Effects of Slash Pile Burning after Restoring Conifer-Encroached Aspen

Interim Pile Building Guidelines for Aspen Injury Risk Reduction

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Introduction

Removal of conifers encroaching aspen stands has been advocated and is being practiced in the Lake Tahoe Basin (EIP Project #10080: Aspen Community Restoration Projects). In remote and roadless areas, thinning of conifers is generating large volumes of wood and pile burning is currently being implemented to handle this biomass on site. However, the effects of pile burning on aspen are unknown, and there is an urgent need for guidelines to support design of thinning treatment prescriptions; specifically burn pile size and safe distances from live aspen trees of any size to prevent injury.

Objectives

This report describes a pilot dataset and preliminary analysis of pile burning impacts on aspen trees in one 2.47-acre stand at Ward Creek (near Tahoe City, CA). The research objectives were to:

(1) Examine the influence of tree size, pile size, and tree-to-pile distance on aspen injury (and in future, mortality) after pile burning;

(2) Use logistic regression models to understand factors associated with aspen injury (and in future, mortality);

(3) Quantify understory vegetation cover before and after burning; and

(4) Develop interim pile burning guidelines

The data and results presented here are only based on a 1-year post-fire assessment from one stand and should be interpreted cautiously. We will continue monitoring the stand for an additional 3 years to observe aspen mortality and how this related to injury severity. In addition, we have repeated this study in an additional five stands around the Lake Tahoe Basin and will be including data from these stands into future analyses.

Study Site

The effects of pile burning on aspen were studied at one site (Ward Creek - WA38) where a 2.47-acre permanent monitoring plot was installed in 2009. Prior to conifer thinning in fall 2009, data for aspen trees > 4 inches dbh and conifer trees > 8 inches dbh were collected. Tree measurements included dbh, height, crown height, map location within the plot, and a record of health status. Thinning of conifer occurred in the fall 2009. We calculated that live conifer stemwood volume totaled 6030 ft^3 ac^{-1} before thinning all smaller conifers up to a diameter limit of 14 inches dbh. This treatment reduced stocking by only 24% yet generated over 1000 ft^3 ac^{-1} of cut conifer stemwood (not including branches and tops) that was piled for burning in 50 piles ac^{-1}. Since the tops and branches of all trees removed (cut and piled) can account for a large part of each pile created, the stemwood volume estimates obtained from standard tree volume equations presented here underpredicted the total volume of cut wood.

Sampling

In 2010, we completed pile location mapping and measurement of 124 piles in the 2.47-acre permanent monitoring plot. Pile measurements included:

- Pile shape description (compatible with pile calculator e.g., half sphere, paraboloid, etc.);
- Width, length, and height of each pile (and necessary additional measurements to allow for accurate volume calculation (e.g. W1, W1, L1, L2, H1, H2) using pile calculator);
- Approximate fuel size-class composition by volume; and estimated packing ratio (for possible use in machine pile calculator given unusually large diameters of logs hand piled in the Lake Tahoe Basin; Kyle Jacobson, personal communication);

Pile biomass and gross volume were estimated using the Piled Fuels Biomass and Emissions Calculator (Hardy 1996 and Wright et al. 2009).

In 2011, we supplemented the existing tree data for aspen trees > 4 inches dbh collected in 2009 by measuring distance to the edge of the nearest burn pile for each tree that remained after the thinning treatment (Figure 1a). To obtain data for trees < 4 inches dbh, 18 burn piles were chosen in areas of the plot where aspen density was high. At each pile, all trees greater than 4.5 ft tall within 11 ft of the pile were mapped and measured for dbh, height, and distance to the edge of the nearest burn pile. A subset of aspen trees less than 4.5 ft tall within 11 ft of the 18 piles were mapped in relation to the nearest burn pile edge, and their height measured.

