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Long-term recovery of forest structure and composition after harvesting in the coastal temperate rainforests of northern British Columbia

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ABSTRACT

We examined young harvested (41–100) and naturally disturbed mature (101–250), and old (>250) temperate rainforests on the central and north coast of British Columbia to quantify the recovery rates of tree size, density, and species composition of young harvested stands towards old-growth condition. Significant variations in recovery rates were noted due to differences in site productivity. Nonmetric multidimensional scaling (NMS) ordinations, Multi-response Permutation Procedure (MRPP) summary statistics, and Sorensen's similarity coefficients (SC) all indicate moderate levels of similarity between young and old stands. Rich sites show greater similarity between young and old forests (SC = 55%) than do medium sites (SC = 41%), indicating more rapid recovery. Differences in tree species composition, especially for western redcedar, were apparent among young and older forests on all sites. We believe that proactive management is required to ensure that western redcedar, an ecologically, culturally, and economically valuable tree species, is maintained as a significant component in the managed second-growth forests of central and north coast British Columbia. Our results indicate that second-growth forests, while not as structurally developed as old-growth, are developing some ecologically important structural characteristics at relatively young ages (80–100 years) and as such, contribute towards ecological integrity and biodiversity of the coastal temperate rainforest landscape.

1. Introduction

Old-growth forests have long been recognized as biologically diverse ecosystems, typically supporting a wide variety of habitats for plant and animal species (Marcot, 1997) and it is the structural and compositional characteristics that provide the foundation for the unique functional attributes of these forests (Franklin and Spies, 1991; Spies, 2004; Bunnell and Dunsworth, 2009). Although there are many different definitions of old-growth around the world, on the west coast of North America, these forests are often described as being centuries old, relatively undisturbed by humans, and containing large numbers of massive trees, dead and down tree boles, and numerous openings supporting a variety of understory plants and tree saplings (Hunter and White, 1997; Spies, 2004). For the purposes of this paper, we have classified coastal forests as old-growth if the main canopy trees are >250 years of age. These forests are considered by many to be critically important to the sustained functioning of numerous ecological processes (Hunter, 1990; Bunnell et al., 1999).

Around the turn of the last century, these old forests were extensive along the west coast of North America, from southern California through British Columbia (BC) and up to Alaska. As industrial activity expanded in the early 1900s, these forests were considered to be almost limitless and were targeted for harvesting to supply ever increasing demands for building materials and other wood and paper products. As industrial forest harvesting increased and became more efficient, larger areas of old-growth forests were impacted more rapidly and operations moved northward to more remote areas along the central and north coast of BC.

With the resulting gradual but steady decline of old-growth timber, public interest in protecting and preserving what remained began to increase (e.g. Hayter, 2003). During the latter part of the 20th century, the general public perception about forests evolved to recognize that, in addition to economic benefits, forests also provide a wide range of ecological and social services. Since that time, many scientific studies have been undertaken in order to better understand the myriad of attributes and functions of old-growth forests (Puettmann et al., 2008). While there have been extensive studies of the coastal old-growth Douglas-fir (*Pseudotsuga menziesii*) forests of the U.S. Pacific Northwest over the last few decades (e.g., Stewart, 1986; Franklin and Spies, 1991; Acker et al., 1998; Van Pelt and Nadkarni, 2004; Harrington and O'Callaghan, 2012)

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and southwestern BC (e.g., Arsenault and Bradfield, 1995; Wells, 1996; Gerzon et al., 2011), the forests of central and northern coastal BC have received far less attention (Banner and LePage, 2008).

Since the late 1990s there has been a focus on protected area establishment and old-growth representation as fundamental aspects of the ecosystem-based management initiative within the temperate rainforests of coastal BC (Price et al., 2009). While these are important conservation initiatives currently underway, it is also critical that we understand and quantify the contribution that the younger regenerating natural and managed forests make towards overall ecological integrity and biodiversity. This is particularly relevant where old-growth representation targets cannot be met, due to inventory deficits or other social or economic pressures, and there is greater reliance on maturing second-growth to help meet conservation targets (Holt and Sutherland, 2003; Coast Information Team, 2004). The second-growth forests now occupying a significant proportion of the coastal landscape will certainly develop old-growth structural characteristics and species composition given sufficient time (over centuries); however, the degree of recovery possible within management rotations of 80–100 years remains in question.

