Tree Size, Growth, and Anatomical Factors Associated with Bear Damage in Young Coast Redwood[1]

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Precommercial thinning is an important tool for coast redwood (*Sequoia sempervirens* (D Don) Endl.) forest management but is often followed by black bear (*Ursus americanus*) damage in northern parts of redwood's natural range (Fritz 1951; Giusti 1988, 1990; Hosack and Fulgham 1998). The bears scrape off bark and feed on the sugar-rich phloem of coast redwood and coast Douglas-fir (*Pseudotsuga menziesii* var. *menziesii* (Mirb.) Franco) (Kimball et al. 1998). A prior study at the same study area within the Mill Creek watershed in Del Norte Coast Redwoods State Park, near Crescent City, in Del Norte County, California, showed that frequency of damage was higher among larger trees in these conifer-dominated mixed even-aged stands, and that redwood was more likely to be damaged than Douglas-fir, especially near roads. Precommercial thinning (PCT) incited damage to redwood, and PCT to lower residual densities incited more damage in Douglas-fir. Unthinned control stands were least damaged. Increment cores collected from pairs of damaged and undamaged redwood trees confirmed that damage occurred after thinning and revealed that,at the time of bear damage, trees sustaining damage had been growing faster than undamaged trees of similar size (Perry et al. 2016). These findings support mitigation strategies such as lighter thinning, leaving higher densities of redwood in anticipation of higher damage rates, and leaving unthinned buffers adjacent to roads and other paths travelled by bears.

We examined relationships between phloem thickness, recent annual radial growth, and redwood tree diameter at breast height (DBH; 1.37 m) on increment cores collected in the stands studied by Perry et al. (2016) at Mill Creek. Breast height increment cores were collected in eight stands: three controls, three low-density (heavily thinned) stands, and two high-density (lightly thinned) stands. In each stand, core samples were taken from three damaged trees and three undamaged neighboring trees of similar diameter and height. In order to ensure damaged tree and neighboring tree experienced similar site and stand conditions, the neighboring tree had to be located < 3.66 m away from the damaged tree (Perry et al. 2016).

At the lab, all core samples were dried at 40 °C for 24 hours, then glued to medium density fiber board. The samples were then sanded down sequentially starting with coarse sandpaper and ending with an extra fine 1600 grit. The samples were scanned and imported into WinDENDRO (Regent Instruments Inc.). Thickness measurements were collected for phloem on undamaged trees, and the last (most recent) annual growth ring and the last 5 years of radial growth immediately preceding the year of damage. Variability in phloem thickness prompted us to gather more data by measuring and coring an additional 27 undamaged trees in six of the sample stands.

We used linear regression analysis with SPSS (IBM Software) to study relationships between DBH at the time of damage, radial growth leading up to the time of damage (1 year or 5 years of growth prior to damage), and phloem thickness measured on undamaged trees (table 1). Data were transformed to reduce skewness in data distributions. Model selection was based on AIC (Burnham and Anderson 2002).

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Table 1—Summary data for redwood tree size (DBH) and anatomical variables: (DBH increment over most recent growing season (1-yr), average DBH increment over most recent 5 years (5-yr), and radial thickness of phloem layer at DBH, Mill Creek, Del Norte County, California)

Variable	n	Mean	Std. dev.	Min.	Max.
DBH (cm)	47	29.81	8.22	15.75	51.74
1-yr DBH increment (mm yr^{-1})	47	3.09	1.36	0.48	5.79
5-yr DBH increment (mm yr^{-1})	47	3.52	1.64	0.61	7.25
Phloem thickness (mm)	47	3.83	0.90	2.01	5.38

The phloem layer was thicker in larger redwood trees, and slightly thicker in redwoods exhibiting more rapid diameter growth over the growing season preceding sampling. The 1-yr DBH increment was a better predictor of phloem thickness than the 5-yr DBH increment. The most parsimonious model for phloem thickness included only tree size (DBH) as a predictor variable. The slightly better-fitting model with equivalent AIC score included tree size and recent DBH growth (1-yr DBH increment) (table 2). The low variance inflation factors (VIF = 1.028; where 1 = no relationship, 10 = important collinearly) indicated that these two predictor variables were indeed independent. Modeled estimates indicated that phloem thickness was influenced by growth rates more among smaller trees in our sample (fig. 1).

