2005

Understory Vegetation Response in Longleaf Pine Forests to Fire and Fire Surrogate Treatments for Wildfire Hazard Reduction and Ecological Restoration

Dale G. Brockway, USDA Forest Service, Southern Research Station, Auburn, AL 36849
and Kenneth W. Outcalt, USDA Forest Service, Southern Research Station, Athens, GA 30602

Objectives

The principal objective is to quantify the responses of the understory plant community to fire and fire surrogate treatments, specifically plant species composition, foliar cover, species richness, diversity, and evenness changes resulting from (1) fire exclusion in the untreated control, (2) prescribed fire, (3) thinning, (4) thinning plus prescribed fire, and (5) herbicide plus prescribed fire. The study should identify the individual species and groups of plants that are most affected (both positively and negatively) by the experimental treatments.

Methods

The overall study consists of a randomized complete block design with five experimental treatments replicated three times. Within each 10-ha treatment unit are located ten measurement plots that are 0.1 ha in size (20 x 50 m). Within each 0.1 ha plot are systematically located twelve quadrats that are each 1 m2 in area. Understory vegetation data were collected from within these 1 x 1 m quadrats. These data consist of percent foliar cover (by vertical projection) for all plants by species and were collected annually during October at the end of each growing season (both pretreatment in 2001 and post-treatment in subsequent years). Understory vegetation data were examined at two levels: the 1 m2 quadrat level and the 0.1 ha plot level. Data for dependent variables were summarized as estimates of the mean for each of the 15 treatments plots. Each plot mean was used to estimate the mean and variance of each of the treatments. For each dependent variable, a comparison of differences among experimental treatments and through the time sequence of repeated measurements was undertaken. Scalar variables were analyzed by a repeated measures analysis of variance (ANOVA, one-way with Tukey's Test), using initial conditions as covariates, to evaluate time and treatment effects and interactions. Treatment responses were contrasted using a set of four pairwise comparisions. The trend through time after treatment was analyzed with orthogonal polynomials. Statistical analysis of the time and treatment interaction for computed diversity indices was completed using the bootstrap technique PROC MULTTEST in SAS. Adjusted p-values, which maintain a constant Type I error across the full range of comparisons were used to determine significant differences among means (10,000 bootstrap interations were used). A probability level of 0.05 was used to discern significant differences.

Results and Discussion

Foliar Cover

The experimental treatments resulted in substantial change in the understory plant community (Table 1). Although the overall foliar cover of all plants in the understory remained generally stable during the period of study, herbicide application in September 2002 resulted in a significant decline (from 51% to 18% cover) during that year (Figure 1). Fire, thinning, and fire+thinning resulted in smaller decreases in total plant cover during the initial 2002 treatment year. However, means for the fire and thinning treatments were not significantly different from the untreated control. By the following year, total plant cover recovered on all treatments with no apparent differences among them. When considering all woody plants or shrubs and tree seedlings, the fire, thinning+fire, and herbicide+fire treatments produced a significant first-year decline (from 38% to 17% cover), with partial recovery in subsequent years (Figures 2 and 3). The effects of the herbicide+fire treatment appeared to persist somewhat longer than other treatments. Woody plants on thinned plots initially declined to a lesser non-significant degree and then emerged with even greater numbers by 2003. The thinning+fire and herbicide+fire treatments significantly decreased (from 13% to 6% cover) the foliar cover of vines, an effect which persisted throughout the study period (Figure 4).

Herbaceous plants generally increased onsite, as a result of the decline in woody plants. During the study period, the foliar cover of all combined herbaceous species doubled on plots receiving the thinning+fire and herbicide+fire treatments (Figure 5). By contrast, the fire and thinning treatments resulted in no significant increase in the overall herbaceous plant cover. Interestingly, the cover of herbs on control plots progressively declined (from 10% to 5 % cover) during this period. The cover of graminoids (principally grasses) increased significantly (from 6% to 13% cover) only on plots receiving the thinning+fire and herbicide+fire treatments (Figure 6). Graminoid cover was largely unchanged by the fire and thinning treatments and declined on the control. The response pattern for forbs (Figure 7) was similar to that for grasses (with increases from 3% to 6% cover). However, forbs exposed to the fire treatment also responded with an increase in foliar cover. For all herbaceous plants, the herbicide application produced a temporary decline in foliar cover during 2002 followed by an increase in subsequent years. The cover data for ferns reflects an overall stable state with no significant positive or negative trends. Invasive shrubs and herbs are not a significant component of this ecosystem (Figure 8).

Plant Diversity

Alpha diversity measures at the 1 m^2 level generally reflected subtle shifts in the composition and abundance of understory plants in response to the experimental treatments (Table 2). Overall species richness was significantly reduced by herbicide application in 2002, but recovered during the subsequent year (Figure 9). Small, non-significant increases in richness resulted from the other treatments. Shannon's index reflected a diversity pattern that was similar to that for richness (Figure 10). Increasing trends for diversity were apparent for all experimental treatments. However, diversity on the control has progressively, though non-significantly, declined. Plant species evenness showed no significant trends through time or across treatments, indicating that the proportional distribution of species has not yet been affected (Figure 11).

Diversity data for herbaceous plants largely paralleled results for all understory species (Figure 12). Herbicide application in 2002 also decreased species richness, after which it recovered. The richness of herbs increased (though non-significantly) through time for the fire, fire+thinning and herbicide+fire treatments. The trend was less clear on the thinning treatment and herb richness appeared to decline on the control. The Shannon index for herbs reflected a similar pattern and the evenness data indicated no significant trends through time or across treatments (Figure 13 and 14). Therefore, diversity values for herbaceous plants were largely driven by species richness. Examination of herbaceous plant data at the 0.1 ha plot level provided additional clarity for these trends (Figure 15). Here, it was evident that the fire, thinning+fire, and herbicide+fire treatments have stimulated progressive increases in herb numbers, while short-term increases in herb richness caused by the thinning treatment appeared to have been nullified by the rapid regrowth of woody plants.

