How to Retain Whitebark Pine in Timber Harvests

Michael Murray

Jenny Berg

Dave Huggard

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Michael P. Murray, <michael.murray@gov.bc.ca>, British Columbia Forest Service, Nelson, BC; **Jenny Berg**, <vedaworks@gmail.com>, University of Victoria, Victoria, BC; **Dave Huggard**, <dhuggard@telus.net>, Apophenia Consulting, Vancouver, BC.

ABSTRACT

In British Columbia, whitebark pine is a component of harvested forests, yet knowledge of post-harvest survivorship and factors that promote successful retention is lacking. Our objectives were to describe the temporal attrition of retained mature whitebark pine trees and to identify factors that likely influence survivorship during the critical initial post-harvest period. We assessed five separate harvest units in southeastern British Columbia. We found that retained trees experienced high annual mortality rates (3%-16%) across harvest sites during the initial five-year post-harvest period. After eight years post-harvest, mortality rates drastically declined. The preponderance of fallen stems oriented towards the northeast suggests that storm system events arriving from the Pacific Ocean are the most significant drivers of blowdown. We estimate that survivorship is positively associated with shorter tree heights and longer crown lengths, a lack of disease cankers, a greater presence of rodent wounding, and higher numbers of surrounding retained trees. Slope and aspect had very minor influence. As these trees are an endangered species, harvest operations should be practiced cautiously in associated forests.

Keywords: blowdown, fire, harvest, *Pinus albicaulis*, silviculture, whitebark pine, wind

INTRODUCTION

Whitebark pine trees are widely distributed among subalpine mixed-conifer forests in southern British Columbia. The most abundant associated tree species are Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*). A gradual increase in harvest acreage above 1800 m elevation began in 2008 in the Kootenay-Boundary Region. The long-term retention of mature whitebark pine trees can ensure that ecological values are better protected.

Before this study, survivorship of whitebark pine retained within commercial harvests had not been examined. We investigated the fate of residual trees to infer some preliminary recommendations. Our objectives were to describe the temporal attrition of retained mature whitebark pine trees and to identify factors that likely promote survivorship during the critical initial post-harvest period.

METHODS

Field sampling was conducted at five separate harvest sites during the summer of 2018. All five sites are located in the Kootenay-Boundary region of southeastern British Columbia. They are considered variable retention cuts and represent the only harvest method deployed to date in the region's whitebark pine stands. Because harvest years differed among the sites, our field sampling captured a range of post-harvest intervals representing 6–17 years. Based on the majority of whitebark pine stands in the region, our study sites are representative of the most common mix of tree species, elevation range, tree ages, and habitat.

At each harvest site a census of standing and downed mature whitebark pine greater than 17 cm dbh (diameter at breast height) was conducted. Trees near the perimeter of the harvest units were excluded if the tree height was greater than the distance to the nearest forest edge. The location of every tree was recorded with a high-precision (GNSS) global positioning device. Every tree was assessed based on the following parameters: height, diameter (dbh), distance and azimuth to nearest forest edge, height to live crown, and percentage of live crown. Slope (%) and aspect (deg) were measured at each tree. For every surveyed tree we tallied the number of mature neighbor trees within a distance equal to or less than the survey tree's height. Each neighbor tree was noted according to status (live, snag, down). All trees were examined for forest health agents.

For dendrochronological analysis, increment cores were collected from all live and dead retained trees using a 4-mm Haglof increment borer taken at approximately 1.3 m above the ground (dbh). Those samples with exceptionally condensed rings were measured with a Velmex uniSlide digitally encoded traversing table at a precision of 0.01 mm. The remaining cores were digitally scanned at a 2400 dpi resolution with an HP flatbed scanner. Digital images were imported into CooRecorder measuring software and exported as ring width files with CDendro software package (Larsson 2014). To ensure that the appropriate calendar date was assigned to each measured ring we used the program COFECHA to aid in accurately cross-dating all increment cores (Holmes et al. 1986).