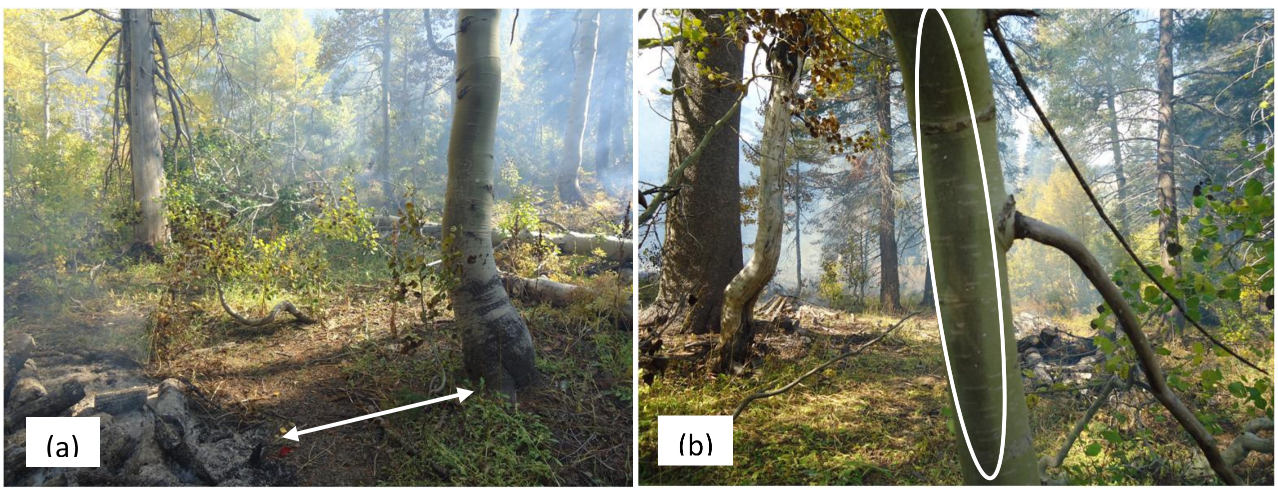

Figure 1. Tree-to-pile edge distance (a) and bole discoloration from heating (b).

Piles were burned in fall 2011 and post-fire tree assessments occurred in summer 2012. Health status, and fire injuries such as crown scorch, bole discoloration, and instances of dead top (small trees), bark splitting and/or weeping were recorded after burning. The health status of trees was recorded as either healthy (H), dead but not related to fire (D), dead from fire but re-sprouting (Ds), or dead from fire with no re-sprouting (Dns). Crown scorch was occularly estimated to the nearest %, and was defined as the percentage of pre-fire live crown volume scorched or consumed by fire. Bole discoloration from heating was assessed because of its potential to indicate cambial damage from fire (Figure 1b). Bole discoloration was measured in two ways: % of tree circumference discolored by fire (at worst-affected place); and length along the stem of the discoloration to the nearest inch. For example, the tree shown in Figure 1b had a bole discoloration approximately 25% circumference and 5 ft length.

Understory vegetation was assessed within and adjacent to the same 18 burn piles that we used to map and measure small aspen trees < 4 inches dbh. Before pile burning we established a series of 1-m^2 quadrats adjacent to burn piles in the four cardinal directions, and re-established the quadrats at the same locations after burning to determine percent cover of understory vegetation (Figure 2). To aid in re-establishing the quadrats at the same locations post burning we installed a stake chaser at the outside center of the third 1-m^2 quadrat. Additionally, after burning we assessed vegetation inside the burned area by establishing a 1-m^2 quadrat in the center of the burn pile and two 0.5 m^2 quadrats on the inside edge of the burned patches. For each quadrat, percent cover was occularly estimated from above the quadrat to the nearest % on all vegetation less than 1 m in height using the following categories: rock, bareground, coarse woody debris, aspen, conifer, shrub, grass, and herbaceous. For quadrats located within the burn pile area we also counted the number of regenerating aspen and conifer germinants.

