The Maintenance of Key Biodiversity Attributes Through Ecosystem Restoration Operations[1]

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Abstract

The requirement to manage for key biodiversity attributes in dry forest ecosystems is mandated in the Forest Practices Code Act of British Columbia. These attributes include snags, large old trees, and large organic debris. In the Squamish Forest District dry forest restoration activities center on the use of thinning operations followed by prescribed fire to restore stand structure and species composition to conditions closer to the historic range of variability. Various strategies have been tested to retain or create key biodiversity attributes. These strategies include wrapping fire-scarred trees with fire shelter material, digging firebreaks around attributes, using “avoidance firing” ignition techniques, and setting prescription limits around fuel moisture content. Some strategies have proven to more successful than others. We present our findings on cost effectiveness and retention success for several attributes and treatment strategies plus a discussion of recommended policy changes to make expectations of retention more in line with operational realities.

Introduction

Many western interior forested ecosystems in North America are considered to be in an unhealthy state. The decline in ecosystem health has been attributed to fire exclusion, livestock grazing, excessive harvesting, and the introduction of exotic species (United States General Accounting Office 1999). Intensive management is required in order to restore ecosystem structure, composition, and functions to a more sustainable condition (Covington and others 1997). Ecosystems are considered best able to respond to disturbances if they are resilient, sustainable, and biologically diverse (Bourgeron and Jensen 1994).

Most definitions of biodiversity include three distinct components: composition, structure, and function. The compositional component represents the variety of fauna and flora within an area. The structural component refers to the arrangement of fauna and flora, including their spatial and age-class distribution. The functional component characterizes the processes and mechanisms occurring within an ecosystem including, but not limited to, nutrient cycling, decomposition, and energy flows (Franklin 1988). The task for resource managers involved in ecosystem restoration is to either preserve biodiversity through static set asides, or to promote biodiversity through restoration efforts in a dynamically-managed landscape (Everett and others 1996).

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Identifying the appropriate location and proportion of attributes to retain or create is the first step in planning restoration operations. The second step is determining how, through restoration strategies of mechanized thinning and prescribed burning, the various associated attributes can be retained or created. Since 1998, the Squamish Forest District Small Business Forest Enterprise Program has carried out a variety of ecosystem restoration trials (Gray and Blackwell, this volume). Employing an adaptive management philosophy to dry forest management has enabled the targeting of specific restoration issues and the building of monitoring plans to address these issues in subsequent operations. This paper presents the results of adaptive efforts to retain and promote a variety of biodiversity attributes, including Coarse Woody Debris (CWD), snags, and large diameter green trees through mechanical thinning and prescribed burning operations in the southern interior of British Columbia.

Study Area

The Haylmore Creek drainage is located in the northeast corner of the Squamish Forest District in southwestern British Columbia. Forested ecosystems range from the Interior Douglas-fir wet warm subzone (IDFww) at the valley floor and lower half of the slope to the Engelmann Spruce/Subalpine Fir moist warm subzone (ESSFmw) above approximately 1400 m. Valley floor elevation is 300 m, with the highest points in the local Cayoosh Range exceeding 2200 m. Climate in Haylmore Creek is characterized as continental with a mean annual precipitation of 549 mm. Mean monthly air temperature ranges from a low of -1.4°C in January to a high of 23.7°C in July. Summer droughts are not uncommon. This general area is referred to as the Coast-Interior Transition Zone due to the climatic overlap of the two systems.

Low elevation forests in Haylmore Creek contain a mixture of Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) and ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) on dry sites and predominantly Douglas-fir, with a minor component of western redcedar (*Thuja plicata* Donn ex D. Don) and paper birch (*Betula papyrifera* Marsh.), on mesic sites.

Methods and Results

Each attribute investigated and managed is described individually in this combined section. Methodology used in inventory and restoration operations is described followed by the operation results.

Coarse Woody Debris

Coarse woody debris (CWD) plays a significant role in forest ecosystem ecology, including the provision of habitat for many autotrophic and heterotrophic species; providing a food source for many decomposer bacteria and fungi; and acting as a sink for important nutrients (Stevens 1997). For the purposes of this report we characterize CWD as large (>15 cm), downed logs and describe their condition using five decay classes (British Columbia Resources Inventory Committee 1997).