To identify potential factors affecting survivorship, we evaluated a set of models using Akaike's "An Information Criterion" (AIC) (Burnham and Anderson 1998). Biophysical measurements were examined as potential factors to predict the survival of retained whitebark pine trees. To reduce the number of variables included in the analysis, correlated variables within each set were screened using AIC model selection. The best subset of variables in each set was used in the final analysis. The final analysis used AIC model selection with 16 models, representing all combinations of including or excluding the selected variables in each of the four sets. All models were general linear mixed-effects models. The analyses were conducted separately for windthrown versus live trees, and for all dead trees (windthrown and standing dead) versus live trees.

RESULTS

We analyzed a total of 197 dead trees and 134 live trees. Mortality rates were highest immediately following harvest (figure 1). At Lavington (LV) operators reported that most retained trees were blown over during a single powerful storm as they were completing harvest. A negative exponential trend characterized three harvest sites, where initial steep declines became increasingly moderated over time. By nine years post-harvest, mortality ceased at all but a single harvest site.

The probability of mortality of retained whitebark pine trees is best explained by a combination of tree characteristics, slope/aspect, and the number of surrounding retained

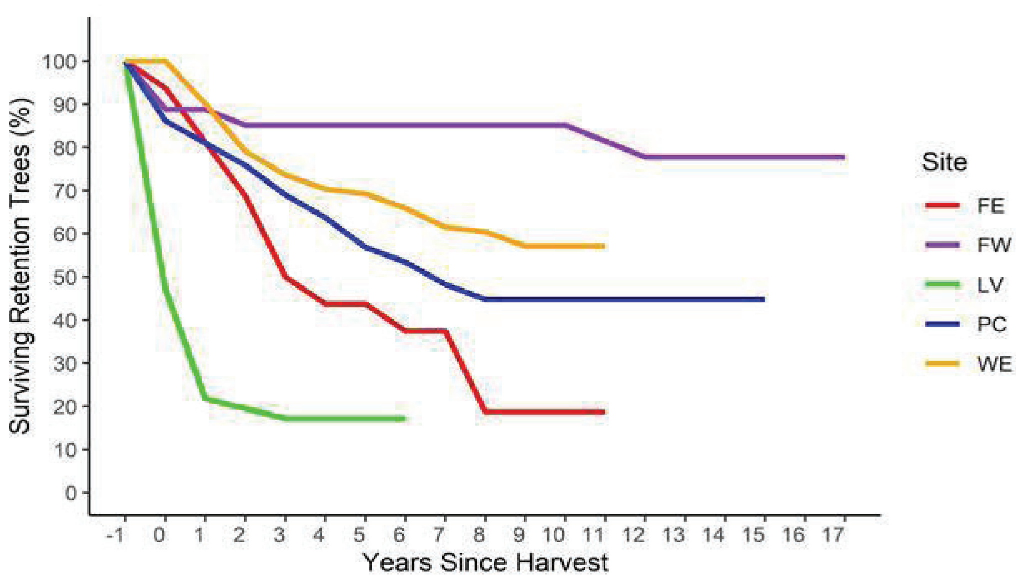

Figure 1. Post-harvest attrition of retained whitebark pine according to harvest site (FE: Findlay East; FW: Findlay West; LV: Lavington; PC: Paturages; WE: West Elk) (Murray et al. 2021).

trees (table 1). We found a strong increase in survivorship, with greater tree crown length accompanied by decreasing tree height. Thus, the probability of post-harvest mortality was higher for taller trees with shorter crowns and lower for shorter trees with long crowns. In examining the importance of neighbor trees, a survivorship probability greater than 50% required a minimum of 7.5 retained neighbor trees within tree height radial distance. For trees that did not survive, we found the vast majority of downed stems oriented in a north-easterly direction from root collar to crown indicating the strongest winds experienced at the sites arrived from south-westerly directions. Interestingly, there were opposite effects depending on the tree lesion type (cankers vs. rodent wounding). Any rodent damage indicated higher survivorship. With one or more blister rust cankers, there would be less than a 50% chance of survival.