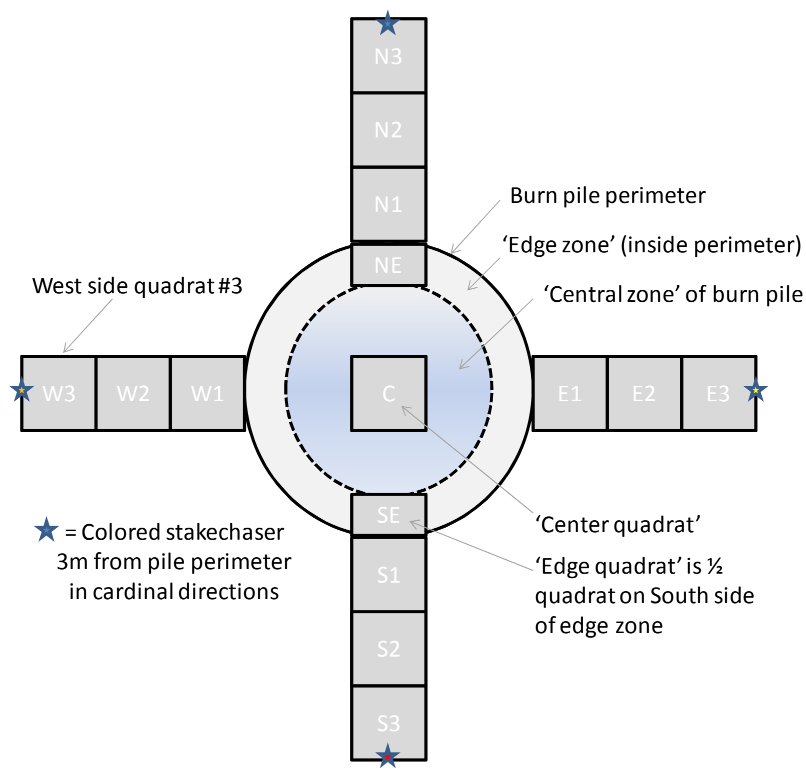

Figure 2. Sampling design to assess percent cover of understory vegetation surrounding burn piles at WA38.

Data Analysis

The data for pile characteristics, tree size, and tree-to-pile distance were linked with the binomial tree injury data for trees at a range of distances from burn piles of varying size. This 'matrix' of data covering the range of burn pile size and placement conditions entered logistic mixed-effects regression models of the probability of tree injury. These preliminary models are shown and can be used to develop interim pile burning guidelines.

The aspen tree injury data were separated into two groups, small and large trees, for summary and analysis because the tree-to-pile distance differed between the two groups and bole discoloration could not be accurately detected on small trees. The large tree group consisted of trees with dbh > 1 inch, and the small tree group consisted of trees with dbh < 1 inch. For both tree groups, trees recorded to have a 'dead' (i.e. cause unrelated to fire) health status were excluded from the dataset.

The pre-burn data on understory vegetation for quadrats surrounding the burn pile were compared to the post-burn data to determine if there were significant changes in percent cover. For quadrats located inside the burn pile area, the post-burn cover data were assessed to see what type of vegetation, if any, returned to these burned patches in the first growing season following pile burning. Future measurements will help us to determine the amount of time it takes for vegetation to reoccupy these burned areas, and attain similar levels of vegetation cover as areas that were not burned.

Results

Range of conditions sampled in the field

Of the 124 piles at WA38, 114 piles were burned. Thirteen of the 18 piles chosen to assess understory vegetation and injury damage on small trees were burned. We collected data for 127 large trees within a tree-to-pile distance ranging from 0 to 33 feet (Table 1). The number of burn piles within 33 ft of large aspen trees was 39. For small trees, we collected data on 224 trees surrounding 13 piles and ranging in tree-to-pile distance from 0 to 11 feet (Table 1). These are the range of conditions to which our analysis and results apply.

Table 1. Stand-level summary data showing the mean, standard error (SE), and range of data collected for aspen trees and burn piles at Ward Creek (WA38).

Data	Variable	N	Mean	SE	Min.	Max.
Large trees	Dbh (in)	127	7.5	0.5	1	24
(>1 in dbh)	Ht (ft)	127	34.3	2.0	5	85
	Tree-to-pile distance (ft)	127	12.4	0.7	0	33
	Crown scorch (%)	127	17.3	2.8	0	100
	Bole discoloration (%)*	127	12.9	2.1	0	100
	Average pile width (ft)	39	9.3	0.2	7	12
	Pile height (ft)	39	4.1	0.1	3	6
	Pile gross volume (ft^3)	39	193.5	12.0	78	485
Small trees	Ht (ft)	224	3.4	0.1	0	9
(<1 in dbh)	Tree-to-pile distance (ft)	224	5.2	0.2	0	11
	Crown scorch (%)	224	46.8	2.8	0	100
	Average pile width (ft)	13	9.1	0.3	7	11
	Pile height (ft)	13	4.0	0.2	3	6
	Pile gross volume (ft^3)	13	176.6	15.2	78	301

*Percent of tree circumference.

