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Management and productivity of cedar-hemlock-salal scrub forests on the north coast of British Columbia

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ABSTRACT

The outer north coast of British Columbia has extensive areas (approx. 235,000 ha) of old-growth forests characterized by western redcedar (*Thuja plicata*), yellow-cedar (*Chamaecyparis nootkatensis*) and salal (*Gaultheria shallon*) on gentle to moderate slopes with imperfectly-drained soils and deep forest floor accumulations. Uncertainty surrounding the long-term sustained yield of these low productivity forests led to the establishment of an operational trial in 2001 on Porcher Island, British Columbia, to address management issues, including the risk of paludification with tree removal, the uncertainty in site potential estimates, and the possible extent of nutrient deficiency amelioration with soil raking, mounding or phosphorus fertilization. Each site treatment was randomly replicated four times in an 18 ha cutblock. In the second year following logging, the aerobic depth of the soil (as determined by the extent of rust on steel pins) averaged 16.9 cm and did not differ between unharvested and harvested plots, suggesting losses in canopy interception and evapotranspiration did not alter the site hydrological balance. Western redcedar survival was 95% with planting and browse protection, and site index estimates of the plantation by age 12 averaged 19.5 m at 50 years (range 7.6–25.9), in stark contrast to measurements of 3.9 m obtained from old-growth stands. Cedar foliar N concentrations increased significantly (range 0.9–1.3%) with the mineral content of soil mounds, demonstrating the benefit of mixing subsoils into the rooting zone, but the wide range in forest floor depths resulted in mounds being overall no more effective than light raking of the forest floor in improving productivity. Phosphorus fertilization (75 kg ha^{-1}) also provided no gains in soil fertility or cedar nutrition, and initial increases in inorganic P were not detected in soils after 10 years. Both site treatments stimulated the natural establishment of red alder (*Alnus rubra*), averaging 3950 stems per ha, which may both facilitate and compete with the cedar plantation over time. Overall we found few obstacles to sustainable yields from cedar-hemlock-salal scrub forests, albeit with the recognition of longer rotation lengths and smaller volume increments than current operational sites on the north coast of British Columbia.

1. Introduction

The hypermaritime zone of north coast British Columbia is unique among west coast temperate rainforests because of the extensive areas (approximately 235,000 ha; Banner et al., 2005) of open, low productivity old-growth forests, comprised predominantly of western redcedar (*Thuja plicata*), yellow-cedar (*Chamaecyparis nootkatensis*) and western hemlock (*Tsuga heterophylla*). These forests occur on gentle to moderate slopes with imperfectly-drained, thick forest floors over either thin veneers of mineral soil, bedrock, or peaty organic soil. These scrub forests (more formally classified as CWHvh2/01 CwHw-Salal sites (Banner et al., 1993)) fall within inventory height classes of 2 and 3 (11–28 m tall), and consequently yield lower timber volumes than steeper upland sites (primarily height classes 4 and 5, 29–46 m tall) where commercial forestry has historically operated since the early 1900s. The high commercial value of western redcedar, along with public pressures on the existing landbase, suggested the possibility of expanding the operable landbase to include these slow-growing forests, but there was uncertainty surrounding the long-term sustainable yields of second-growth stands. The HyP^3 project (Pattern, Process, and Productivity in Hypermaritime forests of coastal B.C.) was initiated in 2000 to determine the feasibility of commercial harvesting and to develop ecologically based management guidelines for

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these CwHw-Salal forests (Banner et al., 2005). The project included an operational study of harvesting methods, site preparation trials and cedar regeneration success.

Low productivity, old-growth forests characterized by western redcedar and ericaceous shrubs (especially salal, *Gaultheria shallon*) extend from northern Vancouver Island along the outer British Columbia coastline (including the west coast of Haida Gwaii) through to southeast Alaska (Banner et al., 1987; Hebda et al., 1997; Nowacki et al., 2001). Regenerating forests typically show relatively poor growth and nutrition in comparison to upland sites, more so for Sitka spruce (*Picea sitchensis*) and western hemlock than western redcedar (Prescott et al., 1996; Kranabetter et al., 2003; Negrave et al., 2007). Some initial hypotheses on the forces driving productivity reductions included the lack of beneficial soil disturbances or intense competition from salal (Prescott and Weetman, 1994), but inherent moisture surpluses and shallow aerobic rooting zones appear to be the most consistent limiting feature of these sites (Asada et al., 2003; Emili et al., 2006; Sajedi et al., 2012). In addition, glacial morainal deposits are rare on the outer north coast, and some CwHw-Salal sites develop over granodiorite and gneissic diorite bedrock that further exacerbate nutrient deficiencies, especially phosphorus (P) (Heilman and Gass, 1974; Kranabetter and Banner, 2000).