DISCUSSION

We found elevated mortality rates occurred during the initial five-year post-harvest period. Due to a paucity of research on whitebark silviculture, it is unclear how whitebark pine compares with the capabilities of other tree species. Alternate species were not retained in our study sites, except at Lavington with very low numbers. The results suggest that most trees fell during storm conditions. We suggest that winter storms and approaching fronts of coastal low-pressure systems are the most significant drivers of blowdown for whitebark pine stands in the southern interior region. For at least one harvest site (Lavington), a majority of trees were blown over while alive.

Although cankered mature trees can survive for decades, if *Cronartium ribicola* remains in the host, chronic stress may interfere with physiological mechanisms that contribute to the tree's ability to withstand wind. Contrary to expectations, we found higher survival in trees damaged by rodents. Rodent damage may therefore indicate healthier trees that can adapt more quickly to post-harvest exposure.

The probability of survival lessened for trees with shorter crown lengths and greater heights. In general, trees that grew in denser stands with resultingly shorter crowns may be less adapted to resisting windthrow when they are exposed at harvest. Furthermore, the top-heaviness seems to make these trees more vulnerable. Our results are consistent with the vast majority of retention studies, indicating that higher retention levels favor positive survivorship rates (e.g., Busby et al. 2011; Montoro Girona et al. 2019; Moussaoui et al. 2020; Rosenvald et al. 2008). There are likely additional factors that favor retention survivorship that we did not examine, which may include pre-harvest stem density, soil (texture, depth, moisture), and rooting structure.

After completion of our study, a fire impacted the Lavington harvest site ("Doctor Creek Wildfire") in late summer of 2020 (figure 2). A survey was conducted in 2021 to determine the post-fire status of the 16 trees that were alive when our research sampling completed in 2018. Of these 16 trees, only one tree was alive (only 10% of foliage was green). Five trees had blown over between 2018-2020 and were consumed in the fire. Overall, 10 trees appeared to be directly killed by the fire. Bole scorch height varied from 25-80% of total height. Of note, about half of the retained western larch (*Larix occidentalis*) trees were alive. The fire resulted in a stand-replacing burn in the surrounding forest. Within the harvest unit, most coarse woody debris was consumed as well as a substantial proportion of duff cover indicating a high intensity event.

Table 1. Logit-scale coefficients for the best model for all dead trees (windthrow and snags) and windthrow only (Murray et al. 2021).

	All Dead Trees			Windthrow		
	Estimate	SE	*p*	Estimate	SE	*p*
Intercept	-0.918	1.154	0.427	-0.792	1.353	0.558
Nfacing	-	-	-	2.399	1.173	0.041
Efacing	-	-	-	-1.907	1.268	0.132
Sqrt(Surrounding Live Down)	-0.447	0.179	0.012	-0.524	0.188	0.005
nCankers	0.141	0.088	0.109	0.249	0.096	0.010
Rodent	-1.760	0.397	<0.001	-2.312	0.468	<0.001
Ht	0.281	0.071	<0.001	0.2460	0.079	0.002
CrownLength	-0.342	0.069	<0.001	-0.3351	0.074	<0.001

Figure 2. Post-harvest retained whitebark pine trees that were killed by the 2020 Doctor Creek Wildfire at the Lavington harvest site near Canal Flats, BC.

MANAGEMENT IMPLICATIONS

For southeast British Columbia and the adjacent Kootenai Region of the USA, we recommend harvest practitioners carefully retain whitebark pine. To increase likelihood of survival, retaining a minimum of eight neighboring trees (within the target tree's height radius) will substantially reduce risk. Choose trees with longer crown lengths and lower frequencies of disease cankers. Trees above average height are at higher risk of becoming windfall. We further recommend that harvest planners lay out ovate patches of retention oriented on a southwest-to-northeast azimuth to reduce hazards from windstorms. Harvesters should consider moving any wood debris away from retained stems. During fire events, we suggest that retained trees be protected by clearing surface fuels away from their driplines, wrapping tree boles with resistant material, and conducting spot suppression (Keane 2018; Murray 2007). All healthy cone-bearing trees are potentially disease resistant, thus represent a life link to the species' future.

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