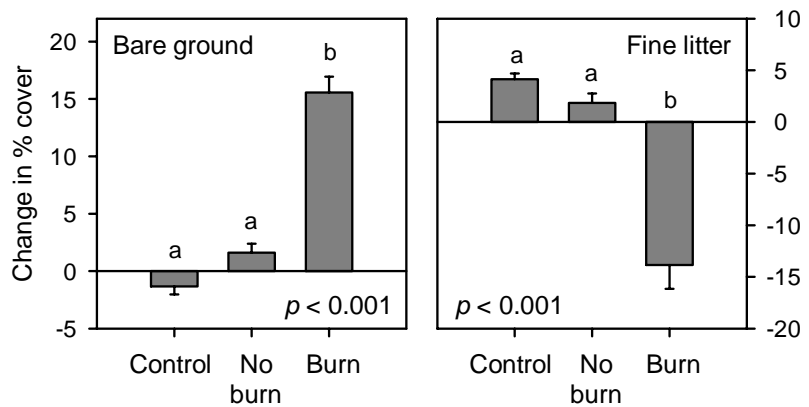


## Early Results

### Tree removal with and without burning

#### Ground-surface conditions

- Ground-surface conditions were unchanged in pile and burn (No burn) treatments (Figs. 30, 31).
- In contrast, broadcast burning (Burn) resulted in significant exposure of mineral soil and loss of fine litter (Figs. 30, 31).



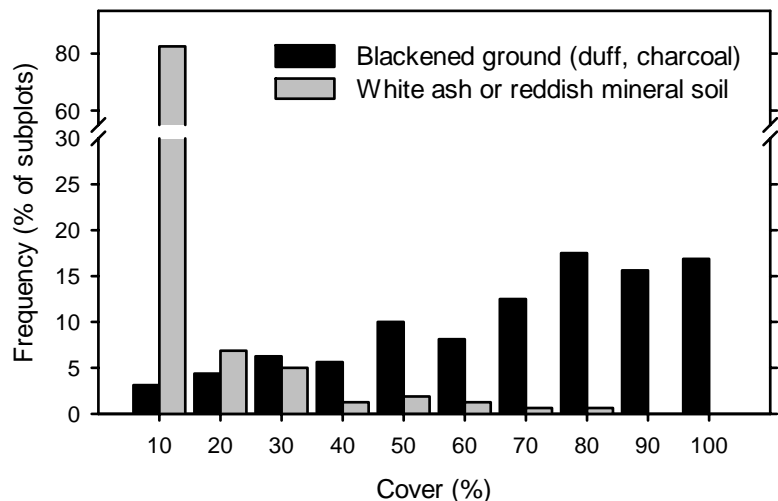
**Fig. 30.** Differences in cover of bare ground (mineral soil) and fine litter among treatments.



**Fig. 31.** Differences in exposure of mineral soil in pile and burn (left) and broadcast burn (right) treatments.

#### Extent and severity of burning

- In broadcast burned plots, burning was extensive, but variable. Half of all subplots had >80% cover of blackened ground (Fig. 32).
- Intensive burning was less common: >80% of subplots had <10% cover of white ash or reddish mineral soil (Fig. 32).

