Gulf Coastal Plain Site

National Fire and Fire Surrogate Study

7th Annual SMIC Meeting Field Trip
19th October 2005

Solon Dixon Forestry and Education Center
Auburn University

National Fire Plan

Disclaimer

This handout is intended for use as supplemental information for the Fuels Treatment Workshop tour conducted October 27, 2005 at the Solon Dixon Forestry and Education Center. The data presented in this handout are preliminary in nature. Thus, no data contained in this handout should be references or cited.

Schedule

Subject	Speaker	Start	Stop	Location	Page
Introduction to Dixon Center	Rhett Johnson	8:15	9:00	Center	3-6
Travel		9:00	9:15		
Layout and Treatments	Ken Outcalt	9:15	9:30	Unit 1	7-22
Prescribed Burning Operations	Dale Pancake	9:30	9:50	Unit 1	23-28
Travel		9:50	10:10		
Overstory	Ken Outcalt	10:10	10:30	Unit 3	29-37
Understory	Dale Brockway	10:30	10:50	Unit 2	38-48
Entomology	Jim Hanula	10:50	11:10	Unit 2	49-55
Longleaf Regeneration	Rhett Johnson	11:10	11:40	Plantaions and Springs	
Travel		11:40	12:00		
Lunch		12:00	13:00	Center	
Travel		13:00	13:30		
Fuels	Ken Outcalt	13:30	13:50	Unit 12	56-63
Birds	Ken Outcalt	13:50	14:10	Unit 12	64-67
Soils	Gramae Lockaby	14:10	14:30	Unit 12	68-80
Herps	Ken Outcalt	14:30	14:50	Unit 13	81-85
Travel		14:50	15:20		
Small Mammals		15:20	15:40	Unit 7	86-87
Travel		15:40	16:00	Center	

Directions to Solon Dixon Forestry Education Center

12130 Dixon Center Road
Andalusia, AL 36420
(334) 222-7779
cannotj@auburn.edu

From the west or south

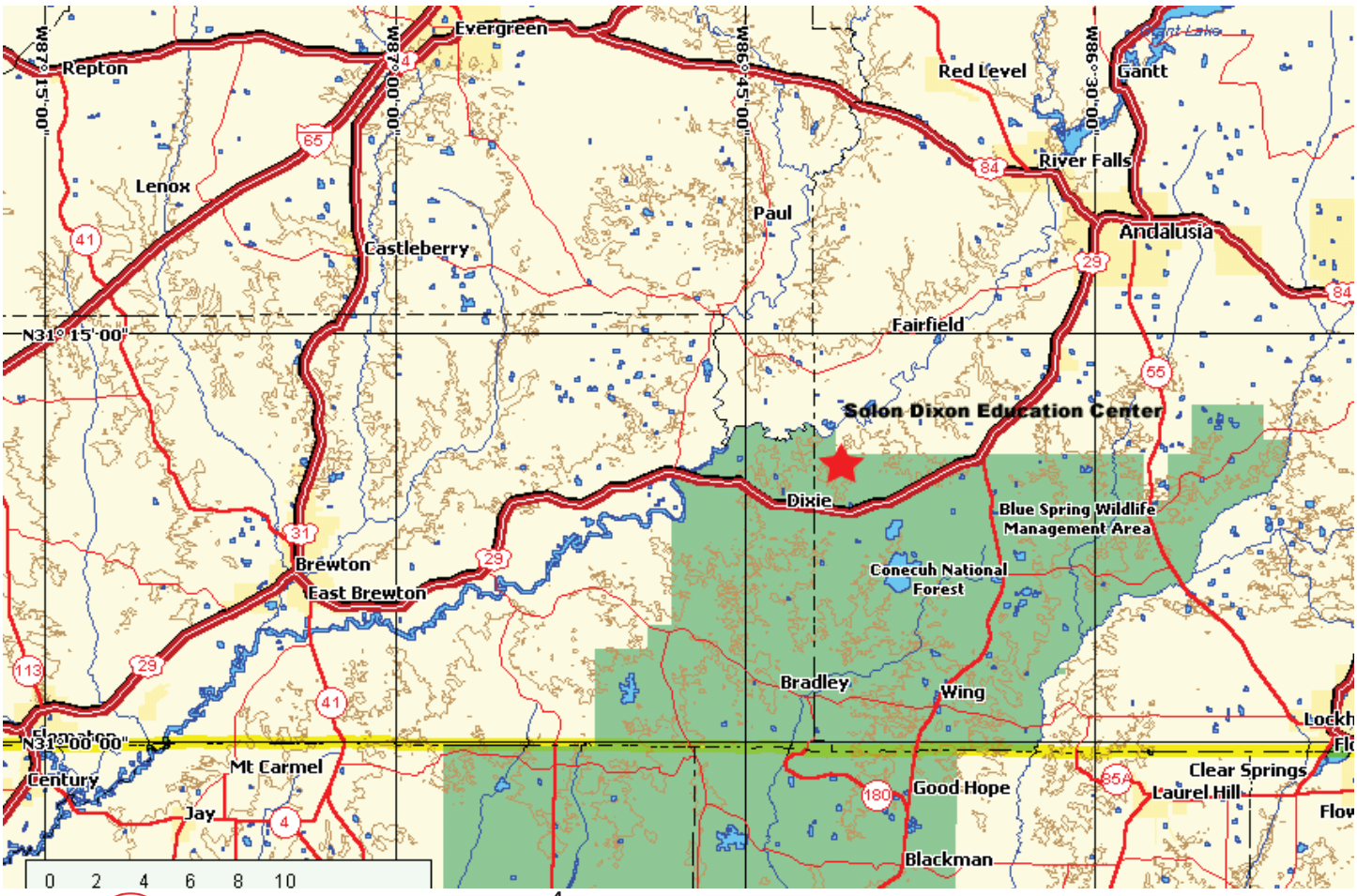
Go to Brewton, Alabama--US 29 from south or southwest; AL 41 from northwest. Take US 29 E toward Andalusia. Go about 20 miles. Look for Dixon Center sign on left of road just past the Escambia/Covington County line. The Center is about 2 miles north of US 29 on the paved road.

From the North

From Montgomery take I-85 S to the Georgiana exit (south of Greenville). Take AL 106 east towards Georgiana (3-4 miles). Turn right (south) on US 31. this road will become four-lane--US 31 will turn right, but stay on the four-lane on AL 55, this will take you to Andalusia. Turn right on US 29, go about 18 miles. Look for the Dixon Center sign on the right. The center is about 2 miles north of US 29 on the paved road.

From the East

Go to Andalusia, AL--via US 84 from Dothan or vicinity. Take US 29 S. Go about 18 miles. Look for the Dixon Center sign on the right. The Center is about 2 miles north of US 29 on the paved road.



One of the finest field facilities of its type in the nation, the Solon Dixon Forestry Education Center offers comfortable, efficient classroom and living accommodations and a diverse 5,300 acre natural resource base for the benefit of students and visitors alike. Since its dedication in 1980, the Solon Dixon Forestry Education Center has managed its natural resources and programs to meet its objectives of: (1) providing quality natural resource education to a variety of user groups, particularly Auburn University students; (2) providing a base for and support of research efforts in natural resource fields; (3) serving as a source of information and technology transfer from the scientific community to the general public; and (4) managing its own natural resources wisely and economically to provide income for the Center's programs.

The Solon Dixon Forestry Education Center was a gift to Auburn University from Solon and Martha Dixon, residents of Andalusia, Alabama. The gift of land and funds with which to construct the facility was, at the time, the largest gift ever made to Auburn University by a living donor. The campus facilities include two dormitories, a dining hall, staff quarters, recreation/laundry facility, maintenance shop, and the new Martha Dixon Administration Building. Most of the Center's classroom activities take place in the Charles Dixon Auditorium, a versatile building constructed with the assistance of a gift from Solon Dixon's sister-in-law, Mrs. Thelma Dixon. Residences for the Center's Director and Assistant Director are located on-site, as is the historic Dixon family home, built in the 1840's. This latter structure houses a museum collection of family, regional, and forestry memorabilia.