The recovery of a disturbed forest can be analyzed using a variety of ecosystem attributes including, but not limited to: terrestrial vegetation communities, bryophyte and lichen assemblages, forest growth and productivity, soil properties (including faunal communities), and tree structure and species composition. Our previous paper (Banner and LePage, 2008) presented results on the recovery of forest vegetation communities following logging disturbances over the last 100 years. This study is the first to analyze the structural development and tree species composition in second-growth forests, originating from timber harvesting, on the central and north coast of BC. To accomplish this, we compare second-growth forest tree size, species composition, and density data to analogous data from mature (101–250 years old) and old-growth forests (>250 years old). The intent of this study is to quantify the degree of forest canopy structural (size and density) and compositional recovery towards old-growth condition within second-growth temperate rainforest ecosystems that have developed after logging disturbance. While ecologists emphatically agree that coastal temperate rainforests that have developed over many centuries cannot fully "recover" from harvesting over a typical management rotation, our intent is to more accurately describe the contribution of recovering second growth structure and composition to the ecological integrity and biodiversity of our managed coastal forest landscape.

2. Methods

2.1. Study area

The geographic scope of this study encompasses the coastal temperate rainforests of central and north coastal BC (51°–55°N). Using the biogeoclimatic ecosystem classification system (Meidinger and Pojar, 1991), this study focuses on the forests of the Coastal Western Hemlock zone, Very Wet Hypermaritime subzone, Central variant (CWHvh2) as described by Banner et al. (1993). This variant includes all coastal islands and a mainland fringe along the central and north coast of BC between northern Vancouver Island and Southeast Alaska (Fig. 1). Specifically, the study examines the medium and rich productivity stands (500–1350 $m^3\ ha^{-1}$) where timber harvesting has been concentrated since the early 1900s. These stands occur mainly on moderate to steep, freely drained colluvial slopes and old-growth forests are typically mixtures of western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), Sitka spruce (*Picea sitchensis*), and amabilis fir (*Abies amabilis*). Depending on the site series (a reflection of moisture and nutrient status and productivity), stand age, and disturbance history, minor amounts of yellow cedar (*Chamaecyparis nootkatensis*) and red alder (*Alnus rubra*) can also be present. The climate of the outer central and north coast of BC is oceanic, characterized by mild temperatures and high to very high annual precipitation (2100–3186 mm). As a result, stand-replacing wild-fires are very rare so natural disturbances are typically smaller in scale and dominated by landslides and windthrow events. Further details on the climate, vegetation, and soils of the study area are provided in Banner and LePage (2008) and Banner et al. (1993).

2.2. Field data collection

Data from "young forests" (41–100 years) were collected between Prince Rupert and Bella Bella (Fig. 1) from stands resulting from forest harvesting over the past century (24 plots). The stands were typically less than 20 ha in size and contained less than 25 stems/ha of dominant residual trees (trees remaining after harvest). At each potential sample location, four of the largest diameter, non-residual, dominant trees were cored at breast height (1.3 m; DBH) and the rings counted in the field using a 20X magnifying lens. Years to breast height corrections for total tree age were made using stem analysis data from similar forests (Banner et al., 2005) and the oldest total age was used as the approximate stand age (time since stand establishment). Field counts of tree age were verified in the lab using a high-powered dissecting microscope.

Prior to final plot establishment, each location was assessed to ensure the sites series was uniform throughout the plot area and there were no recent (post logging) natural or human-caused openings or disturbances (i.e. windthrow patches, landslides, roads, or recent logging) within fifty meters, that might impact stand development. At each suitable sample location, two independent variable radius plots were established 15–20 m apart. Using standard British Columbia variable plot sampling procedures (British Columbia Ministry of Forests and Range, 2006), a basal area factor (BAF) was selected to ensure that a minimum of seven and no more than fifteen trees $\geqslant$12.5 cm DBH were included (average of ten trees per plot). Total height was measured to the nearest 0.1 m using a Vertex Laser Hypsometer and DBH was measured to the nearest 0.1 cm for each tree in the plot.

In order to compare the forest structure of second-growth stands with older forests, we utilized mensuration data collected from the same geographic area during the British Columbia Biogeoclimatic Ecosystem Classification Program (2012). These data were separated into two age groups: "mature forests"; 101–250 years old (34 plots) and "old forests"; >250 years old (29 plots). Stands in these age categories originated from natural disturbances such as landslides, windthrow and possibly fire. For stands less than 250 years old, stand age was considered equal to the age of the oldest dominant (non-residual) tree. Rotten tree cores typically prevented an accurate determination of total tree age in old-growth stands and therefore all stands with tree ring counts >250 in the solid portion of the core were assigned an age of 250 years. To account for the potential effect of site productivity on structural development, we further separated the stands into 2 groups: submesic, nutrient medium (CWHvh2/04 site series); and submesic – subhygric, nutrient rich (CWHvh2/05, /06, and /07 site series). This classification of site series is based primarily on soil moisture and nutrient status as reflected by distinct vegetation communities (Banner et al., 1993; Kranabetter et al., 2003). For the purposes of this paper, these forest site series will be referred to as "medium" and "rich" forests, respectively.

2.3. Data analysis

We used non-metric multidimensional scaling (NMS) ordination to examine the tree species mensuration data for compositional and