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Post-Fire Growth in Ponderosa Pine (*Pinus ponderosa* Dougl.) in Boulder County, Colorado

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Abstract- In this study, I examine the effects of high-intensity fires on the growth rate of ponderosa pine along the Front Range in Boulder County, Colorado. By sampling 107 trees from four sites (two burned, two unburned), I found that both 2 and 6/7 year growth rates of burned ponderosa pines is greater than that of unburned ponderosas. In addition, I found that unburned trees within a burned area have higher growth rates than burned trees in the same area. These increases in growth rates are associated with increases in nitrogen and reduction of competition found after fire. This study indicates that prescribed fires of high-intensity will not adversely damage ponderosa pines and may stimulate their growth.

INTRODUCTION

Many types of flora in fire-prone ecosystems have evolutionary adaptations to fire. Often, these adaptations serve to protect plants or enable plants to regenerate, allowing them to monopolize the abundant resources which exist after fire (Whelan 1995). Similarly, flora which can survive fires, such as ponderosa pine (*Pinus ponderosa*), may also take advantage of the increased post-fire resources. Living in areas which experience surface fires every 5-40 years (Aber and Melillo 1991), such as the Colorado Front Range, ponderosa pine have two major adaptations to fire. First, the cones of *P. ponderosa* exhibit bradyspory (seed retention) and pyriscence (fire-stimulated seed release) which allow seeds to monopolize low competition and increased nutrient concentrations which exist after fire (Whelan 1995). Second, due to its thickness, ponderosa bark acts as an insulator against the heat of fire (pers.

obs.), allowing established trees to survive the surface fires common in ponderosa forests.

However, enduring the passage of fire does not guarantee that an individual tree will survive. Many chemical and physical changes, including changes in temperature, moisture, and nutrient composition, occur during and after fire; these changes can influence post-fire growth rates. For example, researchers propose that an increase in nutrients after fire may lead to increased growth in ponderosa. Heidmann (1985) found post-fire increases in nitrogen which led to minor diameter-growth increases in ponderosa. Similarly, Ryan and Covington (1986) found an 80-fold increase in plant-available nitrogen after fire in high fuel-loaded areas; however, they did not identify any related growth increases. Ponderosa individuals in northeast Washington also showed a post-fire increase in growth; researchers found diameter increases of 36% 7 years after a prescribed fire (Morris and Mowat 1958). In contrast, Wooldridge and Weaver (1965) found no change in diameter growth in ponderosa six years after fire. Decreases in growth after fire have also been reported (Chambers *et al.* 1986).

Sutherland *et al.* (1991) found that an increase in nutrients, namely nitrogen, did not necessarily lead to increased growth in *P. ponderosa*. They indicated that other factors, such as previous condition of the individual, cambial and root damage, and changes in nutrient and water relations, also influence post-fire growth. By modeling these and other factors, Sutherland *et al.* (1991) predicted a reduction in growth for two years after fire with a return to control growth rates after the second year.

In this study, I determine the post-fire growth response of Front Range ponderosa trees in Boulder County, Colorado to high-intensity fires. In addition, I compare these results with previous studies' results to help

identify possible causes of observed growth changes and discuss the implications of these results for local land managers.

METHODS

Study Sites

In this study, I collected samples from four ponderosa sites: two sites located east of Olde Stage Road, Boulder, Colorado, two sites located near Sugarloaf Mountain, Sugarloaf, Colorado (Figure 1). *P. ponderosa* dominated all sites which ranged in slope from 10 - 30 degrees. One Olde Stage site and one Black Tiger site experienced a high-intensity wildland fire within the last ten years; the Olde Stage Fire occurred on November 24, 1990, burning 2,210 acres (Lipsher 1990), while the Black Tiger Fire (near Sugarloaf Mountain) burned almost 2,100 acres on July 9, 1989 (National Fire Protection Agency 1989).