For both tree size groups, three multivariate logistic models were developed to predict the probability of an aspen sustaining a burn injury. The models were: (1) "Any injury": probability of sustaining any fire injury; (2) "Low severity": probability of sustaining a crown scorch > 33% or bole discoloration > 10 % of tree circumference; and (3) "High severity": probability of sustaining a crown scorch > 66% or bole discoloration > 20% of tree circumference. The latter two models were chosen to assess different threshold levels of crown scorch and bole discoloration. We hypothesized that the threshold level of crown scorch or bole discoloration in model 2 (Low severity) would cause sharp decreases in growth and some mortality. The threshold levels in model 3 (High severity) are those we suspect will cause cessation of growth, and later, aspen mortality will likely occur.

Analyzing injury probability

The probability of a large tree (> 1 in dbh) being injured by fire (Any injury, Low or High severity) was related to gross pile volume and tree-to-pile distance (Table 2). A square root transformation of gross pile volume improved model fit. Modeled probability of sustaining a burn injury decreased as tree-to-pile distance increased and pile gross volume decreased. In other words, aspen trees were more likely to be injured when located in closer proximity to larger piles. We tried models including dbh as an independent variable and found the dbh coefficient not significant (P > 0.42), suggesting that the probability of sustaining a burn injury at a given pile-to-tree distance and pile size was the same for large and small diameter trees. More likely is that a larger sample size is needed and the results should only be regarded as 'indicative'.

For small trees (< 1 in dbh), injury probability was significantly related to tree-to-pile distance, tree height, and gross pile volume (for all three models: Any injury, Low severity, and High severity; Table2). Predicted aspen injury increased as gross pile volume increased and tree-to-pile distance decreased. The model predicted higher rates of injury for taller trees than shorter trees at an equivalent gross pile volume and tree-to-pile distance. Said another way, aspen < 1 inch dbh were more likely to be injured as they grew taller, and were in closer proximity to larger piles.

Table 2. Logistic regression coefficients (± standard error) and - 2 Log Likelihood statistic (-2LL) for aspen injury prediction equations following pile burning at Ward Creek (WA38). P_i = predicted probability of injury; B_o = intercept, B_n = model coeeficients; ID = tree-to-pile distance (ft); Gvol = Gross pile volume (ft^3); Ht = Tree height (ft).

		Model form: $P_i = 1/(1+\exp(-(B_0+B_1*ID+B_2*Gvol^{0.5})))$				
		B_0	B_1		B_2	-2LL
Large trees	Any injury	0.7946 ± 2.7	-2.0460 ± 0.4		2.8975 ± 1.3	821.49
(>1 in dbh)	Low severity	-3.5770 ± 1.9	-1.7348 ± 0.3		3.5539 ± 1.0	801.38
	High severity	-3.5182 ± 2.4	-2.2305 ± 0.5		3.6996 ± 1.2	970.39
		Model form: $P_i = 1/(1+\exp(-(B_0+B_1*ID+B_2*Ht+B_3*Gvol^{0.5})))$				
		B_0	B_1	B_2	B_3	-2LL
Small trees	Any injury	-3.6805 ± 1.7	-1.2119 ± 0.2	1.7577 ± 0.4	2.4518 ± 0.8	1145.43
(<1 in dbh)	Low severity	-2.9076 ± 1.6	-1.3256 ± 0.2	0.3813* ± 0.3	1.9683 ± 0.7	1041.53
	High severity	-1.4056 ± 2.0	-1.5858 ± 0.2	0 .6883 ± 0.3	1.1208* ± 0.9	1115.96

*Model coefficient not significant (P>0.05).

Pile width and volume

The injury models shown in Table 2 need gross pile volume as an input. An average pile width-gross volume regression was developed to facilitate implementation of the injury models by predicting gross pile volume from pile width. This equation allows evaluation of pile burning prescriptions based on pile width (assuming piles similar in height to those measured at WA38; Table 1). Average pile width and gross volume (Gvol) for the total number of piles at WA38 (n=124) were used to develop the regressions (Figure 3).