The Dixon Center is managed by the Auburn University School of Forestry and Wildlife Sciences and is used to support the School's teaching, research, and extension programs. Each Auburn forestry student spends one ten week Summer quarter at the Dixon Center taking basic field forestry coursework prior to the junior year and more advanced on-campus courses. Forestry students return to the Dixon Center throughout their tenure at Auburn for short courses and other field exercises.

Auburn students enrolled in other natural resource curricula often use the Center for field trips, special problems courses, and short courses. The Departments of Zoology and Wildlife Sciences, Entomology, Horticulture, and Agronomy are among those who have made use of the Center's facilities and natural resources. The Dixon Center is also available for use by other colleges and universities.

The Alabama Forestry Commission, the Alabama Cooperative Extension System, other state and federal natural resources agencies, and various forest industries use the Center for in-service training education activities. Programs are available for elementary and secondary school groups as well as the general public.

The Dixon Center has served as the site of research projects in a number of fields. Forestry research has centered around herbicide use, forest growth and yield, and forest regeneration. Wildlife research has included work with indigo snakes, gopher tortoises, and gray squirrels. The resource base at the Center includes a pecan orchard, which has served as a site for a number of studies by scientists from Auburn's Departments of Agronomy, Entomology, and Horticulture.

The Center's natural resource base is amazingly diverse for a property its size. The existing forest is varied in age class, species composition, management history, soil type, site index, and management potential. Forest types range from the dry, sandy longleaf pine/turkey oak ridges common in the area to baldcypress/tupelo gum wetlands. Five species of southern pines occur naturally on the property and both upland and bottomland hardwood stands are well represented. Current management is designed to emphasize this diversity, maximizing opportunities for teaching and research.

As would be expected on such a diverse forest,

wildlife populations are varied and thriving. Management efforts are directed toward maintaining healthy and diverse game and non-game populations, primarily through the creation and maintenance of a variety of quality habitats across the property.

A network of nature trails is in place, providing educational and recreational opportunities for the serious student, as well as the casual nature lover. The property, as a result of its geological legacy, contains several lime sink-holes, disappearing springs, and other interesting natural features. Many of these pleasant and unique spots are incorporated into the trail system, as are several historic sites of general interest.

The Solon Dixon Forestry Education Center is located in the pinelands of south central Alabama, about 18 miles south of Andalusia, Alabama, and is surrounded by Conecuh National Forest. It is located on U.S. Highway 29 between Andalusia and Brewton and is two hours or less from Montgomery, Mobile, Pensacola, and Dothan.

Solon Dixon was an Auburn alumnus of unusual accomplishments. He was a student at Auburn University in the 1920's (B.S. in Mechanical Engineering 1926) and served as a faculty member (1928-34) until he returned to his native Andalusia to join the family's forest products business. His business accomplishments are well documented by the success of the Dixon Lumber Company, which he and his brother, Charles, developed and managed. He was equally well known as a forestry leader, conservationist, and farmer, and for his dedication to education.

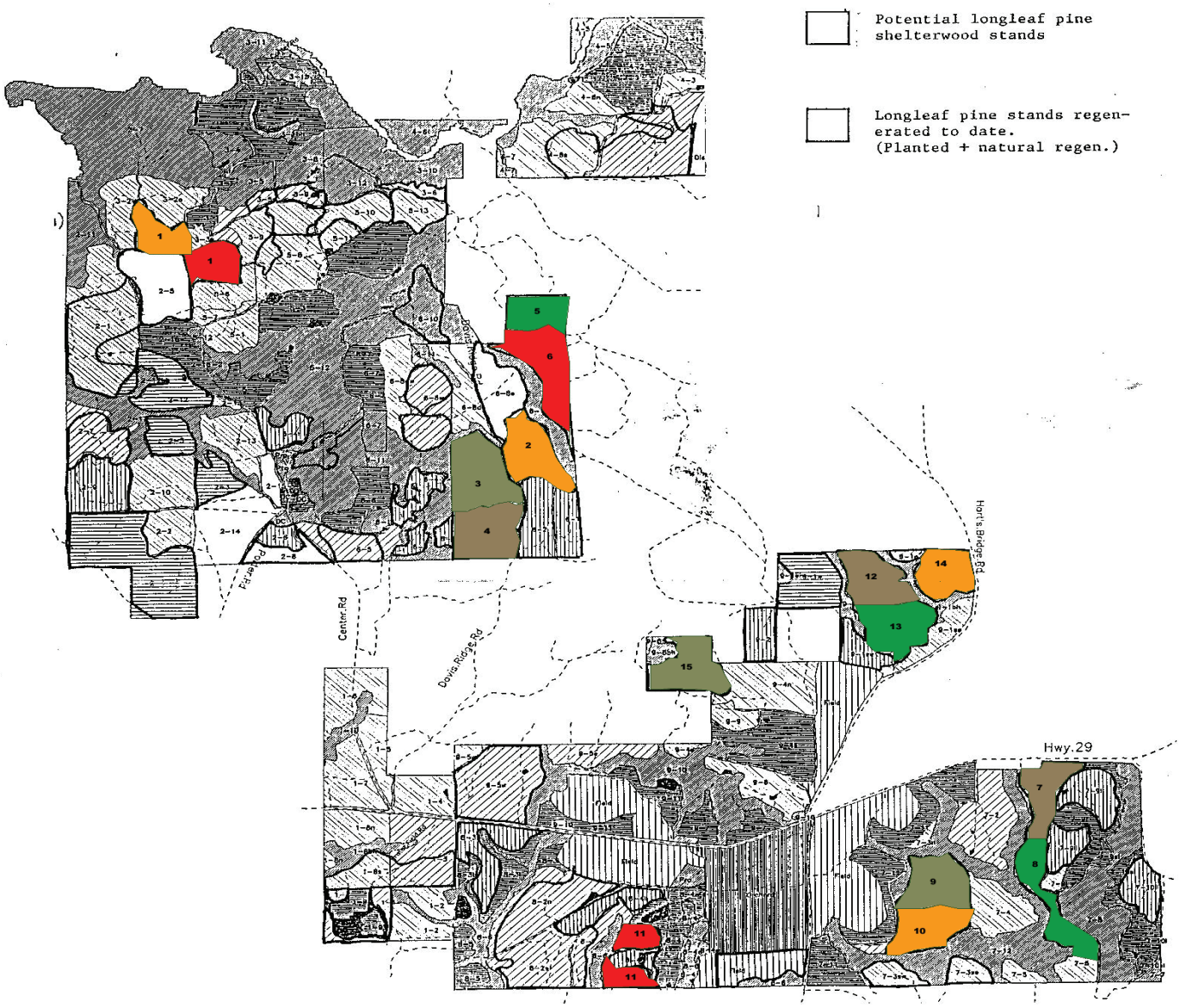
In recognition of his interests and accomplishments in those areas and his many contributions of time and financial resources in furthering their causes, he was awarded the honorary Doctor of Science degree by his Alma Mater, Auburn University, at its 1979 fall commencement.

In 1978, Dr. Dixon made the first of a series of gifts that resulted in the Solon Dixon Forestry Education Center. Completion of this Center was the culmination of much effort and planning by Dr. and Mrs. Dixon (Martha). To fulfill the dream for such a facility, Solon and Martha, with assistance of other members of the family and friends, consolidated properties around the family homestead and arranged for the gift of land and money.