Table 2—Regression models for radial thickness of redwood phloem layer at breast height as a function of tree size (DBH) and DBH increment over most recent growing season (1-yr), Mill Creek, Del Norte County, California (dependent variable: squared phloem thickness, mm^2)

Variable	Estimate	Std. error	Pr > |t|
Intercept	-16.6432	11.08	0.1401
Ln DBH (cm)	7.8832	3.29	0.0210
Ln 1-yr DBH increment (mm yr^{-1})	4.1687	2.64	0.1217
$R^2_{adj.} = 0.144$ $AIC = 174.97$			
Intercept	-13.8969	11.12	0.2178
Ln Dbh (cm)	8.7429	3.30	0.0111
$R^2_{adj.} = 0.116$ $AIC = 175.55$			

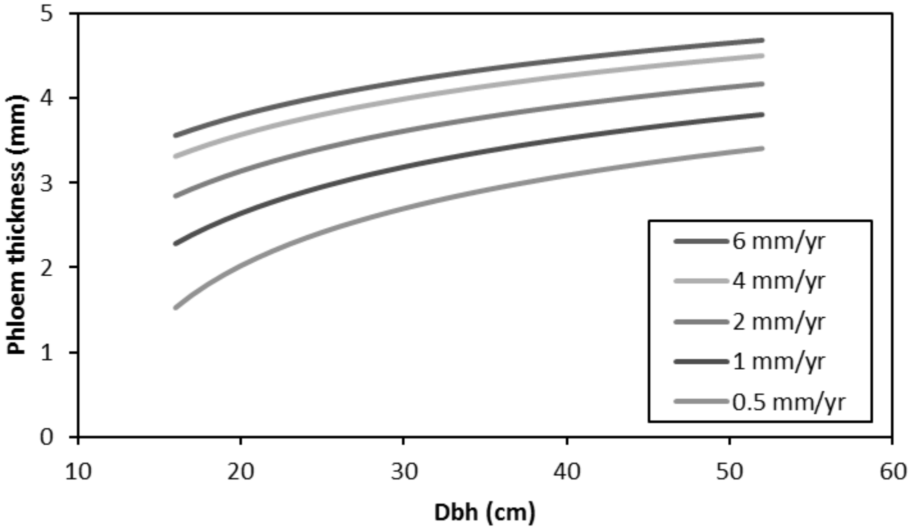

Figure 1—Modeled estimates of phloem thickness at DBH, Mill Creek, Del Norte County, California.

We recommend further study into the relationship between anatomical attributes such as phloem thickness and their relationship to forest management and the probability of bear damage in a variety of stand ages and structures.

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Literature Cited

Burnham, K.P.; Anderson, D.R. 2002. Model selection and multimodel inference. 2nd ed. New York: Springer-Verlag. 488 p.

Fritz, E. 1951. Bear and squirrel damage to young redwood. Journal of Forestry. 49(9): 651–652.

Giusti, G.A. 1988. Recognizing black bear damage to second growth redwoods. In: Crabb, A.C.; Marsh, R.E., eds. Proceedings of the 13th vertebrate pest conference. Davis, CA: University of California: 188–189.

Giusti, G.A. 1990. Black bear feeding on second growth redwoods: a critical assessment. In: Davis, L.R.; Marsh, R.E., eds. Proceedings of 14th vertebrate pest conference. Davis, CA: University of California: 214–217.

Hosack, D.A.; Fulgham, K.O. 1998. Black bear damage to regenerating conifers in northwestern California. Journal of Wildlife Research. 1(1): 32–37.

Kimball, B.A.; Nolte, D.L.; Engeman, R.M.; Johnston, J.J.; Stermitz, F.R. 1998. Chemically mediated foraging preference of black bears (*Ursus americanus*). Journal of Mammalogy. 79(2): 448–456.

Perry, D.W.; Breshears, L.W.; Gradillas, G.E.; Berrill, J-P. 2016. Thinning intensity and ease-of-access increase probability of bear damage in a young coast redwood forest. Journal of Biodiversity Management and Forestry. 5(3): 1–7.