The retention of adequate quantities of CWD throughout the restoration process,and into the future is of concern to researchers who hold the belief that long-term site productivity and wildlife habitat may be impacted if too much CWD is removed during the restoration process (Tinker and Knight 2001). However, questions arise over how much CWD should be retained in these ecosystems and how the quantity of CWD will affect fire severity during either prescribed burning operations or wildfires (Brown and others 2003).

Retaining a predetermined amount of CWD through the thinning phase of restoration is not difficult. However, retaining this material through the prescribed burning phase of restoration is problematic due to its flammability.

Consumption of material in decay classes 1 and 2 was only 9 percent, while the consumption rate for more advanced decay classes was 31 percent. Decay class 1 and 2 material was sound and often still suspended off the ground. Decay class 3 to 5 material was spongy, elliptical in shape, and fully in contact with the ground. Fuel moisture content (FMC) at the time of ignition ranged from 14 to 17 percent in the decay class 1 and 2 material and 20 to 25 percent for the decay class 3 to 5 logs. FMC was measured using a protimeter on the outside of the log. Higher consumption rates in decay class 3 to 5 CWD were most likely explained by the low bulk density of material, high surface-area-to-volume ratios, high flammability due to resin impregnation, and oxygen availability between particles. These qualities contributed to material in decay classes 3 to 5 exhibiting increased flammability when compared to decay class 1 and 2 material. All pieces sampled were either Douglas-fir or ponderosa pine.

Snags

Dead standing trees are recognized as a vital component of wildlife habitat, providing perching, feeding, nesting, over-wintering, and hiding structure for birds, and nesting/denning, feeding, and over-wintering habitat for mammals (Bull and others 1997). Wildlife value is often dependent on the stage of decay. Retaining dead trees, especially tall, large diameter snags, through the restoration process is difficult owing to worker safety regulations, structural soundness during thinning and yarding operations, and flammability of the structure. In restoration treatments in British Columbia, snags are either felled or retained in designated Wildlife Tree Patches (Ministry of Environment, Lands and Parks and Ministry of Forests 1995). The patch dimension is based on snag height and its structural soundness.

Analysis of snag retention on restoration units in this study was limited to thinned-and-burned and burned-only units. Any of these units that included harvesting had all snags felled as per Worker's Compensation Board (WCB) regulations (Workers' Compensation Board of British Columbia 1997). Prior to treatment, the density of large (>50 cm) snags averaged two per hectare, with most classified in conditions five to nine.

Snag retention was measured on two spring burns; one carried out in 2001 (burn only), and the second in 2002 (thin and burn). The 4.3 ha burn only unit contained eight snags prior to treatment, while the 11 ha thinned and burned unit contained 22 snags. Snag survival was 50 percent in the burn only unit and 36 percent in the thin and burn unit. Snags lost in the burn only unit were attributed to snags burning and falling over, and snags that had to be felled during project mop-up as per worker safety regulations. All 14 of snags lost in the thin and burn unit were felled prior to burning due to safety issues. In the thin and burn unit, thinning crews would be working in the vicinity of snags for several days, and as a result 64 percent of snags were felled. The only option open for retaining the remaining eight snags was to designate "no work" zones around two small snag patches. In these patches, ingrowth trees, which were the target of the restoration treatment, could not be thinned.

Live Green Trees

The category “live green trees” refers to the older tree cohort left following restoration thinning. This is in contrast to smaller diameter, younger cohort trees that are retained as future legacy structures. Live green trees in the study area are typically characterized by large diameters (>70 cm), clear boles, thick bark, moderate crown ratios (0.4 to 0.6), high crown areas, large diameter limbs, and often fire scars, or cavities. There may be large accumulations of bark scales, needles and cones, especially in the case of ponderosa pine, at the base of these trees. In addition to their aesthetic and genetic values, these trees are considered to have very high wildlife values.

Retaining live green trees during the thinning phase of restoration is achieved through marking to leave guidelines. On rare occasions trees are lost to falling or yarding damage, or they are intentionally felled because they are located in a yarding corridor. However, the proportion of live green trees lost during this phase of restoration operations is minimal.