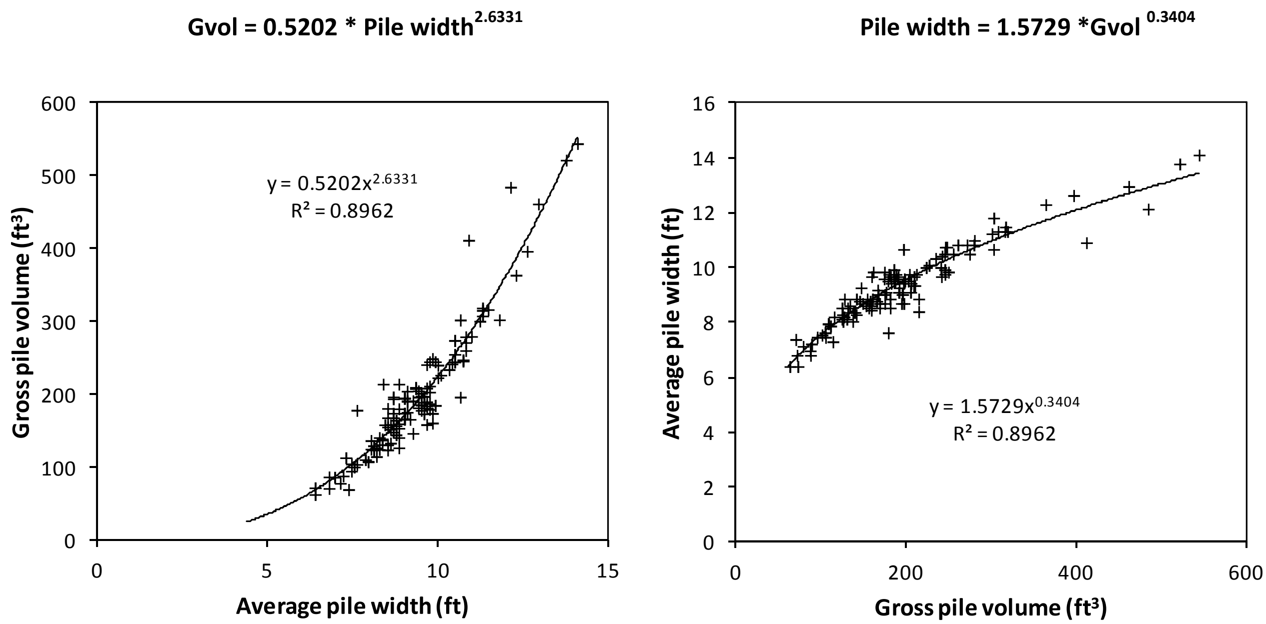

Figure 3. Relationship between burn pile width (average of width and length measurements) and gross pile volume calculated by entering width, length, and height measurements into the pile calculator (Wright et al. 2009).

Figure 4 was developed by applying the injury probability models (Table 2) to three hypothetical pile sizes; 6 ft, 9 ft, and 12 ft width burn piles. It shows the effect of pile width on probability of injury for large and small trees, and can be used to develop interim pile burning guidelines. Example scenarios representing different management objectives are presented in an "Application to management" section at the end of this report.