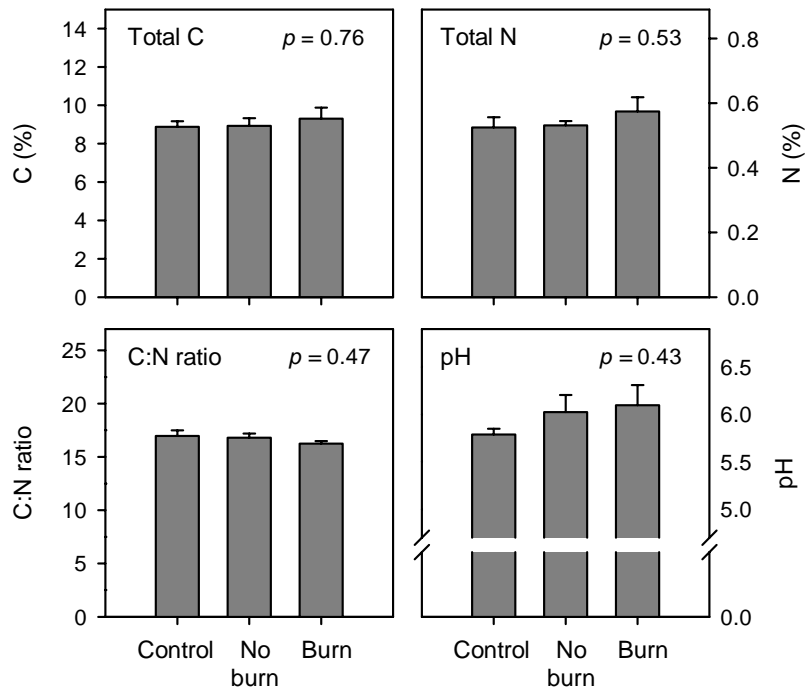


**Fig. 32.** Frequency of subplots with increasing cover of blackened soil or white ash (indicative of more intensive burning).

## Initial effects on soil properties

### Total C and N, C:N ratio, and pH

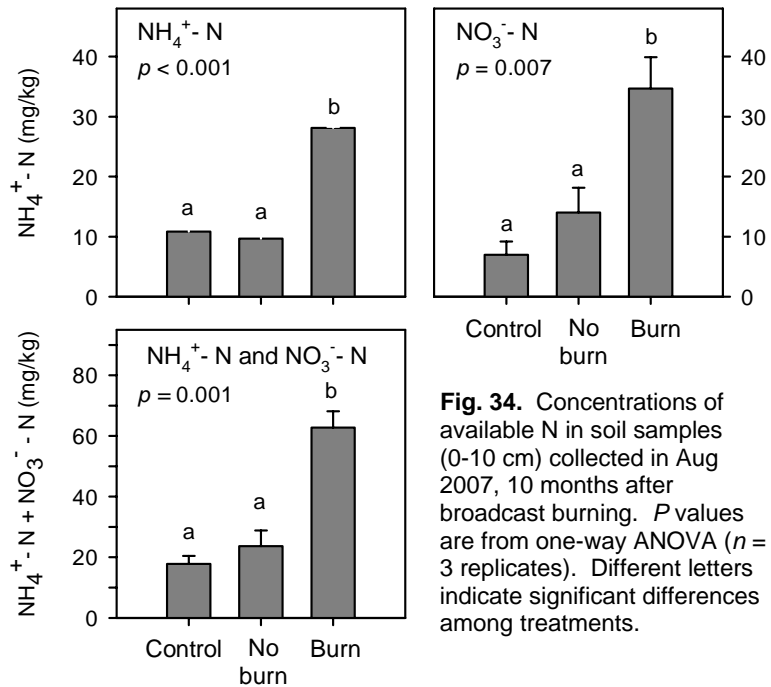
- Ten months after broadcast burning we were unable to detect significant effects of logging or burning on soil pH, total C, or total N (Fig. 33).



**Fig. 33.** Total C, Total N, C:N ratio, and pH of soil samples (0-10 cm) collected in Aug 2007, 10 months after broadcast burning. *P* values are from one-way ANOVA ( $n = 3$  replicates).

### Available N

- However, concentrations of  $\text{NH}_4^+$ -N and  $\text{NO}_3^-$ -N were two to three times greater in broadcast burn than in pile and burn (No burn) treatments (Fig. 34).



**Fig. 34.** Concentrations of available N in soil samples (0-10 cm) collected in Aug 2007, 10 months after broadcast burning. *P* values are from one-way ANOVA ( $n = 3$  replicates). Different letters indicate significant differences among treatments.

