopy removal and the recruitment of new seedlings. The presence of understory vegetation may limit ingress of new conifers through competitive exclusion (Wohlgemuth et al., 2002), and ingress will also vary according to the type of substrate and the degree of disturbance that has resulted from harvesting (Wright et al., 1998a; LePage et al., 2000; Heineman et al., 2002). Disturbance can be considerable where harvesting or site preparation techniques include root removal to control infection by root diseases (Sturrock et al., 1994). Shade-tolerance varies somewhat according to environment (Carter and Klinka, 1992), but in general, advance species that are common in southern interior forests range from shade-tolerant to moderately shade-intolerant (Klinka et al., 2000) and include Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), interior spruce (*Picea engelmannii* Parry *x glauca* [Moench] Voss), western redcedar (*Thuja plicata* Donn ex D. Don), subalpine-fir (*Abies lasiocarpa* (Hook.) Nutt.) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.).

Regardless of shade tolerance and origin, light availability is a primary determinant of early tree growth (Wright et al., 1998b), and relationships between regenerating conifers and light transmittance have been characterized for a range of ecosystems (Chen, 1997; Kobe and Coates, 1997; Wright et al., 1998a). Reponses of advance conifer regeneration following canopy removal may differ from those of planted or seed origin stock that becomes established after disturbance (Claveau et al., 2006); moreover, responses are likely to depend on crown characteristics (Chen et al., 1996; Williams et al., 1999) and health at the time of release (Ruel et al., 2000). Where systems that retain the overstory are used, competition by retained trees for below-ground resources may also be a significant factor (Strand et al., 2006).

In 1995 and 1996, experiments were established at the Mount Seven (lower elevation MS zone) and Ice Road (ICH zone) sites in southeastern British Columbia to examine the suitability of a shelterwood silvicultural system, in combination with both traditional harvesting and a pushover harvest technique applied to control the spread of root disease (Sturrock et al., 1994). Over time, as the benefits of examining ongoing retention became apparent, a decision was made not to harvest the retained overstory trees (as would occur in a shelterwood system), and to consider these to be partial retention experiments. Light retention, heavy retention, or complete overstory removal were achieved using traditional hand-felling or pushover harvesting techniques. Responses of planted and advance natural regeneration of varying shade tolerance were examined. Natural conifer and broadleaf tree regeneration densities were also quantified because of their potential to contribute to overall stocking and affect the need for silvicultural treatments such as brushing or juvenile spacing. Detailed examination of root disease responses to harvest method and retention level are being examined in a related study and are not reported here. Our objective was to describe the responses of regeneration species of varying shade tolerance to three overstory retention levels and two harvest methods, and to interpret them in terms of overstory basal area, understory light and vegetation characteristics, and previously reported soil characteristics (Quesnel and Curran, 2000). Specifically, we intended to (1) quantify 10-year survival, growth, and vigour responses of (i) planted Douglas-fir, western larch (*Larix occidentalis* Nutt.), and interior spruce (MSdk site) or western redcedar (ICHmw2 site) and (ii) advance natural Douglas-fir, interior spruce, and subalpine-fir (MSdk site) or western redcedar and western hemlock (ICHmw2 site), and (2) quantify the density of natural conifer and broadleaf regeneration that was present at each site after 10 years.

Table 1
Site, stand, and harvest treatment characteristics at the study sites.

	MSdk site	ICHmw2 site
Location and site factors		
Latitude/longitude	51°17′N/116°56′W	49°58′N/118°43′W
Elevation (m)	1100–1300	840–980
Slope (%)	15–45	25–40
Aspect	N to NW	N
Soil moisture regime	Submesic	Mesic to subhygric
Soils nutrient regime	Medium	Medium
Humus form	Mor	Mor
Soil order/texture	Brunisol/SiL to L	Brunisol/SiL to fine SL
Parent material	Calcareous	Non-calcareous
Regional climate[a]		
Annual precipitation (mm)	590	840
Annual # frost-free days	68	149
Basal area by harvest and retention treatments (m^2/ha)[b]		
Pre-harvest	53.5 ± 2.9	46.7 ± 1.7
Post-harvest by harvest method		
HF	14.8 ± 2.4	12.4 ± 1.4
PO	11.5 ± 2.4	11.8 ± 1.4
Post-harvest by retention level		
NR	0.0 ± 2.9	0.0 ± 1.7
LR	14.1 ± 2.9	12.8 ± 1.7
HR	24.6 ± 2.9	23.6 ± 1.7

[a] Based on Braumandl and Curran (1992).
[b] 'Post harvest' basal area values are based on data collected for trees (DBH ≥ 4 cm) immediately following harvest (1995 at the MSdk site and 1996 at the ICHmw2 site). 'Pre-harvest' values are based on data collected in the same years from adjacent unharvested treatment units (see Section 2).

2. Methods

2.1. Site descriptions

The first site is located in the Dry Cool Montane Spruce biogeoclimatic subzone[1] (Braumandl and Curran, 1992), and is hereafter called the MSdk site. It is on the slopes of Mount Seven, 4 km east of Golden, BC (Table 1). Prior to harvesting, the 120-year-old even-aged stand was dominated by Douglas-fir, with smaller amounts of interior spruce and lodgepole pine (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.). Tomentosus root disease (*Inonotus tomentosus* (Fr.:Fr.) S. Teng.) was present throughout the

[1] At the time the study was established (DeLong et al., 2005), the Mount Seven study area was considered to be transitional between the Kootenay Moist Cool ICH biogeoclimatic variant (ICHmk1) and the Dry Cool Montane Spruce subzone (MSdk) (Braumandl and Curran, 1992). Following refinement of biogeoclimatic mapping boundaries, it is now well within the MSdk.