Effect of Pile Size on Probability of Injury -

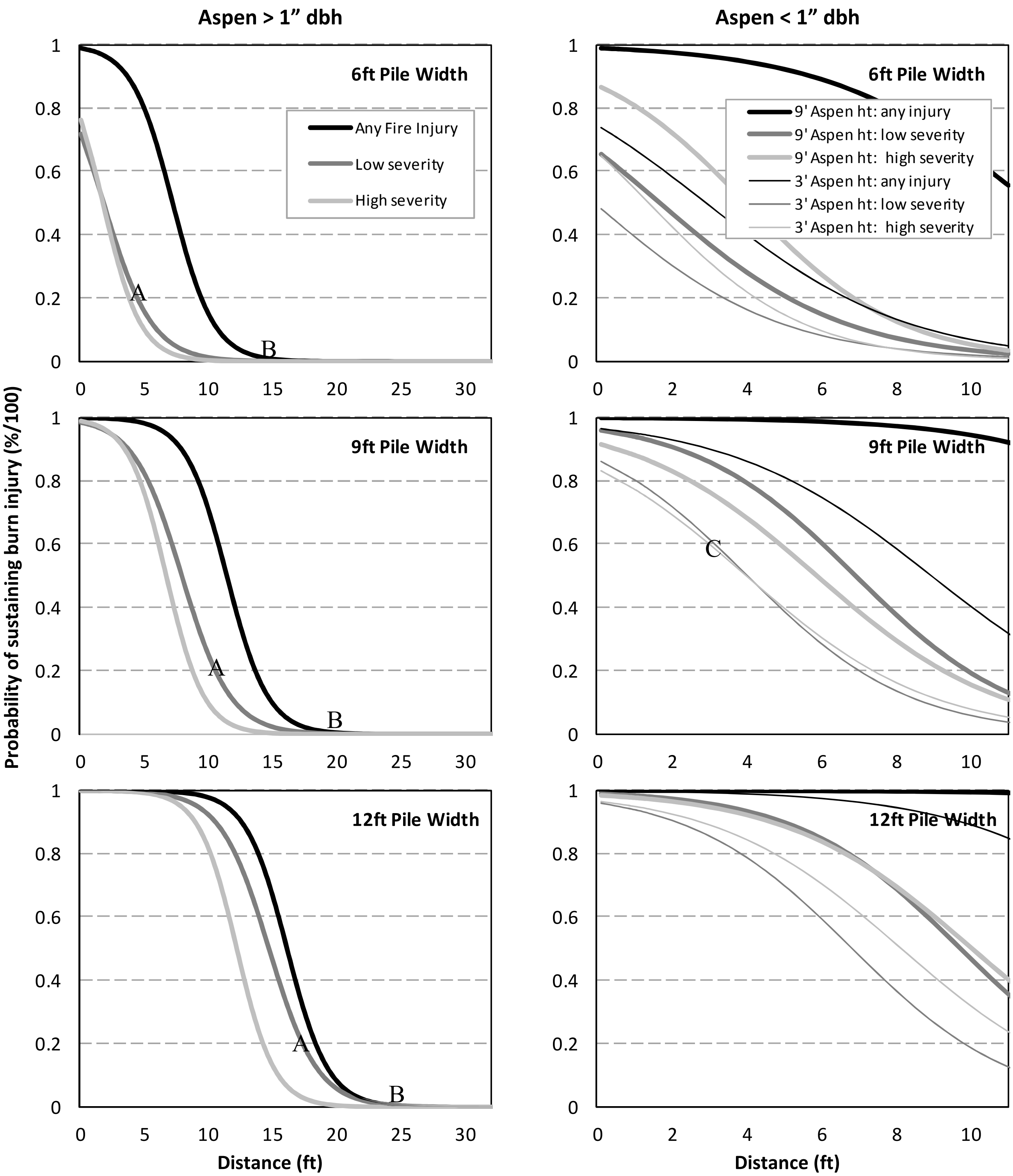

Figure 4. Predicted probability of aspen injury related to pile width and distance from burn pile (e.g. where probability of 0.5 = 50% chance of injury) based on pile and injury data from fall burning in 2011 at one site (WA38). Scenario A: 20% probability of “low severity” injury; B: 0% probability of “Any injury”; C: 60% probability of “high severity” injury to small trees.

Understory vegetation -

The percent cover of understory vegetation was high surrounding burn piles both before and after pile burning (Figure 5). The percent cover for herbaceous vegetation was highest with an average of 36 and 38% for quadrats pre- and post-treatment, respectively. The average cover for grass, coarse woody debris, aspen, shrub, and conifer categories were each less than 10% for both measurements with only slight differences occurring between pre- and post-pile burning measurements. Most interesting was that bare ground did not increase between measurements, especially within the quadrats located closest to the burn piles where we expected the pile burning to 'creep' beyond the pile area (i.e. N1, E1, W1, S1; Figure 2). Upon inspection, in most cases the fire did not extend beyond the burn pile area. In other cases, we found evidence that the fire did extend beyond the burn pile area but percent cover for vegetation had already, within the first growing season, returned to pre-burn levels.