Sampling Methods

At both the Olde Stage burn site (OS-B) and the Black Tiger burn site (BT-B), I categorized ponderosa individuals which exhibited ≥ 1 meter of bark scorch as burned trees. In addition, I classified ponderosa individuals at the OS-B site which exhibited $\leq .25$ square meter of bark scorch as unburned trees within the burn (OS-UB). I have designated the unburned sites as follows: Olde Stage unburned site - OS-U, Black Tiger unburned site BT-U. At all four sites, I measured tree DBH and sampled only trees with DBHs ranging from 32.3 centimeters to 48.5 centimeters. Then, using an increment core borer, I extracted samples from the trees meeting the above criteria at each site. Sample sizes ranged from 18 cores from the OS-UB site to 25 cores from the OS-B site (Table 1). I then numbered and measured the cores for both two

Sample Type	Number of Samples
OS-B	25
OS-U	24
OS-UB	18
BT-B	20
BT-U	20

Table 1 - Sample sizes in number of cores for each of the five site types.

and six or seven year post-fire growth in millimeters per year. Since the fires occurred in two different years (BT - 1989 and OS - 1990), I calculated growth rates at the latest available post-fire year; since the 1997 growing season had not yet commenced at the time of sampling, I calculated seven- and six-year growth rates for the Black Tiger and Olde Stage fires respectively. I calculated the burned, unburned, and unburned in burn mean growth rates for each site. Burned and unburned values from both the OS sites and the BT sites were combined, and statistical analysis consisting of a two factor ANOVA was performed using JMP statistics package (SAS Institute Inc.).

RESULTS

At both two and six/seven years, ponderosa individuals in burned plots displayed higher growth rates than those in the unburned plots (Figures 2 and 3); however, these differences in growth rates show only slight significance, $p_2 = 0.0809$ and $p_{6/7} = 0.0626$ (Table 2). In addition, the unburned individuals located inside the Olde Stage burn displayed equal or greater growth than the burned trees; again, these data show only slight significance.

Post-fire Age	F value	df	p
2 Years	2.5762	2/104	0.0809
6/7 Years	2.8469	2/104	0.0626

Table 2 - Statistical values for 2- and 6/7-year post fire growth rates for all sites.

DISCUSSION

This study indicates a trend of increased growth in *P. ponderosa* when exposed to high-intensity fires. Researchers have identified several possible reasons for the increased post-fire growth rates shown to occur in *P. ponderosa* along the Front Range. Sutherland *et al.* (1991) proposed a model to summarize the factors influencing post-fire growth in ponderosa:

$$\text{PFG} = \text{PC} + \text{CD} + \text{RD} + \text{FL} + \text{TI} + \Delta\text{N} + \Delta\text{W} + \text{Y} + \text{TY}$$

PFG = post-fire growth

CD = cambial damage

FL = foliage loss

ΔN = change in nutrient availability

Y = year since burning

PC = previous condition

RD = root damage

TI = thinning

ΔW = change in water relations

TY = response and recovery factor

Researchers have examined several of these factors in-depth. First, ash produced by fire releases nutrients ordinarily caught up in forest litter (Weaver 1967, Covington and Sackett, 1992, Peterson *et al.* 1994, Whelan 1995). Most importantly, increases in nitrogen which accompany fire can lead to increased growth in *P. ponderosa* (Ryan and Covington 1986). This increase in nitrogen results from higher mineralization and decomposition rates resulting from increased soil temperatures, pH, availability of cations. Similarly, increased temperatures from fire can also stimulate nitrogen fixation by microbes, leading to higher nitrogen concentrations (MacLean *et*