Conclusion

The most effective treatments for mitigating the wildfire hazard and restoring the natural structure and function of longleaf pine forests appear to be the thinning+fire and the herbicide+fire treatments. Both are very effective in rapidly establishing the appropriate stand architecture that then facilitates the safe application of periodic surface fires to achieve and maintain overall forest health. Application of these two treatments also enhances habitat quality by promoting the re-establishment and expansion of native grasses and forbs in the understory plant community. The only noteworthy disadvantage of the herbicide+fire treatment is the decline in understory plants during the period immediately following herbicide application. Fortunately, these resilient ecosystems rapidly recover from this transitory impact. Although the fire treatment is also of some value, it produces results that appear to be less consistently beneficial across the full range of plant groups. While thinning was thought to perhaps serve as a surrogate for prescribed fire, it is now recognized that its effects and benefits are ephemeral and easily lost once woody vegetation regrows to occupy an even greater proportion of the site. Thus, thinning that is not rapidly followed up (in perhaps no more than one year) with prescribed fire is of little value in mitigating wildfire danger or contributing to the aims of ecological restoration.

Table 1. Understory Plant Cover (%) at the Dixon Forest (treatments applied during 2002).

	Control	Fire	Thinning	Thinning Plus Fire	Herbicide Plus Fire
All Plants:					
2001	43.9	54.2	38.2	41.2	51.3
2002	38.0	33.6	30.3	26.0	18.2
2003	44.4	48.9	48.7	40.5	39.8
2004	33.7	36.1	49.1	40.0	44.8
All Woody Plants:					
2001	34.6	41.1	34.1	32.7	40.0
2002	33.6	18.9	25.3	16.9	14.7
2003	38.3	33.1	40.6	27.7	19.8
2004	28.8	20.4	42.7	20.8	25.3
Trees & Shrubs:					
2001	18.9	19.0	23.3	19.1	26.8
2002	20.9	8.5	16.1	11.7	8.5
2003	21.4	16.4	28.9	19.8	15.1
2004	16.0	9.5	29.2	13.8	18.7
Vines:					
2001	15.3	22.1	10.8	13.6	13.2
2002	12.7	10.4	9.2	5.2	6.2

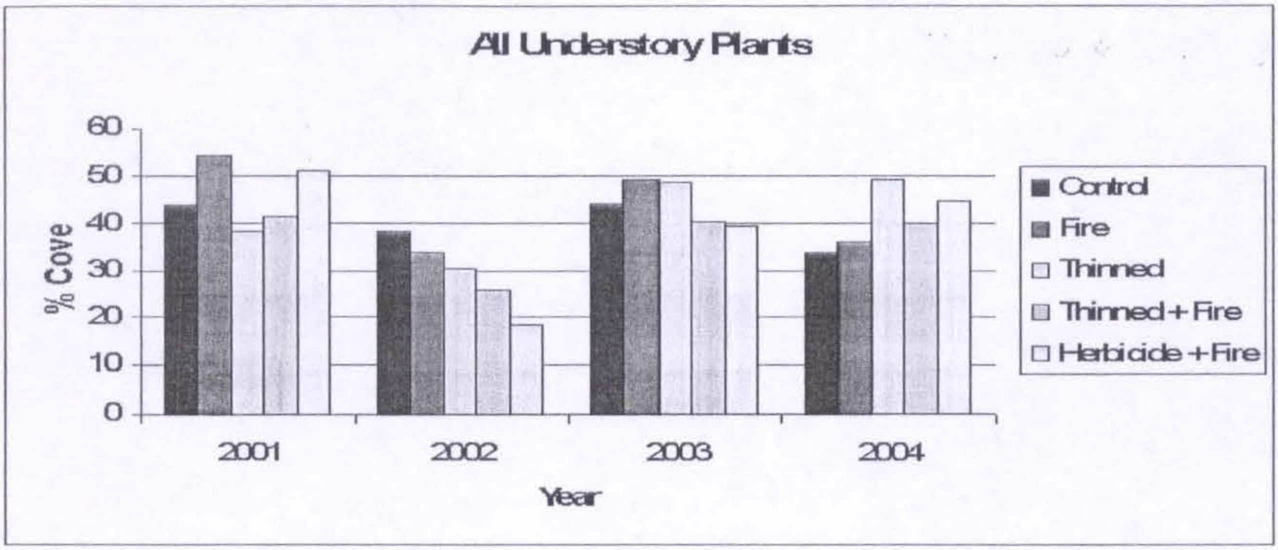
2003	16.9	16.7	11.8	7.9	4.7
2004	12.7	10.9	13.5	6.9	6.6
All Herbs:					
2001	9.6	13.1	4.1	8.5	11.3
2002	4.4	14.7	5.0	9.1	3.5
2003	6.1	15.7	8.1	12.8	20.0
2004	4.9	15.7	6.4	19.2	19.5
Graminoids:					
2001	7.0	9.5	2.8	5.2	7.3
2002	2.5	5.2	2.5	3.1	2.9
2003	4.5	9.2	5.4	7.8	9.8
2004	3.5	8.6	5.1	11.8	14.0
Forbs:					
2001	1.4	2.7	0.8	2.5	2.9
2002	1.6	8.6	2.0	4.9	0.4
2003	1.5	6.2	2.3	4.9	10.0
2004	0.8	6.8	0.8	7.0	4.9
Ferns:					
2001	1.2	0.8	0.4	0.8	1.0
2002	0.3	0.9	0.4	1.1	0.1
2003	0.1	0.3	0.4	0.1	0.1
2004	0.6	0.3	0.5	0.4	0.5
Invasive Shrubs:					
2001	0.00	0.00	0.20	0.34	0.00
2002	0.00	0.04	0.01	0.00	0.00
2003	0.00	0.17	0.01	0.05	0.00
2004	0.00	0.05	0.10	0.02	0.00
Invasive Herbs:					
2001	0.07	0.32	0.04	0.00	0.03
2002	0.00	0.01	0.00	0.01	0.00
2003	0.00	0.03	0.01	0.01	0.00
2004	0.00	0.01	0.03	0.01	0.00