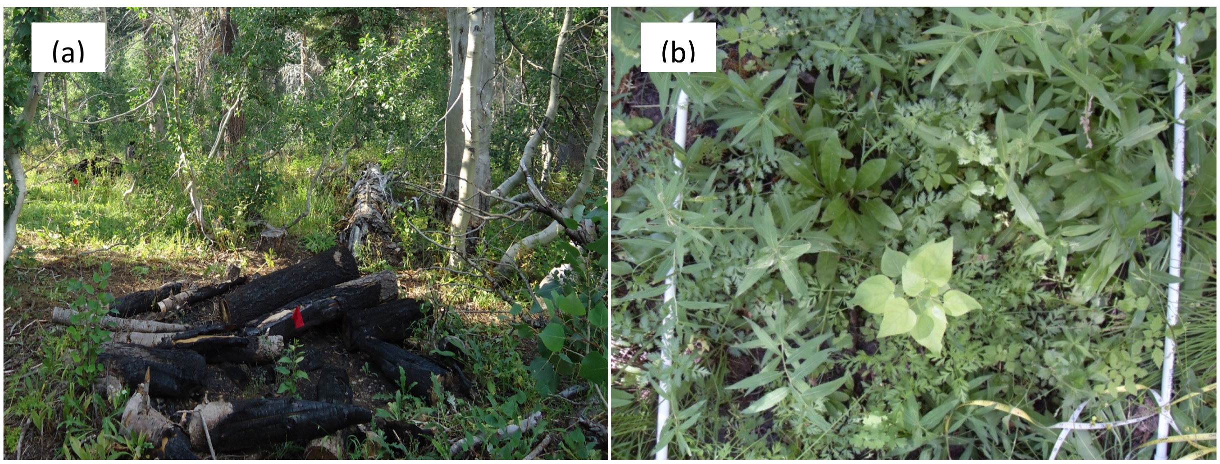

Figure 5. Post pile burning treatment images showing the presence of aspen and understory vegetation (a) and a quadrat with 4% aspen (sucker at center of quadrat) and herbaceous vegetation and grasses covering the remaining 96% (b) at Ward Creek (WA38).

For the areas located within the burned patches (i.e. center and edge quadrats; Figure 2), cover was mostly comprised of bare ground and unconsumed wood, with an average cover of 91% for these two categories (Figure 5a). The average percent cover for herbaceous species and grasses was 6 and 2%, respectively. Percent cover values for aspen, firs, and shrubs were less than 1% within burned patches.

Tallies of new regeneration inside the burned patches indicated that the presence of aspen was lower than that of firs, and was found only in 5 of the edge quadrats (Table 3). Firs were found within 14 of the edge quadrats and all of the center quadrats.

Table 3. Summary data showing the mean, standard error (SE), and range of data collected for regenerating aspen suckers or conifer seedlings per $1m^2$ within burned areas following pile burning at one site, WA38.

Location inside burn pile	Species	N	Mean	SE	Min.	Max.
Center	Aspen	13	0	0	0	0
	Conifer	13	10	1.92	1	21
Edge	Aspen	26	1	.81	0	20
	Conifer	26	4	1.67	0	30

Application to management

Example scenarios showing the potential use of Figure 4

The following scenarios are based on preliminary data and models collected from one site at Ward Creek (WA38). The models will be improved upon after pile burning occurs in 5 additional aspen stands around the basin.

A: If you are willing to accept a "low severity" burn injury (but not a "high severity") on 20% of large aspen trees near piles, what is an appropriate prescription for pile size and pile distance from aspen trees?

Answer: 4 ft distance from 6 ft wide pile
10 ft distance from 9 ft wide pile
17 ft distance from 12 ft wide pile

B: How far away do piles need to be from large aspen trees to ensure that zero damage from pile burning will occur?

Answer: 15 ft distance from 6 ft wide pile
20 ft distance from 9 ft wide pile
25 ft distance from 12 ft wide pile

C: Piles are placed at least 3 ft away from small aspen trees and are on average 9 ft in width. What is the probability of a "high severity" fire injury for trees 3 ft in height?

Answer: 60%

Application instructions

If you plan to build 6ft, 9ft, or 12 ft-wide piles then read the Injury Probability directly from Figure 3. Other scenarios can be evaluated by: Step 1 – plugging a pile width into the equation in Figure 3 (on the left) to get an estimate of gross pile volume, and then Step 2 – plugging the gross volume (Gvol) into the Injury Probability model given in Table 2.

Literature cited

Hardy, C.C. 1996. Guidelines for estimating volume, biomass, and smoke production for piled slash. Gen. Tech. Rep. PNW-GTR-364. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 17p.

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