Three issues surrounding the harvesting and management of CwHw-Salal forests were addressed in the operational study. The first concern was the risk of paludification after logging, the extent of which would depend on soil moisture response to reduced interception and transpiration following canopy removal (Lavoie et al., 2005). A rise in water tables has occurred in other wet forest types following harvesting, especially on transitional sites between wetlands and uplands where the water table is deeper than in the true wetlands (Dubé et al., 1995). A second issue was accurately quantifying inherent site productivity, where the absence of historical stand-replacing disturbances leads to complex stand structures, infrequent gap dynamics, and long periods of stagnant regeneration in old-growth forests (Hennon and McClellan, 2003; Gavin et al., 2003). As a result, site index of western redcedar averaged only 3.9 m at 50 years in CwHw-Salal stands (Banner et al., 2005), but height-age curves applied in old-growth forests can significantly underestimate second-growth site potential (Nigh, 1998). The inherently poor site potential raised a third issue, which was the feasibility in alleviating soil limitations to tree growth, especially by bolstering nitrogen (N) and P availability (Blevins et al., 2006). We examine relatively unobtrusive, low cost treatments to achieve this goal, rather than intensive interventions such as drainage ditches, shearblading or prescribed burning (Lavoie et al., 2005). The site treatments include spot mixing richer mineral subsoils to the surface, as might occur with natural blowdown disturbances (Bormann et al., 1995), or by a single P fertilizer application to potentially boost long-term soil N availability and site productivity (Kranabetter et al., 2005).

Long-term sustained yields in managed plantations requires adequate regeneration of preferred tree species, along with the conservation of soil resources and maintenance or enhancement of site productivity. In this study we address these fundamental principles by reporting on the short-term effects of timber harvesting on site hydrological balance, along with 10 year post-treatment responses of site preparation and P fertilization on key soil properties, tree growth and foliar nutrition. These results provide some insights into the inherent productivity and site limitations of CwHw-Salal forests, and will help guide forest managers as they consider expanding harvesting into these scrub forest ecosystems.

2. Methods

2.1. Forest description

Along with both cedar species, the 01 CwHw-salal ecosystem (Banner et al., 1993) is floristically characterized by abundant western hemlock, with dense layers of ericaceous shrubs, especially salal, false azalea (*Menziesia ferruginea*) and Alaskan blueberry (*Vaccinium alaskaense*). The herb layer consists of scattered deer fern (*Blechnum spicant*), bunchberry (*Cornus canadensis*) and occasionally skunk cabbage (*Lysichiton americanum*) on wetter microsites, along with a moss layer dominated by step moss (*Hylocomium splendens*), lanky moss (*Rhytidiadelphus loreus*) and, less frequently, common green peat-moss (*Sphagnum girgensohnii*). Soils are imperfectly drained with deep forest floor accumulations dominated by a partly decomposed, slightly greasy, reddish-brown humic horizon (Resimors; Green et al., 1993), and are typically classified as Ferro-Humic Podzols or Humic Folisols (Soil Classification Working Group, 1998). Further details and images of forest ecosystems of north coast B.C. can be found in Banner et al. (2005).

2.2. Treatment installation

The study is located 40 km south of Prince Rupert (British Columbia) on Porcher Island, near the community of Oona River (53°57″N, 130°15″W), in old-growth forests of the Coastal Western Hemlock very wet hypermaritime subzone (CWHvh2; Banner et al., 1993). Estimated climate normals (1961–1990) are 7.9 °C for mean annual temperature and 2728 mm for mean annual precipitation (Wang et al., 2006). In 1998, timber cruising and ecosystem sampling were carried out within a 50-ha candidate area to identify stands dominated by the CwHw-Salal site series. Cutblock boundaries were located based on ecosystem sampling data, together with field notes and air photo interpretation, to cover a total area of 18 ha. The cutblock occurs on gentle slopes (5–25%) with a southerly aspect. Soils were imperfectly to poorly drained with deep forest floors (occasionally 50 cm+) over saprolitic schistose veneers. Old-growth stands of this site series were dominated by western redcedar, which accounts for about 50% of the volume, and western hemlock, with lesser amounts of yellow-cedar, Sitka spruce, and shore pine (*Pinus contorta* var. *contorta*). Based on a pre-harvest timber cruise, gross and merchantable volumes for the Cw-Salal stands were 333 $m^3\ ha^{-1}$ and 235 $m^3\ ha^{-1}$, respectively. Basal area averaged 50.5 $m^2\ ha^{-1}$, with 574 stems ha^{-1} at an average diameter of 36.1 cm.

The site was harvested during the summer of 2000 using a diameter-limit approach that removed all western redcedar and yellow-cedar between 17.5 and 150 cm diameter. Cedars outside this range (equal to only a few scattered trees, <5% of the original basal area) were left standing to provide residual stand structure, a ready seed source for natural ingress, and to reduce the amount of coarse woody debris on the ground. Shore pine and western hemlock stems were felled and used to construct temporary ground skidding trails. Trees were hand felled, moved to collection points by wide-tracked back hoes (‘hoe-chucking’) and then taken off the block by a track ground skidder. Twelve plots, about 0.1 ha in size, were established after harvesting under full sunlight conditions within the cutblock, and pre-treatment forest floor depths were recorded over a systematic grid imposed on each plot consisting of 3 lines with 5 points.

CwHw-Salal sites contain a huge amount of organic material (dead and down trees, humus layers, moss and vegetation), and removal of slash and disturbance of the surface organic layer might improve growing conditions by warming and aerating the soil. Surface scarification could also create better seedbeds for natural