The Gulf Coastal Plain site is 35 km southwest of Andalusia, Alabama (31o 9′ N, 86o 42′ W) on the Solon Dixon Forestry Education Center, which is owned and operated by Auburn University School of Forestry. The locale has a humid temperate climate, characterized by summers with high temperatures and humidity, and mild winters. Moisture is abundant with most rainfall arriving as convective afternoon thunderstorms during the summer or wet season. Average annual precipitation is 1422 mm, average temperature is 19oC, and the growing season is 230 days. In this western highlands region of the Gulf Coastal Plain elevations range from 30 to 100 m above mean sea level covering all aspects. Slopes are moderate to steep across rolling hills dissected by numerous streams. There are also a number of small depressional sinks, some of which hold permanent water. The soils developed from unconsolidated Pleistocene sands deposited over clay layers of the Citronelle Formation. Soils under study sites are paleudults of the Troup, Orangeburg, Dothan, Malbis and Bonifay series. These soils have loamy sand or sandy loam surface horizons that promote rapid drainage, but the finer textured material in the lower horizons improves both moisture and nutrient holding capacity. These are moderately productive soils especially on the lower slopes.

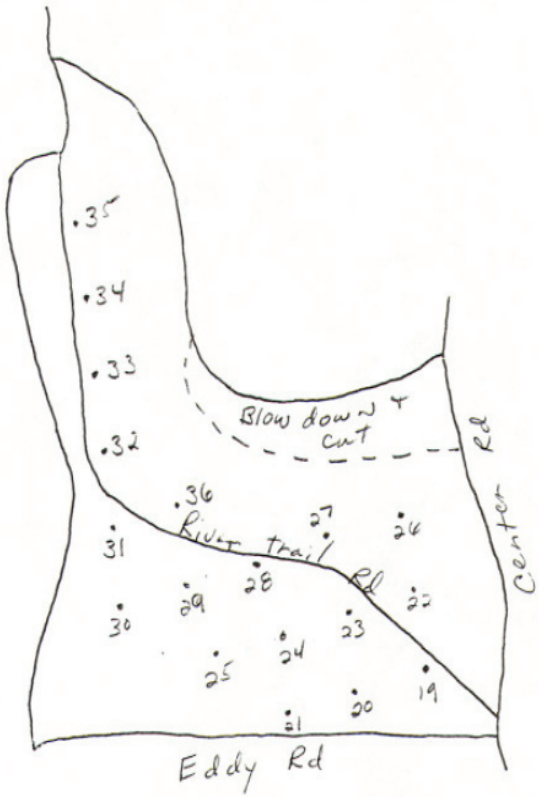
Historically much of the middle and upper Gulf Coastal Plains consisted of forests with an overstory dominated by longleaf pine (Pinus palustris) with pockets of other southern pines and occasional hardwoods, while the understory was grass dominated with lesser amounts of woody shrubs. The open condition and grassy understory were maintained by frequent, every 2 to 5 years, low intensity fires from lightning and native American ignitions. Like much of the region, the Dixon center longleaf forests underwent a period when fire frequency was significantly reduced. When Auburn University obtained the property in 1980, a great deal of it had not been burned for 10 to 16 years. This reduced fire frequency resulted in compositional changes in the overstory and understory and the development of a midstory layer. Although longleaf pine still dominates much of the forest, other southern pines are also abundant including loblolly (P. taeda), shortleaf (P. echinata), slash (P. elliottii), and spruce pine (P. glabra). In many areas there is also a substantial hardwood component dominated by oaks (Quercus spp.). The understory is dominated by woody shrubs with yaupon holly (Ilex vomitoria) the most abundant and lesser amounts of blueberries (Vaccinium spp.) and gallberry (I. glabra). The conditions on this site are typical of those found throughout the region. Treatments are needed that will reduce the midstory ladder fuels and thereby wildfire hazard, change the overstory composition to more fire tolerant species, and readjust the composition and structure of the understory so grasses and forbs are dominant. These changes must be accomplished without compromising long-term integrity or sustainability of the ecosystem.