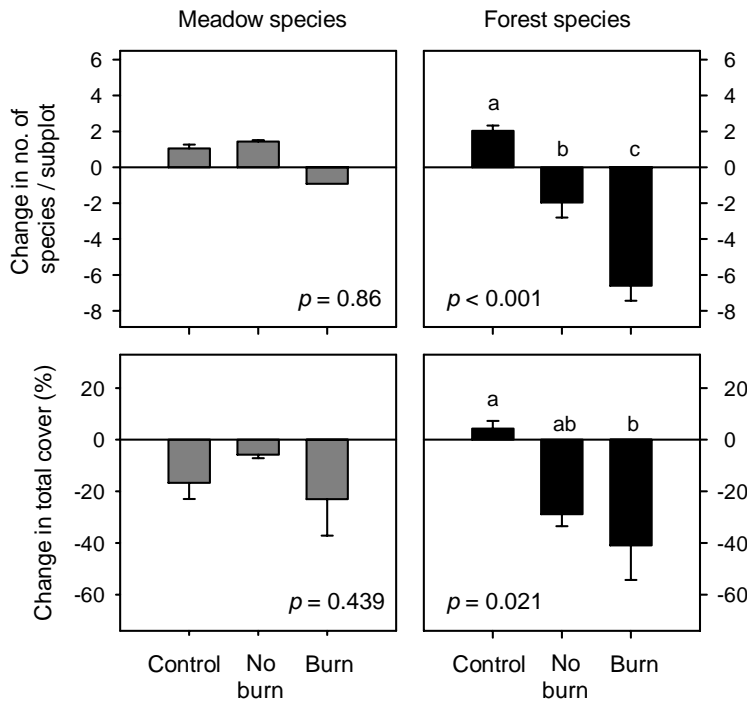
**Initial responses of vegetation**

First-year responses to treatments offer a limited view of the long-term potential for restoration. However, they offer some insights into the initial effects of fire and its interaction with vegetation structure.

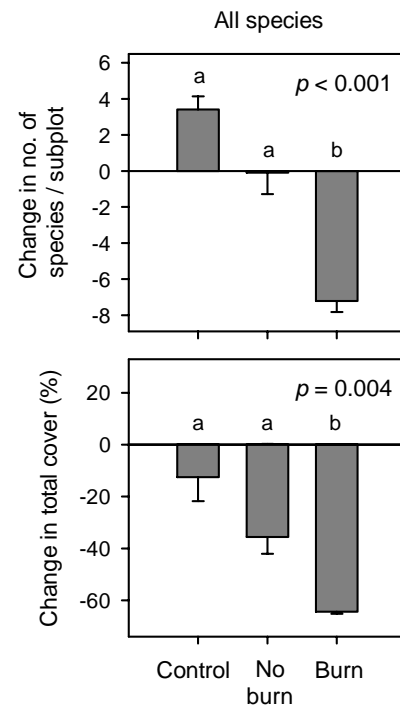
***Is fire necessary for restoration or is tree removal sufficient?***

**Plant richness and cover.** Removal of the overstory resulted in large declines in plant richness and cover (Fig. 35). Declines were significantly larger in burned than in unburned treatments.

**Forest and meadow species.** Declines in richness and cover were largely attributable to forest species; meadow species were less sensitive to fire (Figs. 36, 37).



**Fig. 36.** First-year changes in richness and total cover of meadow and forest species among treatments. See Fig. 35 for other details.

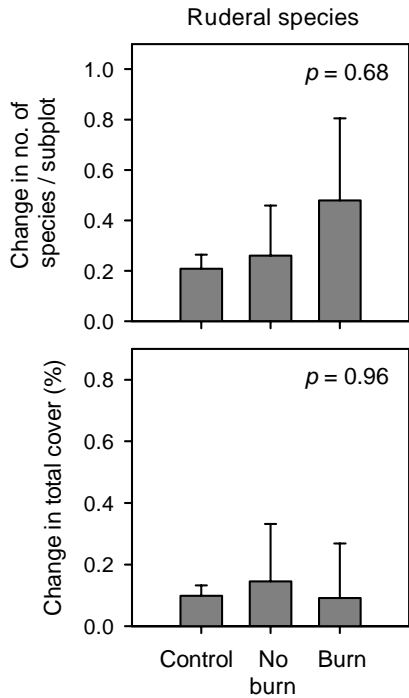


**Fig. 35.** First-year changes in richness and total plant cover among treatments. P values are from one-way ANOVA (n = 3 replicates). Different letters indicate significant differences in means among treatments.