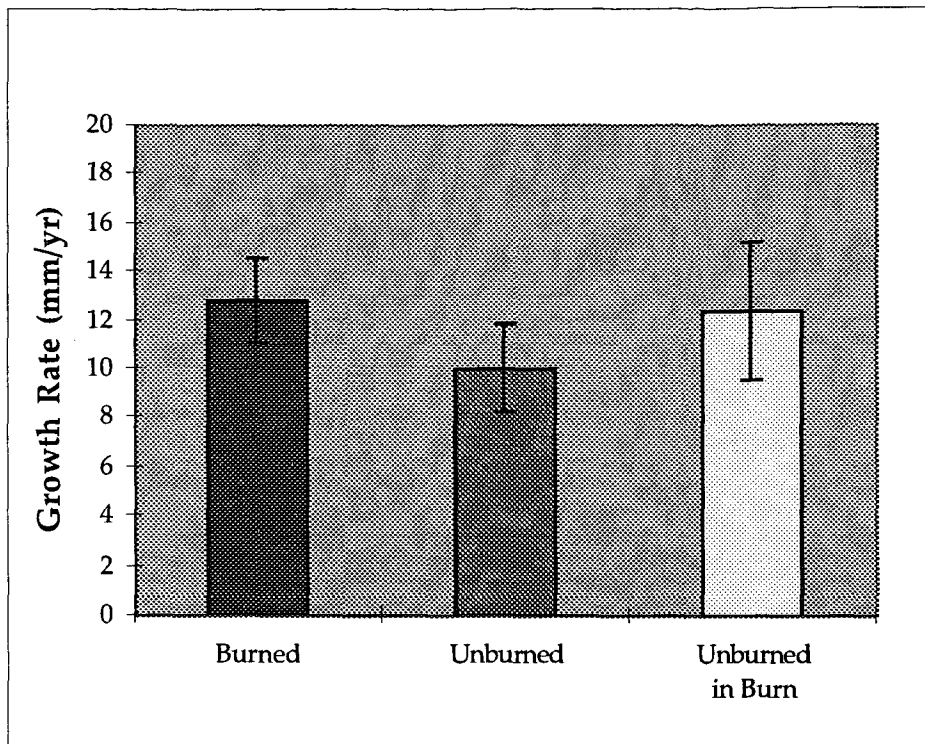


Figure 2 - Comparison of mean, annual growth and 95% confidence intervals 2 years after fire in three burn category, ponderosa sites.

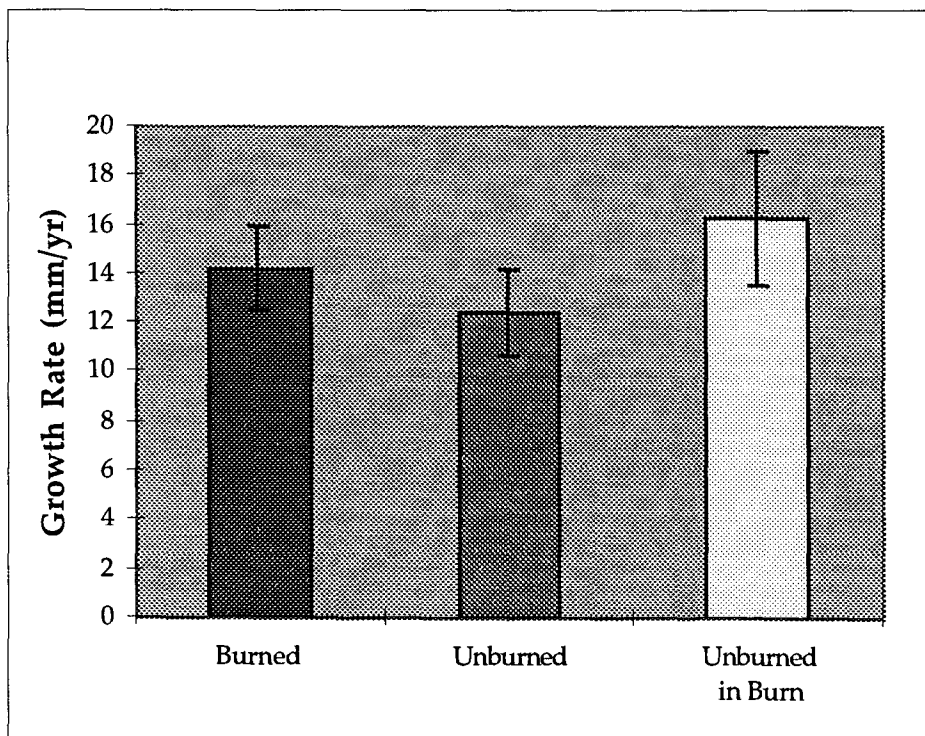


Figure 3 - Comparison of mean, annual growth and 95% confidence intervals 6/7 years after fire in three burn category, ponderosa sites.

al. 1983). Sampling of nitrogen levels in the sites used for this study would indicate the importance of higher nitrogen concentrations in ponderosa growth rate.