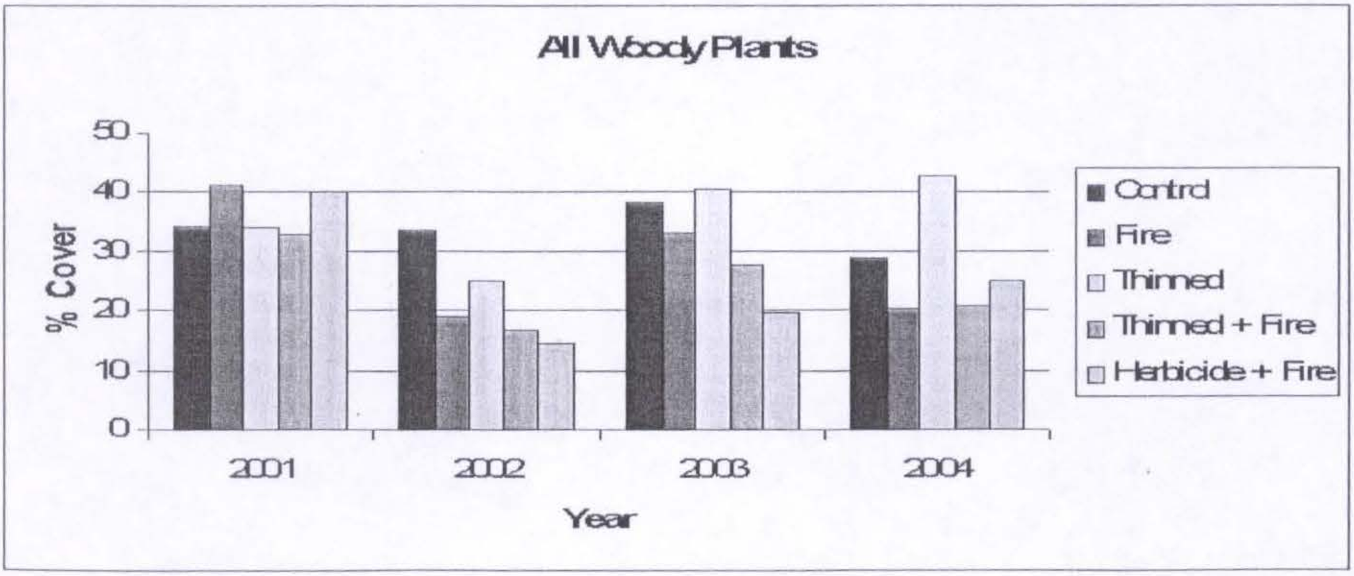
Table 2. Understory Plant Diversity at the Dixon Forest (treatments applied during 2002).

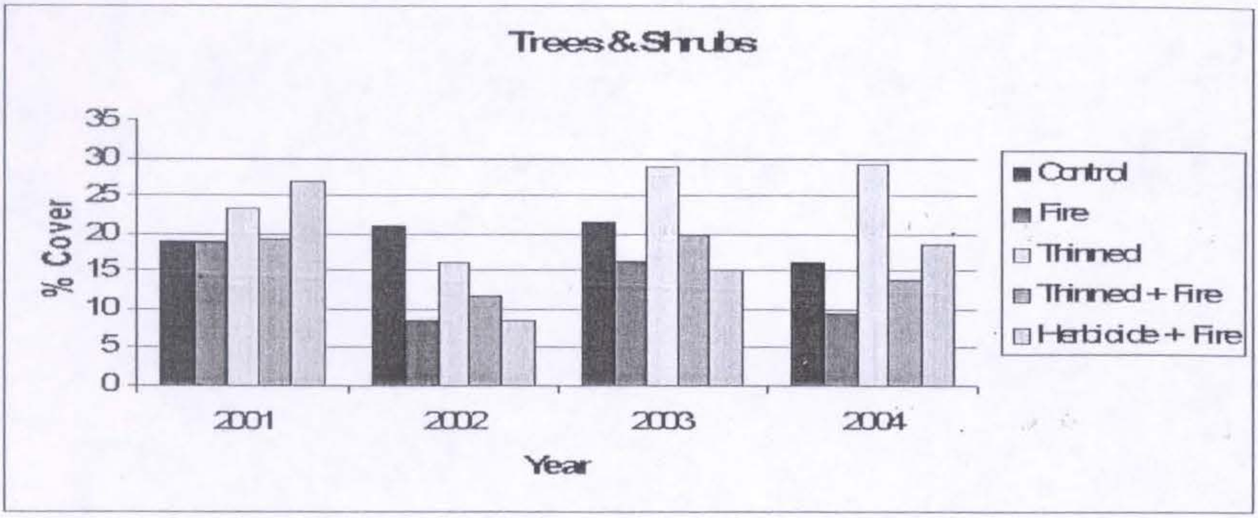
	Control	Fire	Thinning	Thinning Plus Fire	Herbicide Plus Fire
Richness of All Species/m2:					
2001	6.6	6.8	5.1	6.0	7.6
2002	7.2	8.1	6.2	7.0	4.3
2003	6.2	8.2	6.9	8.2	9.0
2004	5.1	8.1	6.4	9.6	8.6
Shannon Diversity of All Species/m2:					
2001	1.84	1.89	1.56	1.71	1.94
2002	1.83	2.05	1.76	1.96	1.41
2003	1.76	2.02	1.79	1.92	2.29
2004	1.70	2.16	1.76	2.34	2.20
Evenness of All Species/m2:					
2001	0.34	0.34	0.36	0.35	0.31
2002	0.31	0.30	0.34	0.33	0.39
2003	0.35	0.32	0.34	0.27	0.31
2004	0.38	0.32	0.34	0.29	0.31
Richness of Herbs/m2:					
2001	2.1	2.3	1.1	2.1	2.8
2002	2.6	4.0	2.1	3.5	1.4
2003	1.9	3.8	2.3	4.1	5.1
2004	1.2	3.7	1.6	5.1	4.0
Shannon Diversity of Herbs/m2:					
2001	0.80	0.85	0.40	0.84	1.01
2002	1.16	1.38	0.92	1.25	0.62
2003	0.80	1.24	0.87	1.31	1.58
2004	0.61	1.35	0.63	1.63	1.34
Evenness of Herbs/m2:					
2001	0.42	0.40	0.30	0.44	0.40
2002	0.47	0.38	0.43	0.42	0.46
2003	0.42	0.37	0.39	0.39	0.37
2004	0.41	0.40	0.34	0.37	0.39