**Fig. 37.** Persistence of a large clone of the forest herb, *Smilacina stellata*, in a pile and burn (No-burn) treatment where it had dominated the understory. Survival was poorer in broadcast burned treatments.

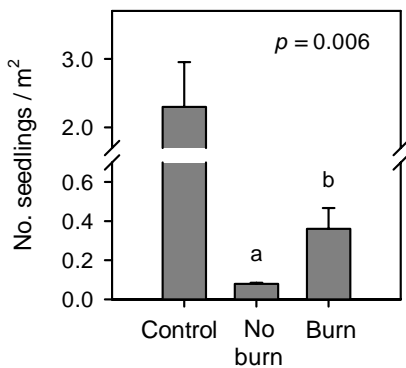


**Ruderal species.** Ruderal species, including native and exotic herbs and grasses, contributed minimally to plant diversity and cover (mean <0.2%) in the first growing season (Fig. 38).



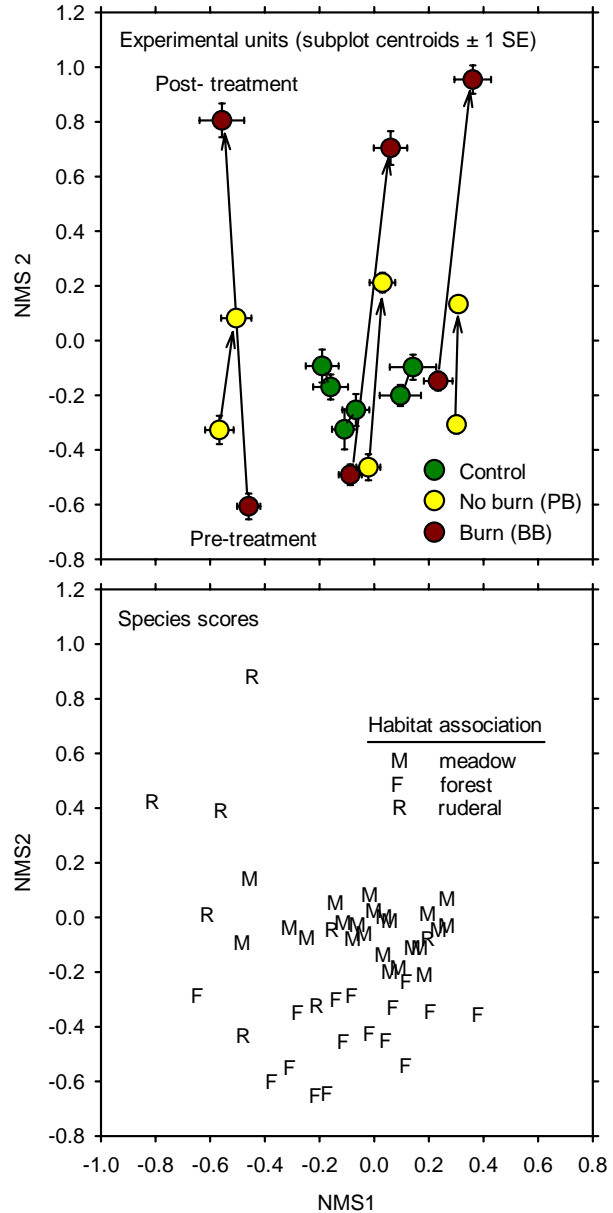
**Fig. 38.** First-year increases in richness and cover of ruderal species among treatments. See Fig. 35 for other details.