Retaining live green trees during the prescribed burning operations is more difficult. Experience has shown that there are significant issues of survivability based on tree species, whether or not the tree contains an open fire scar, and the fuel complex in the unit. An analysis of differences between legacy retention in thin and burn units versus burn only units yielded a noticeable difference between the two treatment types. Mortality of legacy trees in thin and burn units reached 19 percent by year 2 following the burn. Both Douglas-fir and ponderosa pine experienced a mortality rate of 19 percent, which in the case of Douglas-fir was partially attributed to Douglas-fir bark beetle (*Dendroctonus pseudotsugae* Hopkins) and structural failure. Immediately post-burn (all burns were carried out in the spring) a number of trees were attacked by bark beetles, but only 5 percent were killed. All mortality was associated with the thin and burn unit. Fire damage and associated bark beetle attacks are well documented in the literature (Edmonds and others 2000). In order to limit tree mortality associated with fire and beetle interactions precautions were taken during the burn to limit crown scorch. These are principally burning under higher moisture contents, and limiting ignition strip widths.

Douglas-fir legacy trees did not experience significant crown scorch in either treatment type; however, in many cases fire ran up the bole burning resin on the outside of the bark. Structural failure of trees was primarily due to fire entering large rotten limbs and burning into rotten heartwood. If the bole was weakened by internal burning, the top of the tree would break off, creating a large diameter case-hardened snag. This resulted in the mortality of 14 percent of the Douglas-fir in the thin and burn unit and 6 percent of the Douglas-fir in the burn only unit.

Ponderosa pine mortality for all causes was 19 percent in the thin and burn treatment and 6 percent in the burn only treatments. Of those killed, seven percent was due to a combination of red turpentine beetles (*D. valens* LeConte), western pine beetles (*D. brevicomis* LeConte), and mountain pine beetles (*D. ponderosae* Hopkins). In some cases trees were not attacked until the year following the burn. Bark beetles attacked only 2 percent of ponderosa pine trees in the burn only treatment. In both treatment types crown scorch was minimal.

Structural losses are the most significant management concern for ponderosa pine legacy trees. Unlike Douglas-fir, where fire runs up the bole and enters heartwood through rotten branches, fire seldom runs up the bole on ponderosa pine.

Open cavities at the base of the bole, caused by repeated fire-scarring, is the structural weak point of these trees. Following an earlier burn in 1999, where all fire-scarred pine were lost, an attempt was made to mitigate future losses through a combination of fuel removal at the base of the trees and by covering the fire scar area with an ember barrier. Fuel removal limited the heat residence time at the base of the tree, while the barrier prevented embers from entering the scar cavity.

In a heavily thinned restoration unit burned in the spring of 2001, 123 trees were wrapped with fire shelter material purchased from Cleveland Laminating Ltd. Of the 123 trees, 22 (18 percent) were Douglas-fir, and 101 (82 percent) were ponderosa pine. The shelter material was placed over the wound and stapled into place. The bottom of the material was anchored to the ground with rocks. Total cost of the project was $21.09/tree (Cdn): $848.00 for two rolls (1 yd x 300 yd) of material, and $284.00/day x 6.2 man-days to apply the wrap. Total mortality post-burn was 30 trees (24 percent of the total): seven Douglas-fir (32 percent of fire-scarred trees) and 23 ponderosa pine (23 percent of fire-scarred trees). All seven Douglas-fir were burned through the wrap and then burned out at the base and fell over. Of the 23 pine that were killed, 13 (57 percent) had been burned through the wrap and were hand felled because they were deemed a worker hazard, while 10 (43 percent) burned through the wrap, burned out the base, and fell over.

In an attempt to determine whether the wrap would be more effective in lighter fuels, the experiment was repeated in the spring of 2002 on an 11 ha thin and burn restoration unit (*Table1*). In this unit the majority of Douglas-fir ingrowth trees were felled and scattered. A total of 18 trees were randomly located and wrapped in the unit; 14 were pine and four were Douglas-fir. Surface fuels were also pulled back 1 m from the bole of the tree. No wrapped trees were lost to the burn in this second experiment.

