We divided the 24 plots into 11 that were burned and thinned, eight burned with no thinning, two thinned but not burned, and three left untreated as a control. Practical constraints necessitated assignment of unequal numbers of plots for each treatment. Prior to treatments, there were an average of 92.1 overstory trees per acre (227.5 trees/ha) and 9,397 saplings per acre (23,210.6 saplings/ha). We defined overstory trees as being greater than 4.5 inches diameter at breast height. Our initial goal was to reduce the overstory by 25 percent, and increase the prevalence of white oak and pine species while reducing that of red and black oaks. From September to December 2000, local loggers harvested all overstory trees, except white oaks and pines, on thinning-treatment plots. Prescribed burns were conducted in either March 2001 or February 2002.

In August 2002, we found that the number of overstory trees per acre was significantly lower in thinned plots (36.4), but did not change in response to burning alone (115.7). Neither burning nor thinning significantly affected sapling density. Although the total number of groundcover species increased from an average of 10.9 species per plot to 20.2 species in the burned and/or harvested areas, this increase was not statistically significant when compared to the average number of species in control plots (12.5). In contrast, we found that burning significantly increased the floristic quality index (FQI) (Swink and Wilhelm 1994) in plots. Before treatments, the mean FQI for all plots was 14.35. By 2002, the average FQI of burned plots increased to 19.85 compared to 14.64 for unburned plots. Plants with high coefficients of conservatism in Missouri that were new or increased after burning included black edge sedge (*Carex nigromarginata*), cypress panicgrass (*Panicum annulum*), Sampson's snakeroot (*Orbexilum pedunculatum* var. *psoralioides*), and western rough goldenrod (*Solidago radula*).

While numerous studies have shown the benefits of using prescribed burns to restore woodlands and barrens in the midwestern United States (for example, Anderson and Schwegmann 1999, Laatsch and Anderson 2000), few have demonstrated the potential of using judicious forest harvesting to restore the structure of native pine-oak woodlands. Our initial data from this project indicate that prescribed fire alone, and in combination with forest thinning, are useful strategies, and we are continuing to monitor the long-term effects of these treatments.

In areas like Carter County, where timbering has historically supported local economies, the use of harvesting as a restoration tool is valuable both to the landscape and the people who inhabit it (LeVan-Gree and Livingston 2003). By restoring these pine-oak woodland communities for ecological as well as social benefits, we are creating a biologically diverse and stable landscape in which to live, a beautiful place to recreate, and a small yet sustainable source of income for the future.

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References

Anderson, R. and J. Schwegman. 1991. Twenty years of vegetational change on a southern Illinois barren. *Natural Areas Journal* 11:100-107.

Laatsch, J. and R. Anderson. 2000. An evaluation of oak woodland management in northeastern Illinois, USA. *Natural Areas Journal* 20:211-220.

Ladd, D. 1991. Reexamination of the role of fire in Missouri oak woodlands. Pages 67-80 *in* G.V. Burger, J.E. Ebinger, and G.S. Wilhelm (eds.), Proceedings of the Oak Woods Management Workshop. Charleston: Eastern Illinois University.

LeVan-Green, S. and J. Livingston. 2003. Uses for small-diameter and low value forest thinnings. *Ecological Restoration* 21(1):34-38.

McCarty, K. 1998. Landscape-scale restoration in Missouri savannas and woodlands. *Restoration & Management Notes* 16:1(22-32).

Swink, F. and G. Wilhelm. 1994. *Plants of the Chicago region*. Indianapolis: Indiana Academy of Science.

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Seeding with Natives Increases Species Richness in a Dry Ponderosa Pine Forest (Arizona)

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Many restoration practitioners in the southwestern United States have questioned the efficacy of seeding native understory species in regional ponderosa pine (*Pinus ponderosa*) forests, where limited soil moisture and inopportune precipitation events may prevent many seeds from germinating. Moreover, some researchers and land managers are concerned that seeding could potentially introduce exotics or plants of unknown genetic history (Allen and others 2002). Seeding, however, may provide a supplemental source of propagules in thinned and burned areas that lack mature, seed-dispersing native plants. Sowing native plant seeds on bare mineral soil that is sometimes exposed by prescribed burns may help jump-start revegetation and provide resistance to colonization by non-native species.

To better understand the effects of seeding, we compared changes in species richness and composition in 11 seeded and 8 unseeded 0.25-acre (0.1-ha) monitoring plots located in a ponderosa pine-Gambel oak (*Quercus gambelii*) forest at Grand Canyon-Parashant National Monument (GCPNM) in northwest Arizona. All plots were located in areas that were thinned by fall 1998 and burned in early 1999. Pine trees were thinned from an average density of 75 trees per acre (185 trees /ha) to 18 per acre (46 trees/ha). The seeded plots were evenly spaced throughout nearly 175 acres (71 ha), where, in the summer of 1999, Bureau of Land Management staff had hand broadcast seed at an average rate of 8 lbs of pure live seed per acre (9 kg/ha). The certified weed-free seed mix included native species that were previously inventoried in the study area and were commercially available and affordable (Table 1). The main management objective was to create a grass-dominated understory that would provide continuous fuels to carry frequent ground fires (Schoppmann 1999).