**Conifer recruitment.** Conifers recruited at greater density in burned than in unburned treatments (Fig. 40), consistent with the greater exposure of mineral soil by burning.



**Fig. 40.** Density of conifer seedlings (<1 m tall). The  $p$  value is from a t-test between no-burn and burn treatments. Densities in the controls are shown for comparison.

**Changes in composition.** Compositional change as expressed in ordination (NMS) space, was consistently greater in burned than in unburned treatments (Fig. 39). Movement along NMS2 coincided with a shift in dominance from forest (F) to meadow species (M).



**Fig. 39.** NMS ordination of the nine experimental units showing average responses to treatments (subplot centroids  $\pm 1$ SE). Arrows connect pre- and post-treatment samples. Common taxa shown in the species ordination are coded by habitat association. Note the shift in No-burn units toward greater dominance of meadow (M) species.

**Does the potential for restoration depend on the stage of conifer encroachment?**

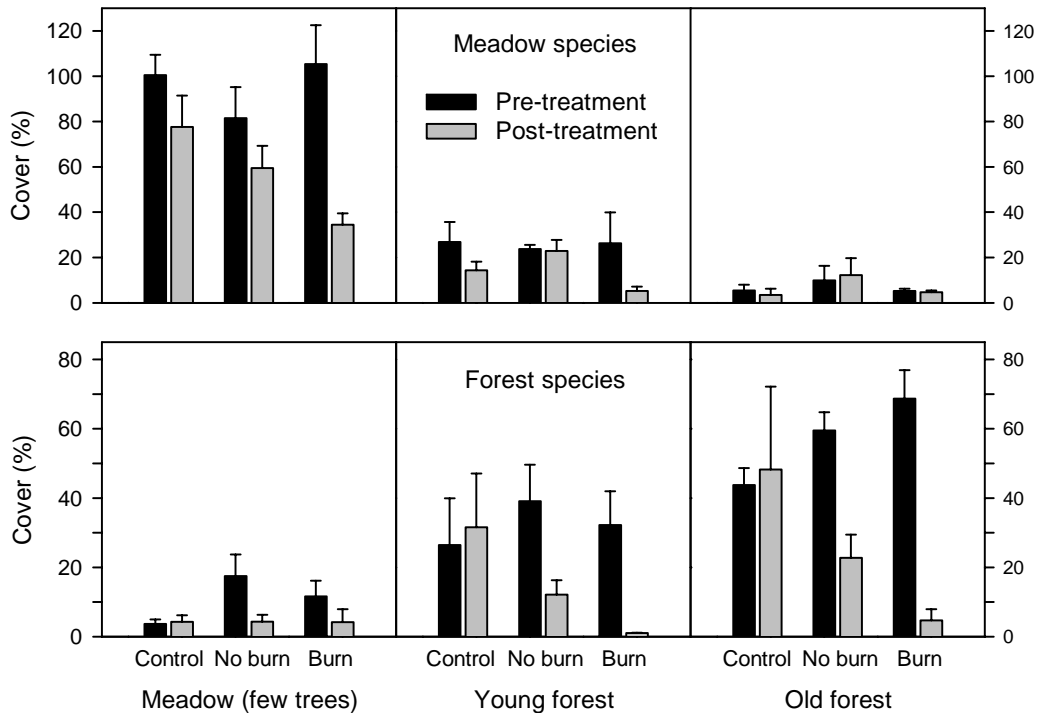
**Open areas with relatively few trees.** In relatively open areas, meadow species declined markedly after burning. Nevertheless, they remained the dominant plant group (Fig. 41).

**Young and old forest.** In areas of young and old forest, where forest understory species had been dominant, meadow species showed:

- neutral or positive responses to overstory removal (No burn), and
- neutral or negative responses to burning (Burn) (Fig. 41).