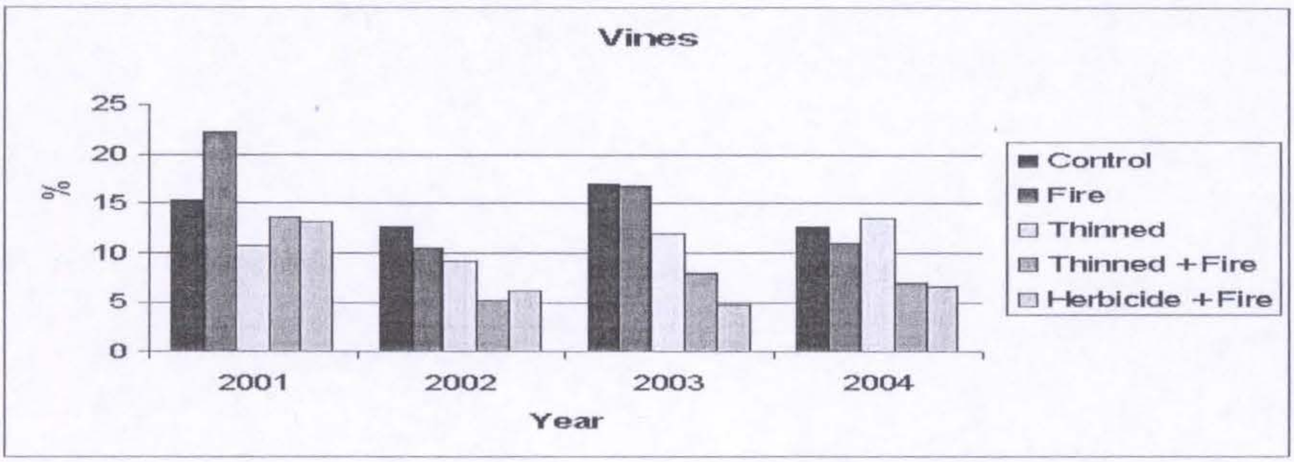
¦ichness of Herbs/0.1 ha:

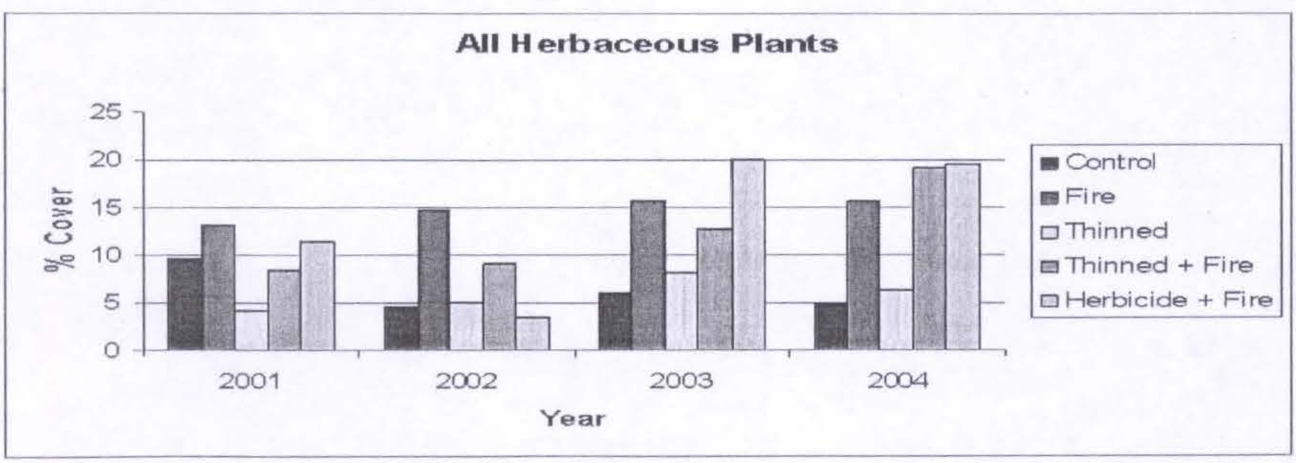
2001	10.5	11.3	6.1	10.8	14.9
2002	13.8	16.9	12.1	17.4	7.5
2003	11.3	17.1	12.7	20.0	25.6
2004	6.5	16.2	8.3	23.4	18.5