Treatment Units on Solon Dixon Forest

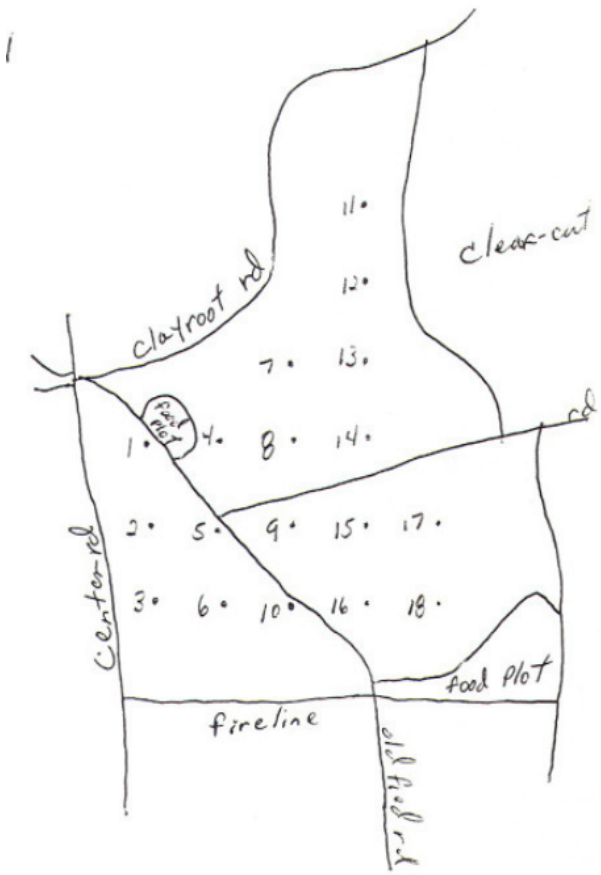


12-12-2000
DCP

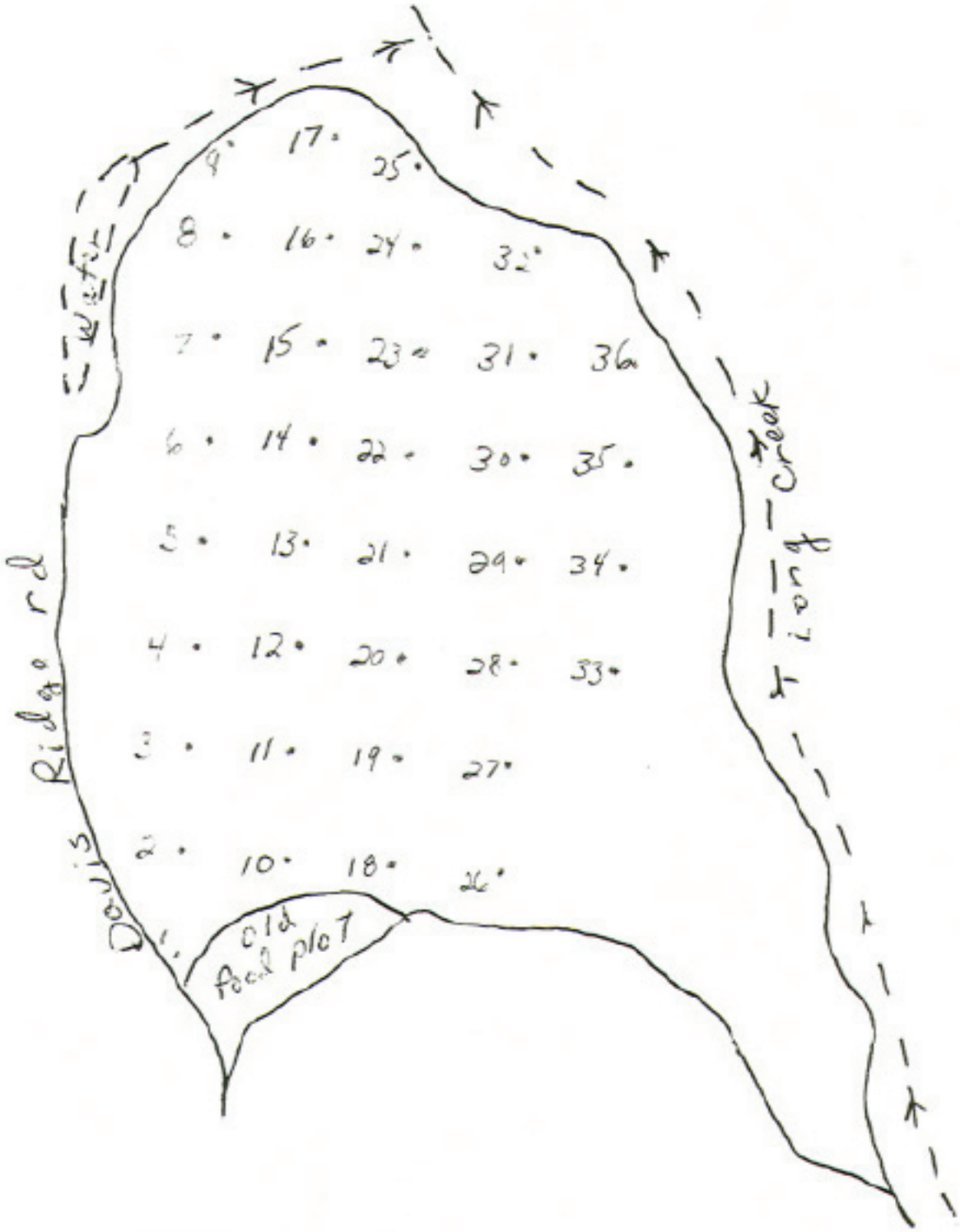
Unit 1W - Burn

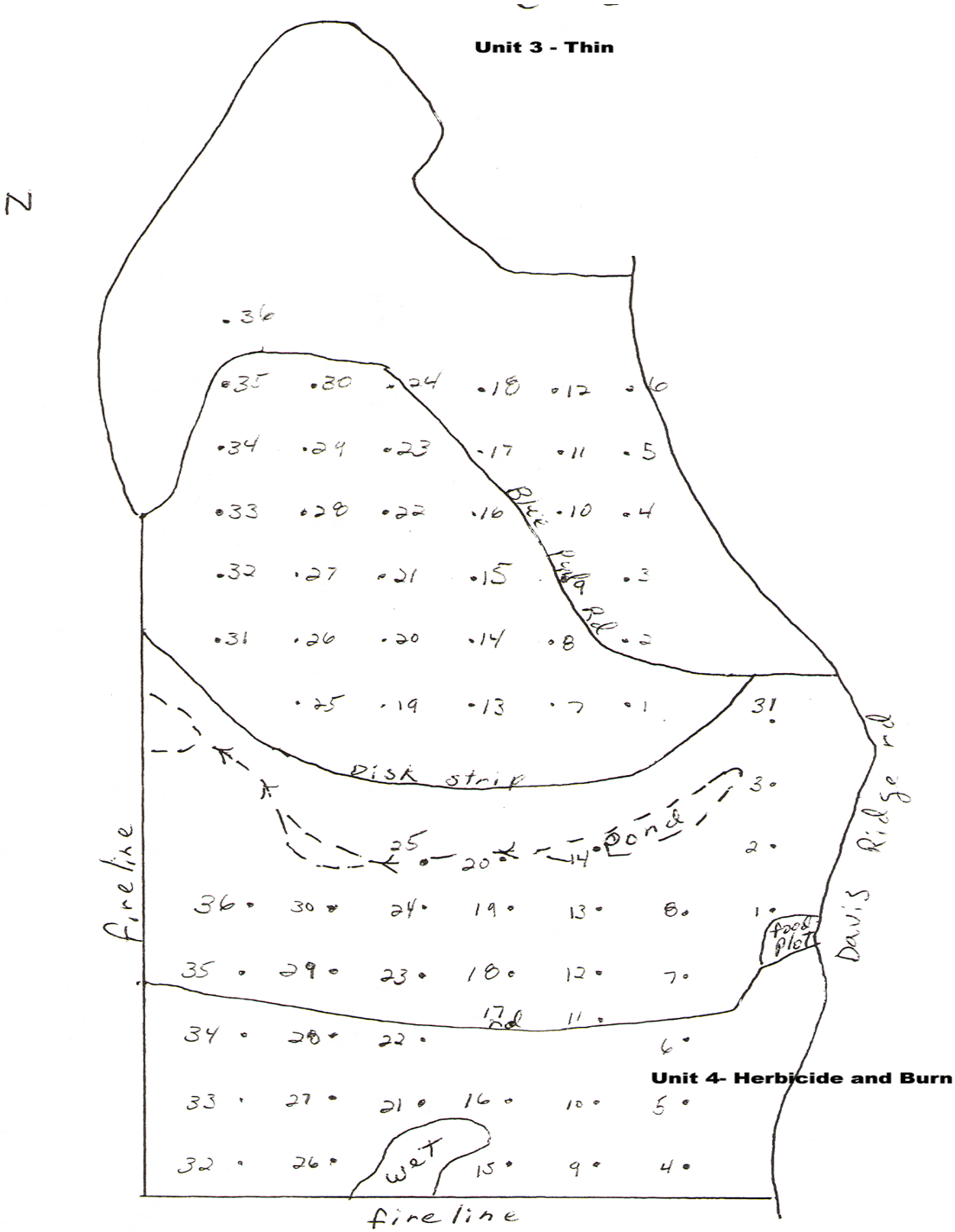


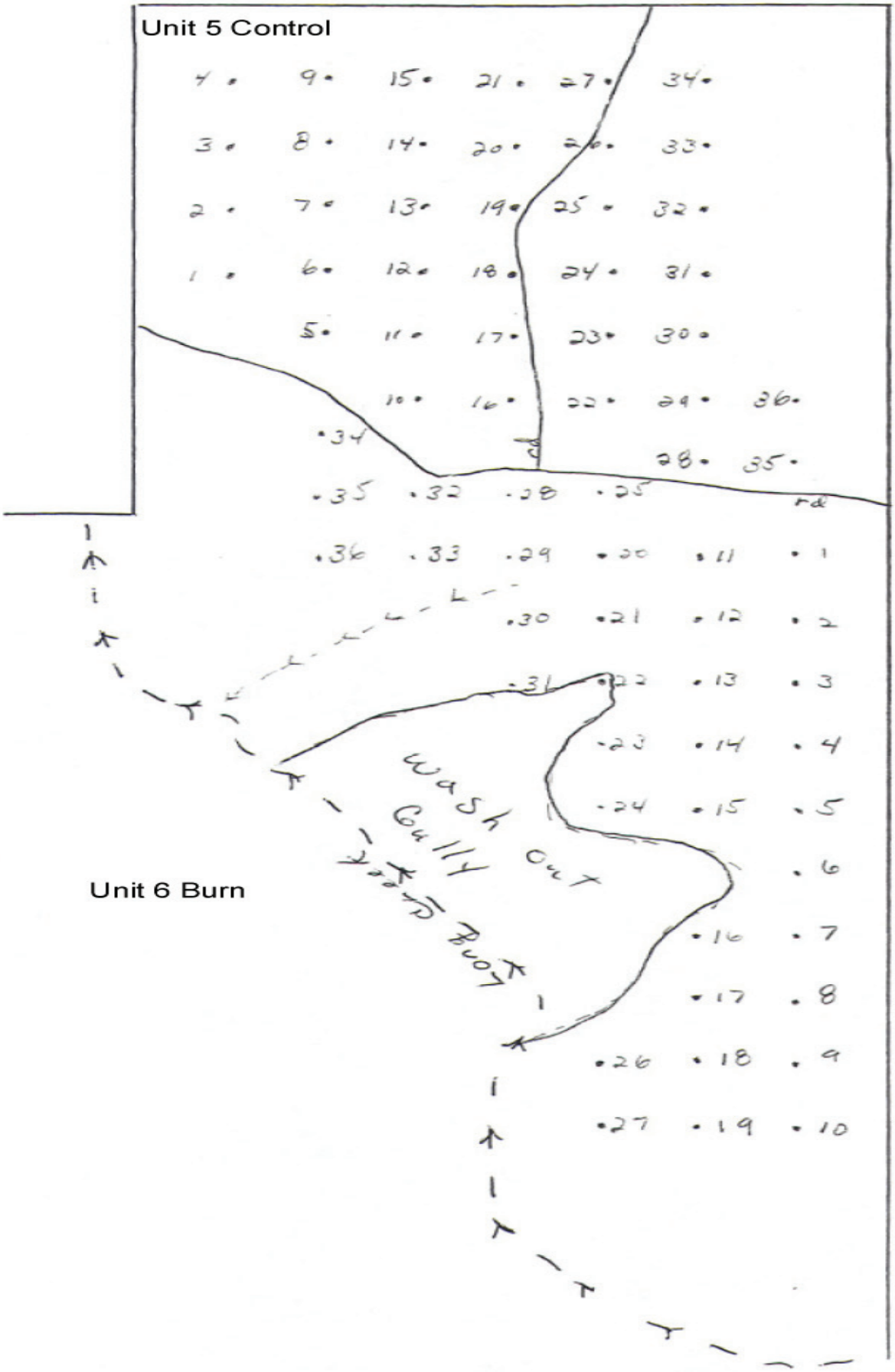