Table 1—*Fuel bed characteristics for the heavily thinned and lightly thinned restoration treatment types.*

	Fuel loading (kg m^{-2})						
Treatment Type	**0-0.6 cm**	**0.6-2.5 cm**	**2.5-7.5 cm**	**<7.5 cm**	**>7.5 cm rotten**	**>7.5 cm sound**	**Total**
Heavy							
pre-burn	1.66	0.65	1.86	4.17	1.44	3.48	9.09
post-burn	0.29	0.16	0.70	1.15	1.19	3.23	5.57
Light							
pre-burn	0.38	0.58	0.16	1.12	0.31	0.00	1.43
post-burn	0.31	0.34	0.00	0.65	0.31	0.00	0.96

The survivability of legacy trees is heavily influenced by the fuel bed characteristics in the restoration units. There was a significant difference (p=0.011) in total fuel loading between the two treatment types (*table 1*). Pre- and post-burn analysis indicates that there was a significant difference in burn intensity between the two units. High levels of fine fuel consumption–82 percent, 76 percent, and 63 percent for each of the 1-hr, 10-hr, and 100-hr fuel size classes–were recorded in the heavily thinned unit compared to very low levels–18 percent, 42 percent, and 100 percent–in the lightly thinned unit.

Discussion

The retention of coarse woody debris, snags and large diameter old green trees, are important elements of biodiversity in dry forest ecosystems. Tactically managing these attributes is problematic when restoration activities reach the operations level. Difficulties arise when trying to maintain or promote biodiversity attributes that may be a function of current biological conditions, or are associated with inflexible government regulations. Both were encountered when carrying out restoration operations in Haylmore Creek. Beginning with coarse woody debris, we present a set of discussion points detailing where we had successes and failures and recommend some possible solutions to these problems.

While it is recognized that CWD has an important function in these ecosystems, maintaining appropriate levels of it while not jeopardizing other resources is key. Too much CWD on a site that will be exposed to frequent fire as part of an ongoing restoration program can lead to long-term site productivity impacts. Maintaining adequate amounts on the site through the thinning phase of restoration is not difficult. Logging contractors rarely remove large old logs unless they are very solid or are a valuable species such as western red cedar. Additional amounts of CWD are added to the site in the thinning phase, most of which is very solid decay class 1 to 2 material. Snags not located in Wildlife Tree Patches or “no work” zones will be felled and incorporated into the CWD volume. Through the burning phase, the more decayed and pitch-impregnated material has a high probability of being consumed. This process is more pronounced during drought cycles. Very little in the way of mitigation can be done to prevent this. Less decayed material, however, has a very high probability of surviving the first burn. As we have seen on our projects, there is an additional input of large CWD to the site following the burn due to the loss of green retention trees.

Retaining snags was less a function of flammability than of regulations guarding worker safety. All snags in thinning units had to be felled unless they were located in “no work” zones. In restoration units that did not include pre-burn thinning, snags were lost if they were deemed to be “unsafe” to work around during mop-up. In these cases snags had caught fire and were structurally unsound. The only other option open for retaining snags is to locate them in reserve patches. Our hypothesis concerning this strategy is that reserve patches don’t mitigate the factors causing accelerated decomposition of snags; namely, the high moisture content in closed canopy reserves provides a hospitable environment for insects, bacteria and fungi. These thickets of trees surrounding snags need to be thinned in order to dry out snags and make them less hospitable to decay agents. The only positive note regarding snag management is the recruitment of new snags from the live green tree population. Many of these old, case-hardened trees exhibit fairly high longevity (Smith 1999).

There are several fairly inexpensive but successful strategies available for mitigating the losses in live green trees during the burning phase of restoration operations. These include fuel pull back at the base of the tree, wrapping scar cavities with fire shelter material, applying certain ignition techniques around these trees and aggressive mop-up immediately following ignition. Longer-term post-burn issues around bark beetle attacks could be addressed with pheromone traps, which can be successful for certain species of bark beetle. Retaining additional future legacy trees is another option if there are significant concerns over the losses of these trees.

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