In contrast, forest understory species showed:

- large and significant declines after overstory removal (Figs. 41, 42), and
- greater loss in burned than in unburned areas (Figs. 41, 42).



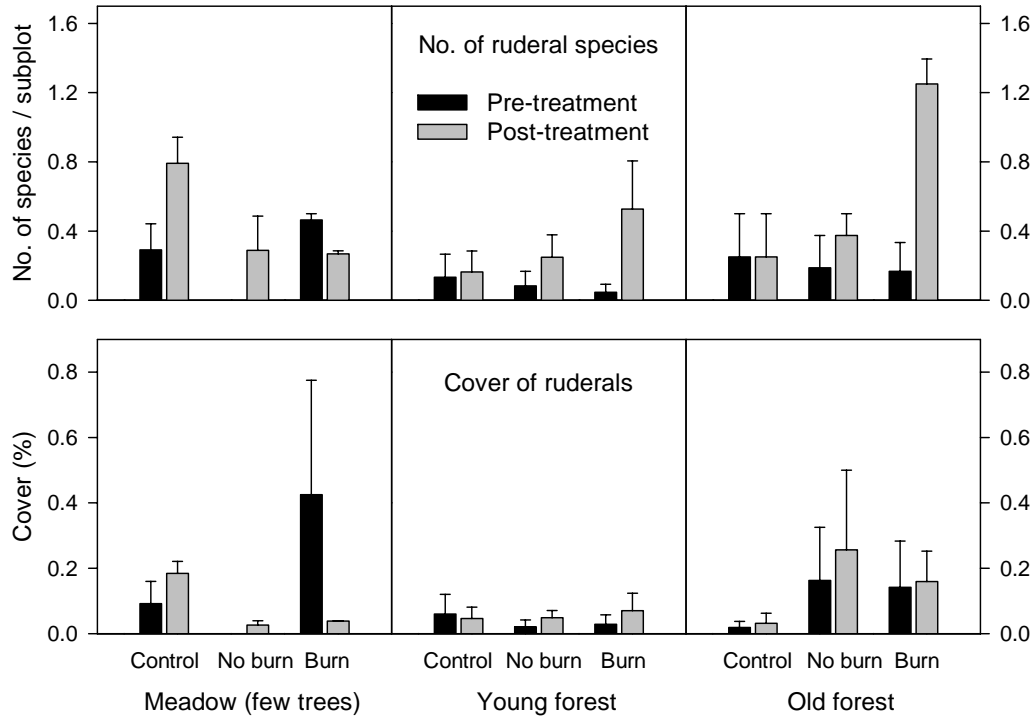
**Fig. 41.** Responses of meadow and forest species to experimental treatments in subplots representing different stages of encroachment: meadow (few trees), young forest, and old forest.



**Fig. 42.** Old forest understories in control, pile and burn, and broadcast burn treatments. Note the persistence of *Achlys triphylla* in the no-burn treatment and dominance of meadow species (*Vicia americana*) in the burn treatment.

## Potential for establishment of ruderals

Although populations of ruderal species were generally sparse, first-year responses suggest greater potential for establishment in previously forested areas and greater diversity of species after burning (Figs. 43, 44).



**Fig. 43.** Variation in the number and cover of ruderal species in subplots representing different stages of encroachment: meadow (few trees), young forest, and old forest.



**Fig. 44.** Ruderal species at Bunchgrass Ridge. *Phacelia heterophylla* (left) and *Ceanothus velutinus* (right) emerged from the soil seed bank; *Ceanothus* was most frequent in burned areas. *Rumex acetosella* (center) was most frequent in areas of former meadow (where it was present prior to treatment).

**Conclusion.** Dramatic shifts in the abundance of meadow and forest species and limited recruitment of ruderals suggest strong potential for restoration through tree removal. Short-term responses to broadcast burning indicate that there are tradeoffs in the use of fire. Although burning greatly reduces the abundance of forest species, exposure of mineral soil may also lead to greater recruitment of ruderals and greater germination of conifer seedlings.