Unit 1E - Burn

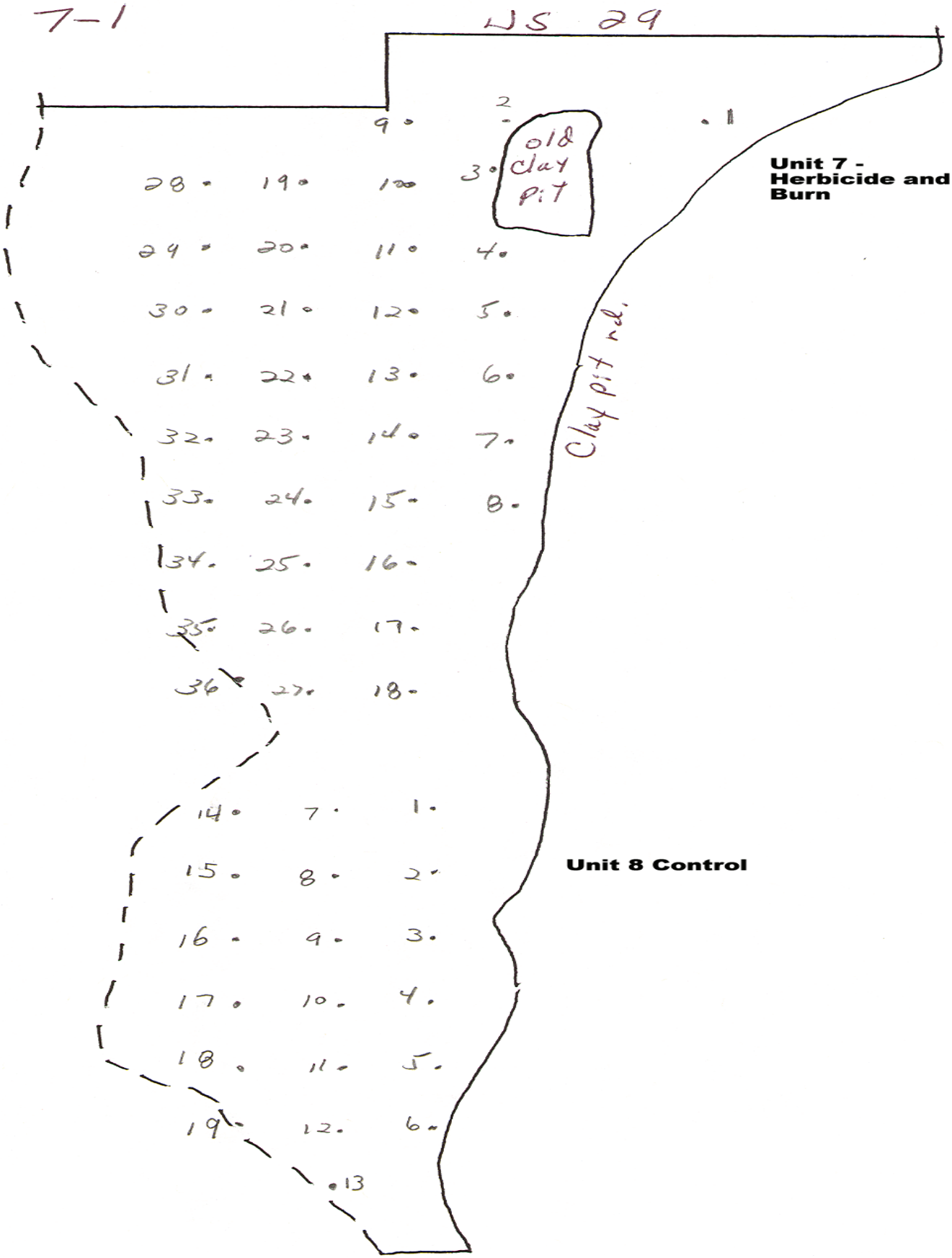


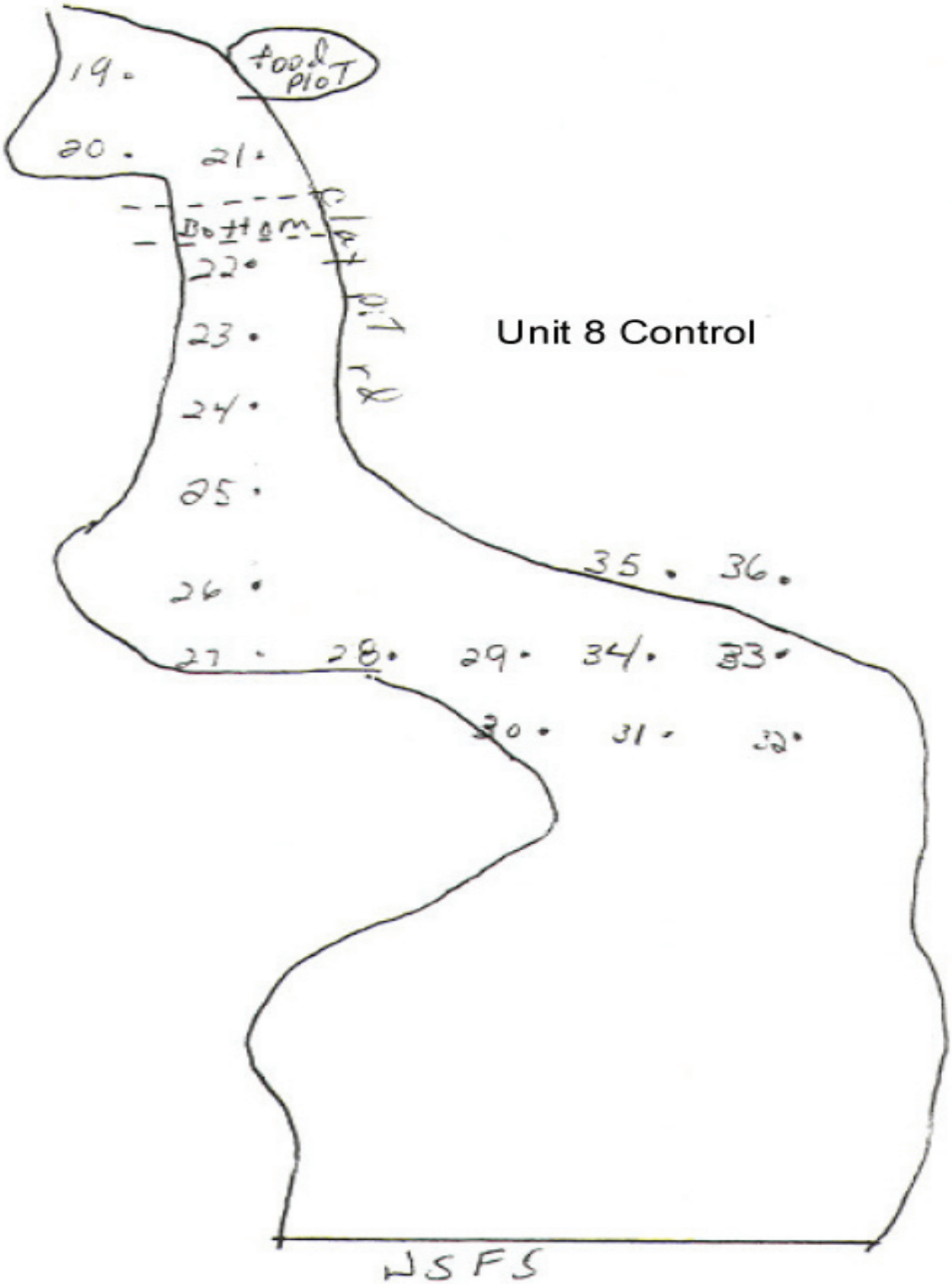
Unit 2 - Thin and Burn

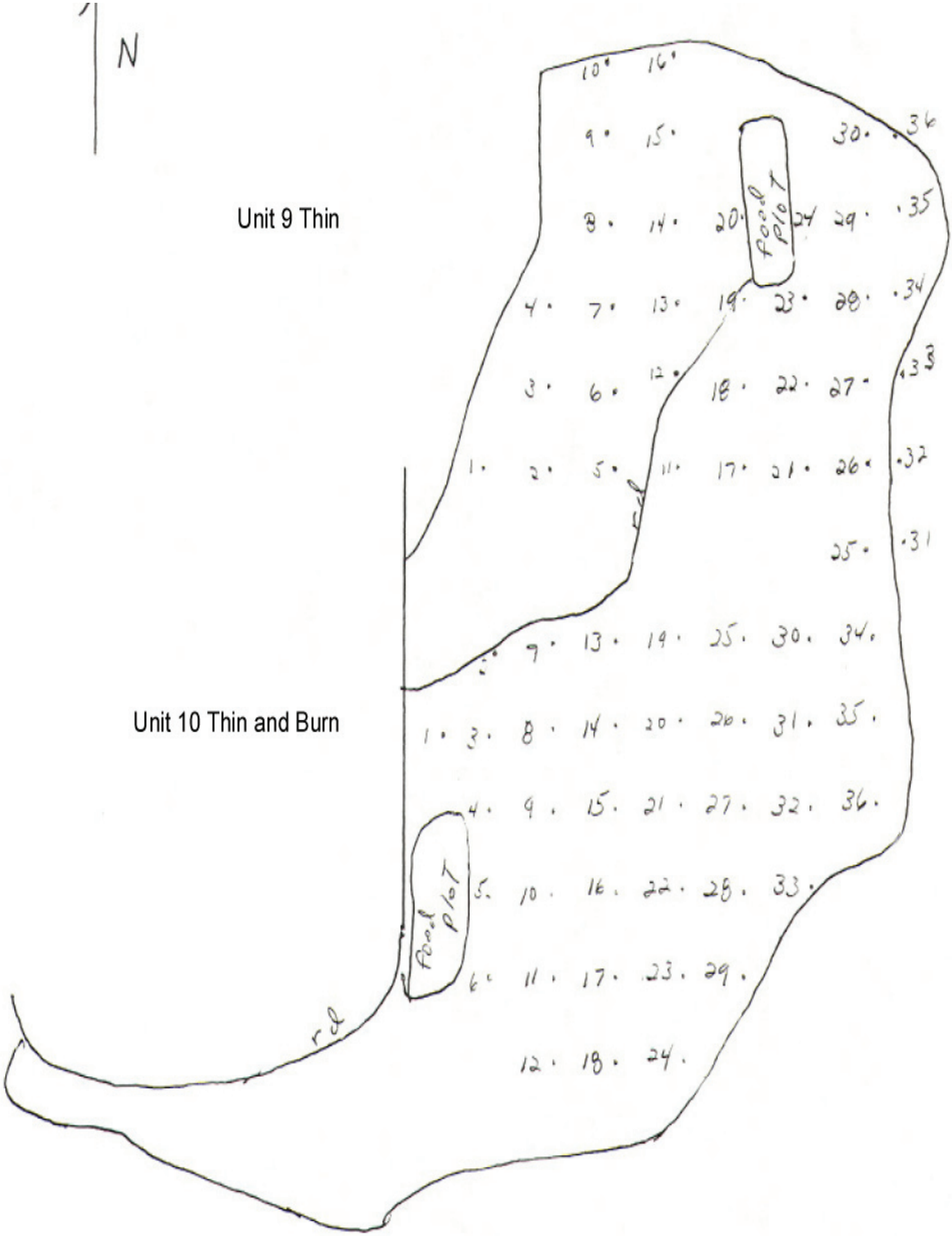



Unit 3 - Thin
N
36
35 30 24 18 12 6
34 29 23 17 11 5
33 28 22 16 10 4
32 27 21 15 9 3
31 26 20 14 8 2
25 19 13 7 1
31
Blue Bluff Rd
Disk strip
30
Pond
25 20 14
2
36 30 24 19 13 8 1
Pond Plot
Davis Ridge rd
35 29 23 18 12 7
17 11
34 28 22 6
Unit 4- Herbicide and Burn
33 27 21 16 10 5
32 26 15 9 4
wet
fireline
fireline