Secondly, the reduction of stand densities (TI in the model proposed by Sutherland *et al.* (1991)) caused by fire acts to increase growth rates through higher nutrient availability and increased light and water availability (Sutherland *et al.* 1991, Peterson *et al.* 1994). A spatial test, such as the nearest-neighbor test, performed at burned and unburned sites in this study could identify if a reduction in competition occurred at these sites, and consequently, the importance of this reduction on growth rates. In addition, studies comparing growth rates in relation to differing intensities of fire are also needed. While high-intensity fire increases growth rates in *P. ponderosa*, lower intensity fires may cause different responses.

The model proposed by Sutherland *et al.* (1991) indicates the importance of damage which an individual incurs in a fire through cambial and root damage. The growth response of unburned individuals within the Olde Stage burn confirms this component of the model. The growth increase shown at both 2 and 6 years implies that the unburned trees, which were damaged to a lesser extent than the burned trees, could allocate more resources to growth, rather than repair. The unburned individuals were able to benefit from the fire (due to increased nutrients and decreased competition) without suffering any adverse fire effects (cambial or root damage). Consequently, I would hypothesize that the extent to which trees are damaged in a fire will affect the amount of resources allocated to repair, and therefore not used for growth. Under this hypothesis, we can expect to see an inverse relationship between fire damage and increased growth rate (Figure 4).

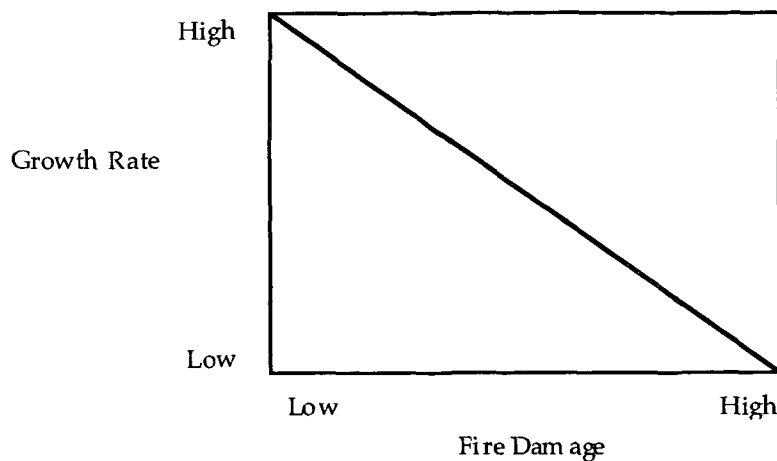


Figure 4- Proposed relationship between fire damage and increased growth rate in *P. ponderosa*.

Although researchers have formulated general principles regarding changes in growth rates after fire, individual trees are subject to varying degrees of fire effects, even over short (2-3 meter) distances (pers. obs.). In this study, individual trees may have experienced very different post-fire microclimates. This phenomenon can lead to varied individual and community responses to a given fire; for example, the model by Sutherland *et al.* (1991) predicted a decrease in growth 2 years after fire, with a return to control growth levels after the second year. However, field studies on *P. ponderosa* indicate a wide range of responses, from increased radial growth (Morris and Mowat 1958, Cooper 1960, Weaver, 1967, Wyant *et al.* 1983, Peterson *et al.* 1994) to decreased radial growth (Wooldridge and Weaver 1965, Chambers *et al.* 1986, Cochran and Hopkins 1991, Peterson *et al.* 1994) to no change in growth rates (Wooldridge and Weaver 1965).

Results from these studies illustrate the variability in growth response which occurs after fire, both in different ecosystems and landscapes and at different temporal scales. For example, Peterson *et al.* (1994) found increased

growth in plots with a burn cycle of 4 - 6 years, while the other plots (1-, 2-, 8-, and 10-year plots) showed decreased growth. These results identify an important component of fire-ecology studies: temporal scale. I examined both 2-year and 6/7-year growth rates, both of which showed similar increases in radial growth when compared to control (unburned) plots. However, my study did not identify fire-return rates for the burned sites, illustrated by Peterson *et al.* (1994) as playing a crucial role in determining species' post-fire growth responses.

CONCLUSION

This study identified post-fire growth responses in *P. ponderosa* along the Colorado Front Range in Boulder County, Colorado. Exposure to high-intensity fire (such as during the Olde Stage Fire or the Black Tiger Fire) can increase radial growth rates in ponderosa pine; researchers have shown an increase in nutrients and the reduction of competition after fire as two major sources for these increases.