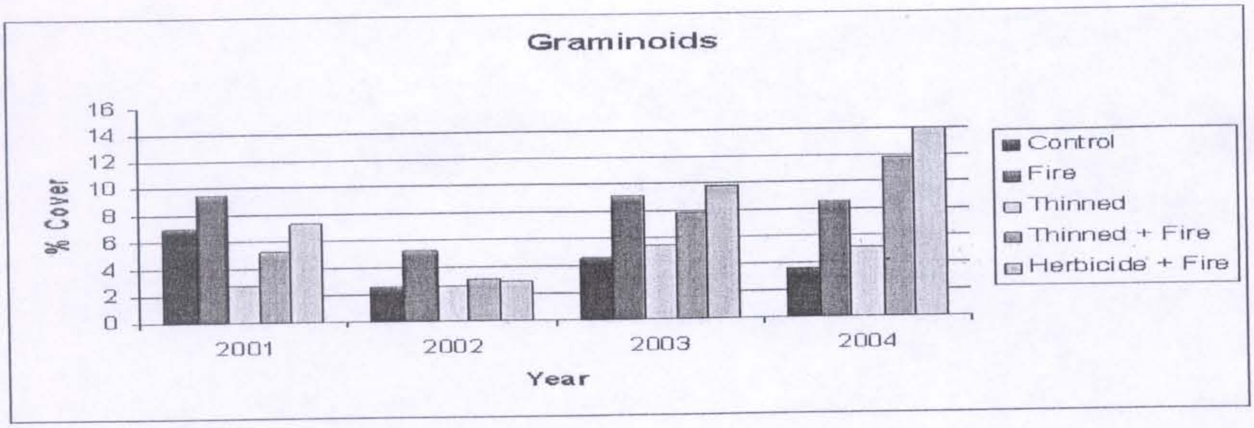


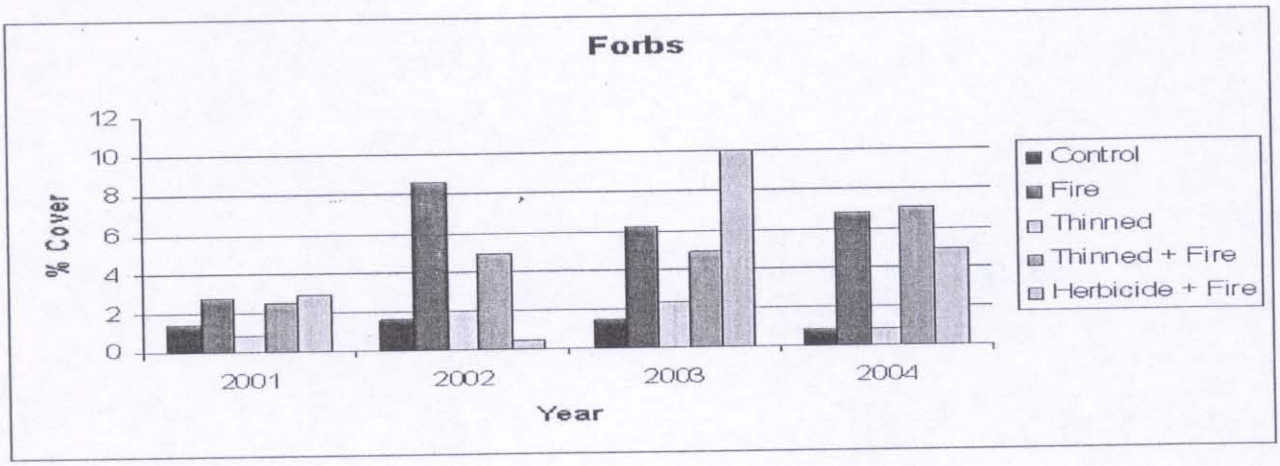


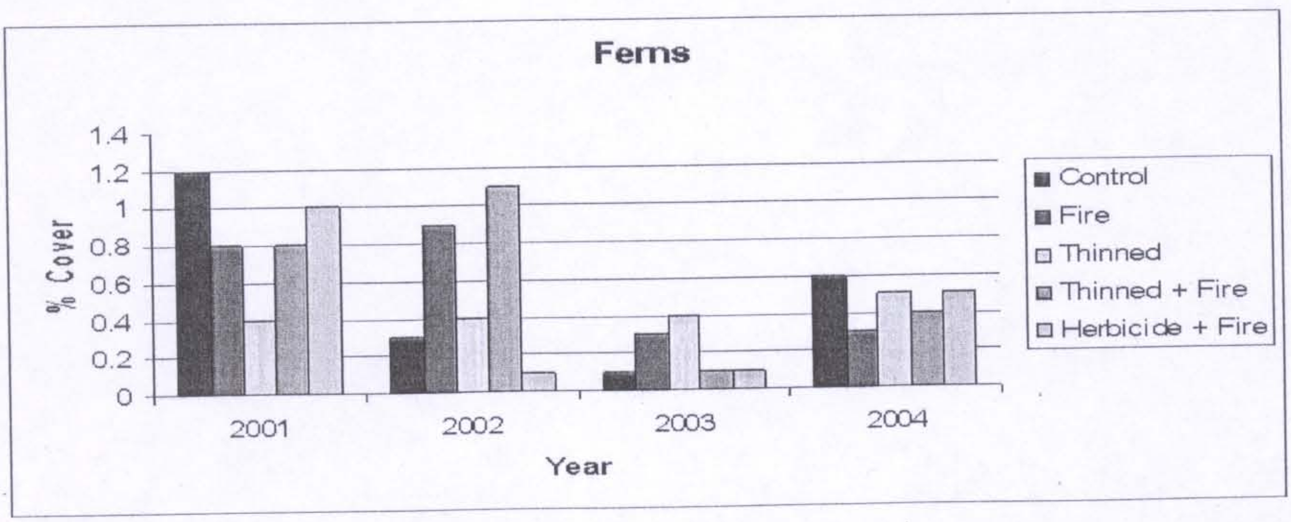

Trees & Shrubs
% Cover
35
30
25
20
15
10
5
0
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire

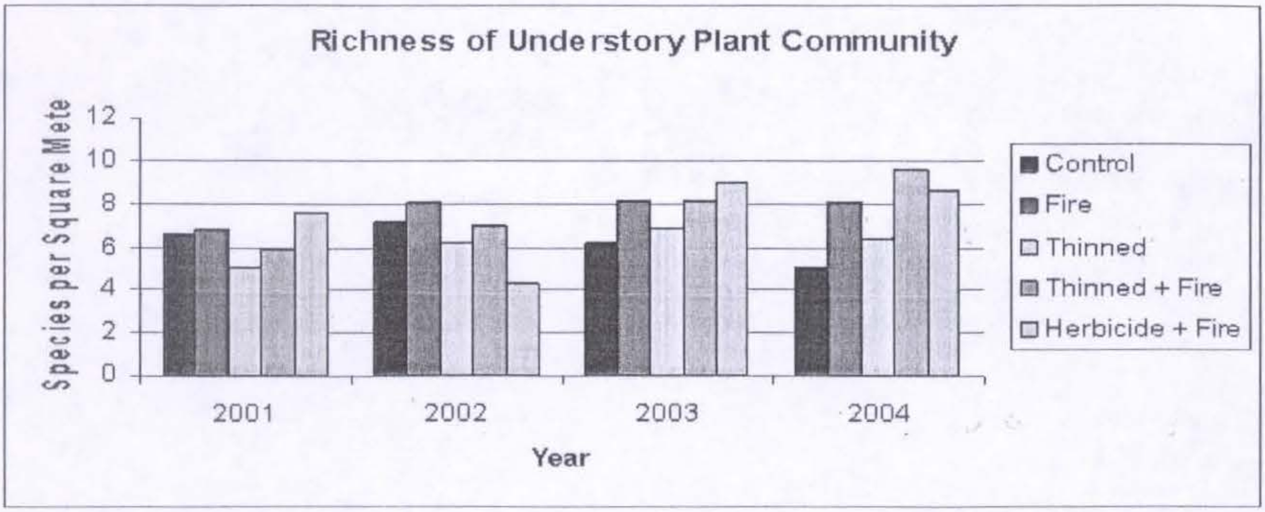

Vines
%
25
20
15
10
5
0
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire

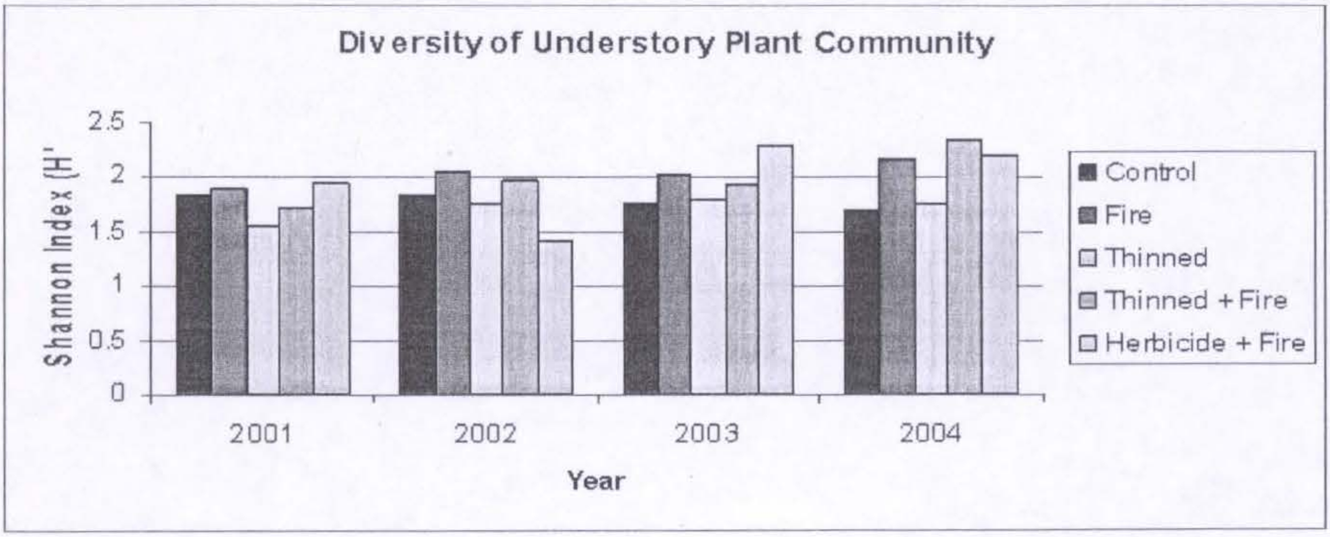

All Herbaceous Plants
% Cover
25
20
15
10
5
0
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire

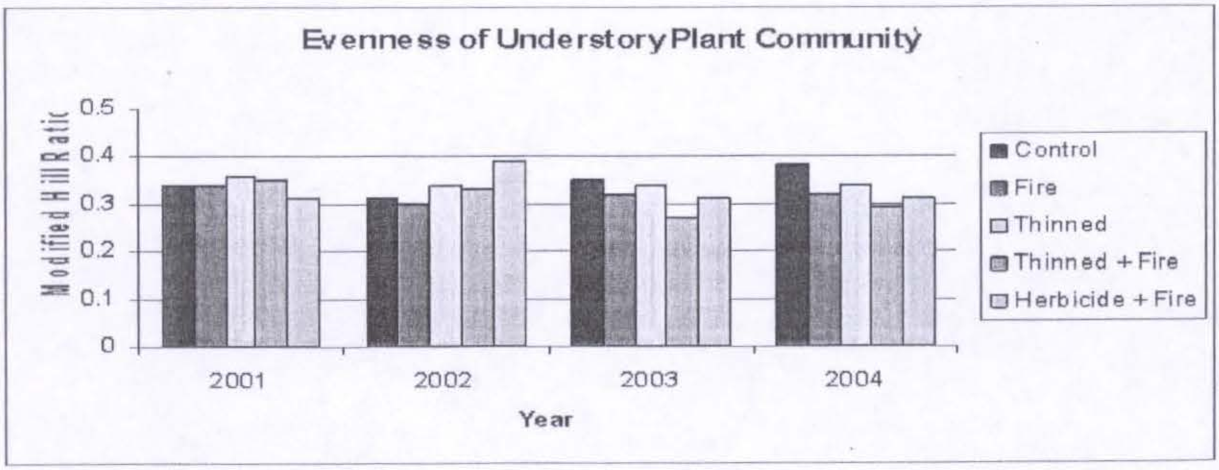

Graminoids
% Cover
16
14
12
10
8
6
4
2
0
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire

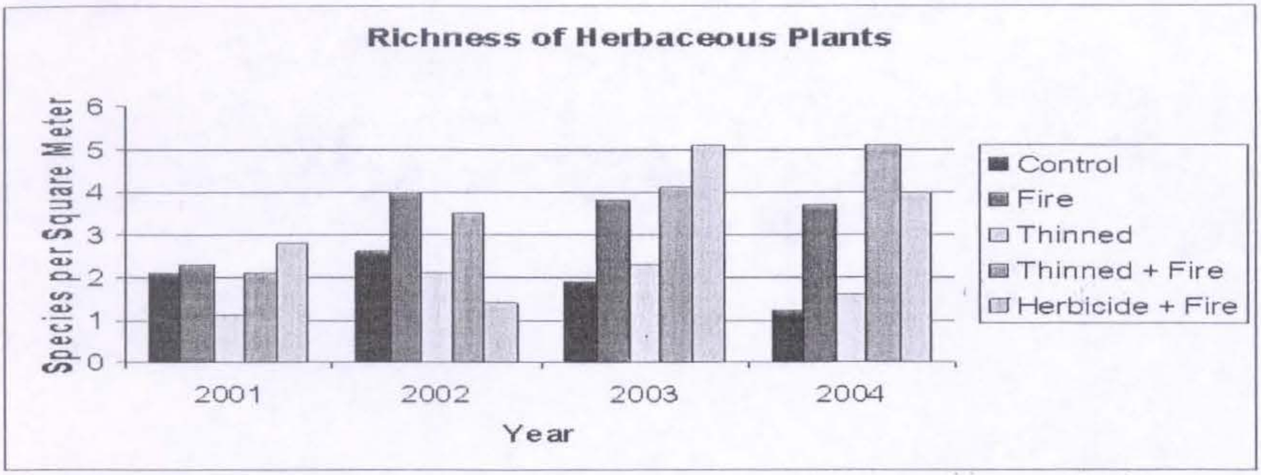

Forbs
% Cover
12
10
8
6
4
2
0
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire

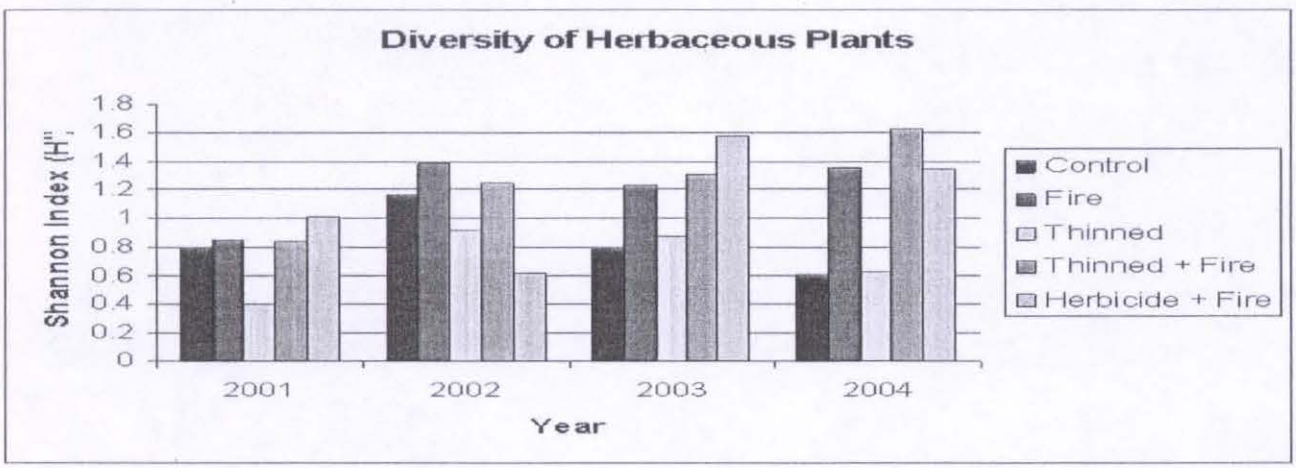

Ferns
% Cover
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire

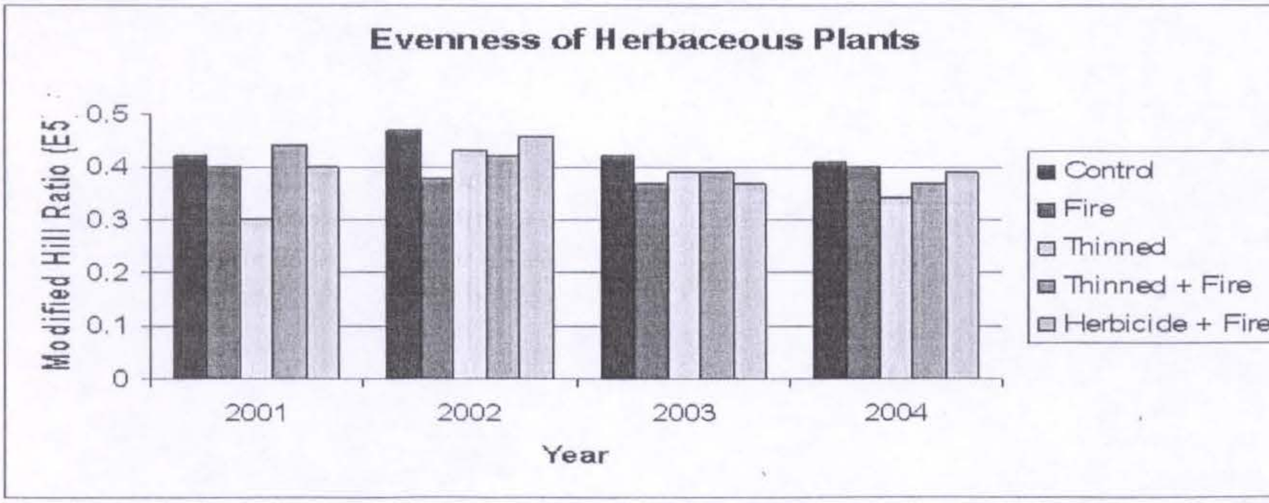

Richness of Understory Plant Community
Species per Square Mete
12
10
8
6
4
2
0
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire

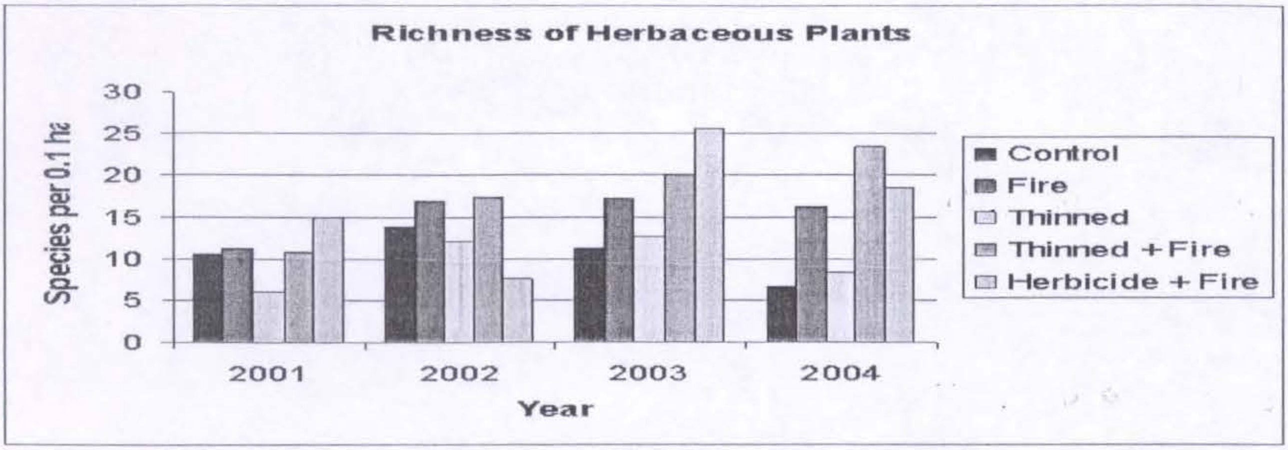

Diversity of Understory Plant Community
Shannon Index (H'
2.5
2
1.5
1
0.5
0
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire

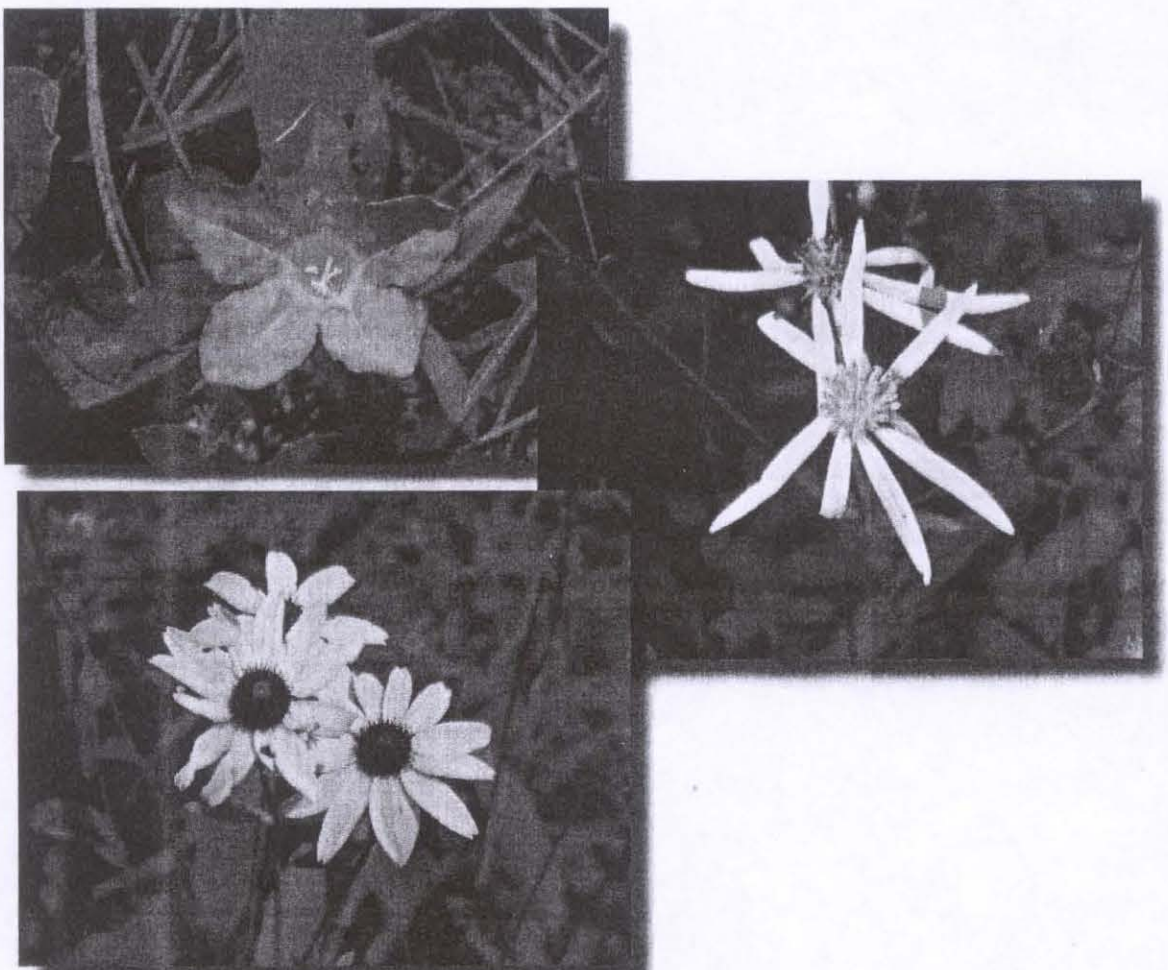

Evenness of Understory Plant Community
Modified Hill Ratio
0.5
0.4
0.3
0.2
0.1
0
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire


Richness of Herbaceous Plants
Species per Square Meter
0
1
2
3
4
5
6
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire


Diversity of Herbaceous Plants
Shannon Index (H')
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire


Evenness of Herbaceous Plants
Modified Hill Ratio (E5
0
0.1
0.2
0.3
0.4
0.5
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire


Richness of Herbaceous Plants
30
25
20
15
10
5
0
Species per 0.1 ha
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire



Gulf Coastal Plain Site

National Fire and Fire Surrogate Study

Fuels Treatment Workshop
October 27, 2005

Solon Dixon Forestry and Education Center
Auburn University

Fire
and Fire Surrogate
Treatments
For Ecosystem Restoration