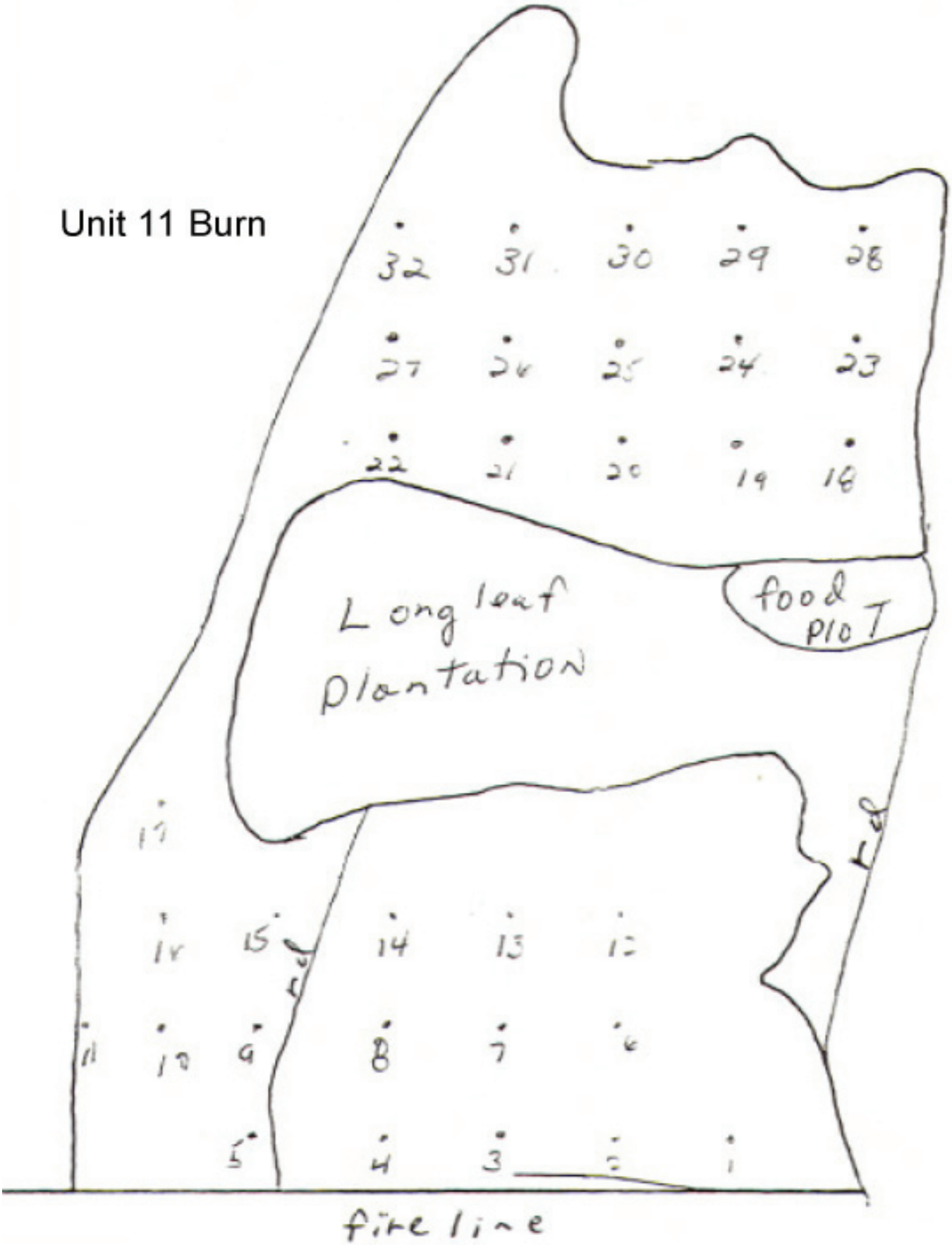

Unit 5 Control
Unit 6 Burn
Wash Out
Gully
Yard Buoy

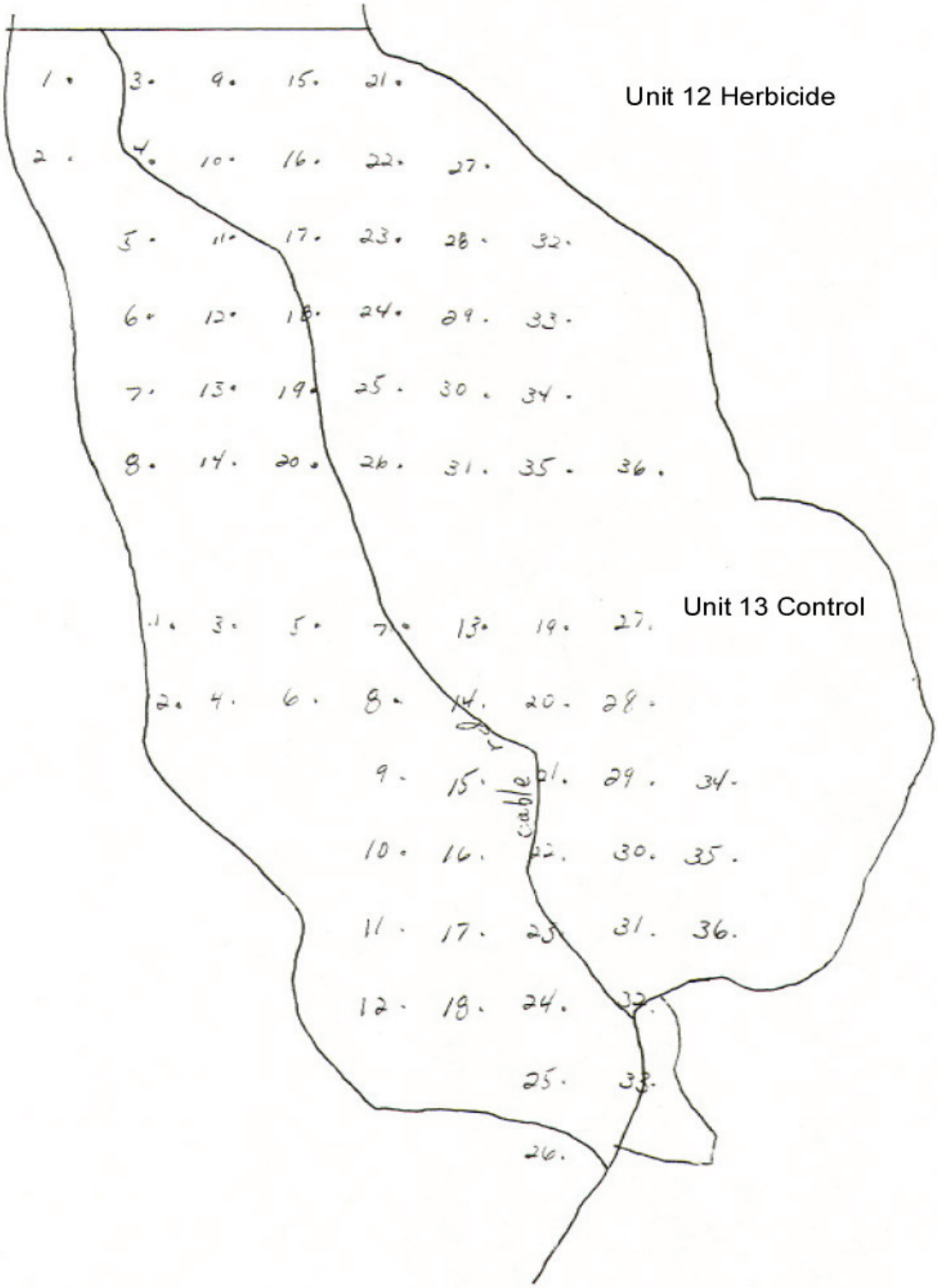

7-1
US 29
old clay pit
Clay pit rd.
Unit 7 - Herbicide and Burn
Unit 8 Control

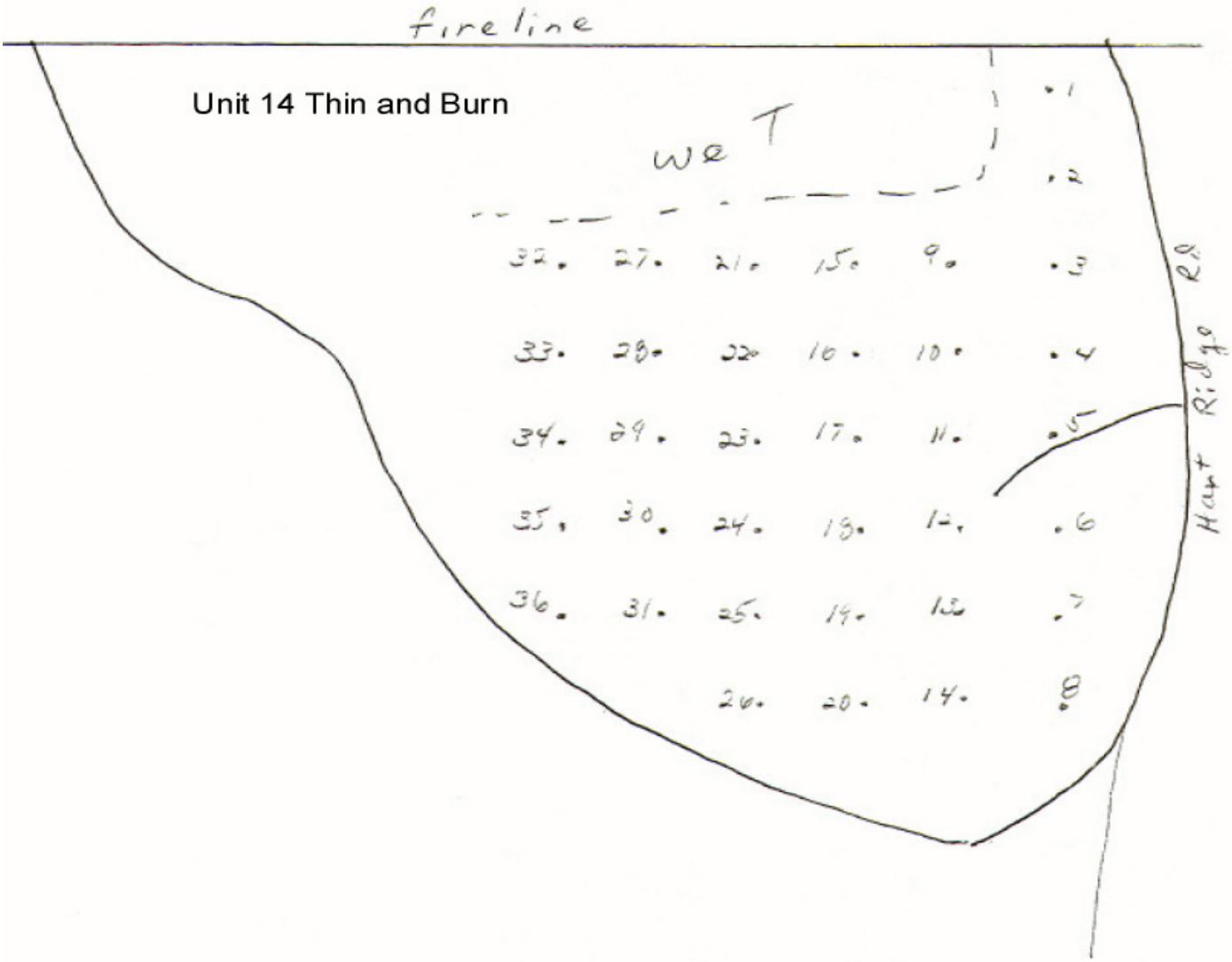

Unit 8 Control
food plot
19.
20.
21.
Bottom
22.
23.
24.
25.
26.
27.
28.
29.
34.
33.
35.
36.
30.
31.
32.
USFS

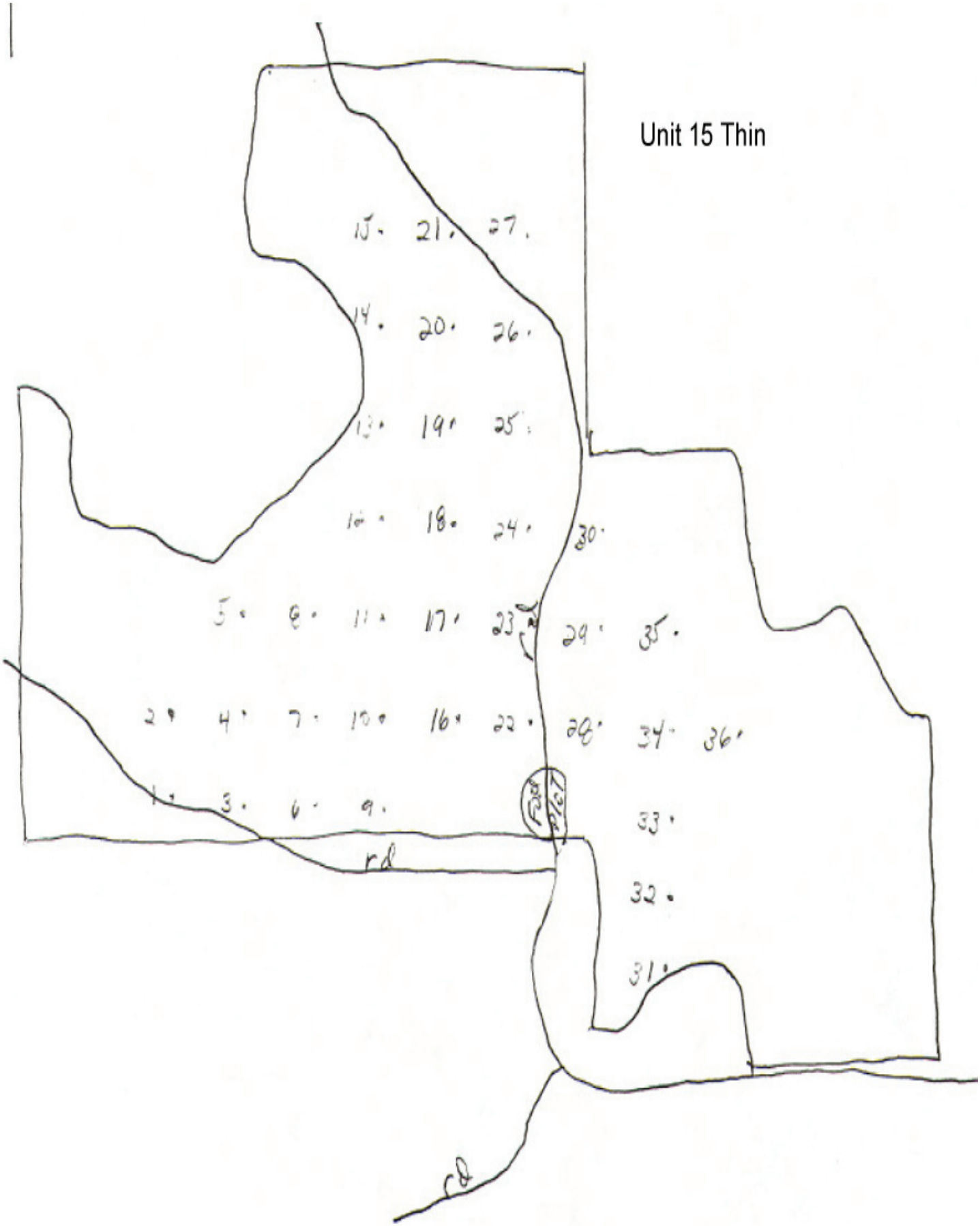

N
Unit 9 Thin
Unit 10 Thin and Burn
food plot
food plot
rd
rd

Unit 11 Burn


32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
Longleaf plantation
food plot
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
fire line


Unit 12 Herbicide
1. 3. 9. 15. 21.
2. 4. 10. 16. 22. 27.
5. 11. 17. 23. 28. 32.
6. 12. 18. 24. 29. 33.
7. 13. 19. 25. 30. 34.
8. 14. 20. 26. 31. 35. 36.
Unit 13 Control
1. 3. 5. 7. 13. 19. 27.
2. 4. 6. 8. 14. 20. 28.
9. 15. 21. 29. 34.
10. 16. 22. 30. 35.
11. 17. 23. 31. 36.