As land managers begin to reintroduce fire into the ponderosa pine environment, knowledge of species' responses to fire is crucial. This study indicates that the use of fire to reduce fuel loads and to increase forest health will not adversely affect *P. ponderosa*, and may, in fact, enhance growth. Further studies which attempt to quantify growth responses must also take into account the fire-return times and intensities in addition to the host of other factors which can influence post-fire growth rates.

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- Chambers, J.L., Dougherty, P.M., and Hennessey, T.T. 1986. Fire: its effects on growth and physiological processes in conifer forests. In: T.C. Hennessey, P.M. Dougherty, S.V. Dossuth, and J.D. Johnson (eds.), Stress Physiology and Forestry Productivity. Martinus Nijhoff, Dordrecht.
- Cochran P.H. and W.E. Hopkins. 1991. Does fire exclusion increase productivity of ponderosa pine? In Proceedings of the Symposium on Management and Productivity of Western-Montane Forest Soils. USDA Forest Service General Technical Report INT-280. pp. 224-229.
- Cooper, C.F. 1960. Changes in vegetation, structure, and growth of southwestern pine forests since white settlement. Ecological Monographs, 30: 129-164.
- Covington, W.W. and S.S. Sackett. 1992. Soil mineral nitrogen changes following prescribed burning in ponderosa pine. Forest ecology and Management, 54: 175-191.
- Grier, C.C. 1989. Effects of prescribed springtime underburning on production and nutrient status of a young ponderosa pine stand. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-185.
- Harrington, M.G. and S.S. Sackett. 1992. Past and present influences on southwestern ponderosa pine old growth. In M.R Kaufmann, W.H. Moir, and R.L. Bassett (eds.), Proceedings of the Workshop on Old-

growth Forests of the Southwest and Rocky Mountain Region. USDA Forest Service General Technical Report RM-213. pp. 44-50.

Heidmann, L.J. 1985. Heavy fertilization increases diameter growth slightly in a 55-year-old ponderosa pine stand in central Arizona. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Research Note RM-452.

Lipsher, S. "Boulder blaze contained; damage about \$2 million." Denver Post, 26 November 1990. 1A+.

MacLean, D.A., S.J. Woodley, M.G. Weber, and R.W. Wein. 1983. Fire and nutrient cycling. Pages 111-132 in *The role of fire in the northern circumpolar ecosystems* (edited by R.W. Wein and D.A. MacLean). John Wiley and Sons, Chichester.

Morris, W.G. and Mowat, E.L. 1958. Some effects of thinning a ponderosa pine thicket with a prescribed fire. *Journal of Forestry*, 56:203-209.

National Fire Protection Agency. 1989. *Black Tiger Fire Case Study*. National Fire Protection Agency, Quincy, MA.

Peterson, D.L., S.S. Sackett, L.J. Robinson, and S.M. Hasse. 1994. The effects of repeated prescribed burning on *Pinus ponderosa* growth. *International Journal of Wildland Fire* 4(4): 239-247.

Ryan, M.G. and Covington, W.W. 1988. Effect of a prescribed burn in ponderosa pine on inorganic nitrogen concentrations of mineral soil.

USDA Forest Service, Rocky Mountain Forest and Range Experiment
Station, Research Note RM-464.

SAS Institute Inc. JMP Statistical Software. SAS Institute Inc., Cary, NC.

Sutherland, E.K., Covington, W.W., and Andariese, S. 1991. A model of
ponderosa pine growth response to prescribed burning. *Forest Ecology
and Management*, 44:161-173.

Weaver, H.A. 1967. Fire and its relationship to ponderosa pine. *Proceedings
of the Tall Timbers Fire Ecology Conference*, 7: 127-149.

Whelan, R.J. 1995. *The Ecology of Fire*. Cambridge University Press.

Wooldridge, D.D. and Weaver, H. 1965. Some effects of thinning a
ponderosa pine thicket with a prescribed fire II. *Journal of Forestry*,
63:92-95.

Wyant, J.G., R.D. Laven, and P.N. Omi. 1983. Fire effects on shoot growth
characteristics of ponderosa pine in Colorado. *Canadian Journal of
Forest Research*, 13: 620-625.