In 2003, we found that species richness in the seeded plots had increased since a 1996 survey by a mean of 27.4 species per plot compared to 17.9 species in the unseeded plots (repeated ANOVA, $f = 6.1$, $p = 0.02$). There were more grass species in the seeded plots, probably because grass seeds were conspicuously absent from the seed bank in ponderosa pine forests at GCPNM (Springer 1999). We found no difference in rate of increase in forb species richness between seeded and unseeded plots.

Six species increased considerably after seeding (Table 1). For example, needle and thread (*Hesperostipa comata*) increased its presence by 36 percent in seeded plots and did not change on unseeded plots. Four other grasses—mountain brome (*Bromus marginatus*), slender wheatgrass (*Elymus trachycaulus*), prairie Junegrass (*Koeleria macrantha*), and western wheatgrass (*Pascopyrum smithii*)—and one forb, prairie flax (*Linum lewisii*), also increased notably. We recommend that these species be included in seeding treatments in ponderosa pine forests at GCPNM and investigated for use at other restoration sites in northern Arizona where they are found in the extant vegetation.

Non-native species increased slightly in all plots after thinning and burning, which is to be expected after disturbance. Unfortunately, we cannot determine whether these species were introduced in the seed mix or in some other manner. We observed a greater increase in native species and no difference in percentage of exotic species between seeded and unseeded plots. Cheatgrass (*Bromus tectorum*), an invasive annual, was abundant in 2003 and is a cause of concern. We suspect that it germinated from the soil seedbank, since it was present on the site before treatment (Springer 1999).

The cost of prescribed thinning and burning in southwestern montane forests ranges from \$200 to \$800 per acre (\$500-\$2,000/ha) (Snider and others 2003). The seeding treatments for this study cost about \$110 per acre (\$275/ha) (Schoppmann 1999). Given the enormous amount of acreage that is under consideration for restoration in this region, these high costs could be a problem. However, we recommend seeding with natives if the primary goal is to increase species richness in degraded ponderosa pine forests. We also recommend additional research to determine the species-specific mortality rates of sown seeds, find more native forb and shrub species that can germinate reliably under semi-arid field conditions, and develop optimal seed mixes and seeding methods for southwestern ponderosa pine forests.

Table 1. Changes from 1996 to 2003 in frequencies (proportion of total plots in which a species was detected) of native seeded species in both seeded and unseeded plots at the Grand Canyon-Parashant National Monument in northwest Arizona.

Seeded Species	% Change Seeded	% Change Unseeded
Grasses		
Achnatherum hymenoides	+18	0
Bouteloua curtipendula	0	0
Bouteloua gracilis	+27	+25
*Bromus marginatus**	+73	-12
Elymus elymoides	+9	0
*Elymus trachycaulus**	+64	+38
Festuca arizonica	0	0
*Koeleria macrantha**	+55	+25
*Hesperostipa comata**	+36	0
*Pascopyrum smithii**	+73	+25
Poa secunda	0	0
Schizachyrium scoparium	0	0
Sporobolus cryptandrus	0	0
Forbs		
Eriogonum umbellatum	0	0
Geranium caespitosum	+9	0
Ipomopsis aggregata	0	0
*Linum lewisii**	+27	+13
Mahonia repens	0	0
Oenothera caespitosa	+9	+25

* Indicates species that notably increased after seeding

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References

Allen, C.D., M. Savage, D.A. Falk, K.F. Suckling, T.W. Swetnam, T. Schulke, P.B. Stacey, P. Morgan, M. Hoffman and J.T. Klingel. 2002. Ecological restoration of southwestern ponderosa pine ecosystems: A broad perspective. *Ecological Applications* 12:1418-1433.

Schoppmann, K. 1999. Seeding trick tank and rye units. Memorandum on file at the Bureau of Land Management, Fredonia, Arizona.

Snider, G.B., D.B. Wood and P.J. Daugherty. 2003. Analysis of costs and benefits of restoration-based hazardous fuel reduction: Treatment vs. no treatment. Progress Report #1, June 13. School of Forestry, Northern Arizona University, Flagstaff. Unpublished report.

Springer, J.D. 1999. Soil seed bank in southwestern ponderosa pine: Implications for ecological restoration. M.S. thesis, Northern Arizona University, Flagstaff.