12. 18. 24. 32.
25. 33.
26.


fireline
Unit 14 Thin and Burn
wet
.1
.2
32. 27. 21. 15. 9. .3
33. 28. 22. 16. 10. .4
34. 29. 23. 17. 11. .5
35. 30. 24. 18. 12. .6
36. 31. 25. 19. 13. .7
26. 20. 14. .8
Hart Ridge Rd


Unit 15 Thin
15. 21. 27.
14. 20. 26.
13. 19. 25.
12. 18. 24. 30.
5. 8. 11. 17. 23. 29. 35.
2. 4. 7. 10. 16. 22. 28. 34. 36.
1. 3. 6. 9. 33.
rd
32.
31.
rd

Treatments
Control - no burn
Burn
Thin
Thin and Burn
Herbicide and Burn

Thinning 2002

Thin and Burn 2002

Herbicide 2002

Block	Unit	Treatment	Thinning	Burn	Herbicide	Burn	Mechanical Treatment	Burn
1	2 (6-3E)	Thin and Burn	February 2002	April 5, 2002		April 28, 2004		
1	3 (6-3W)	Thin	February 2002					
1	4 (6-3W)	Herbicide			Sept. 23, 24, 28, 2002	April 15, 2003		June 8, 2005
1	5 (6-9)	Control						
1	6 (6-9)	Burn		April 23, 2002		May 6, 2004		
2	7 (7-1)	Herbicide			Sept. 28-30, 2002	May 13, 2003		June 20, 2005
2	8 (7-1 & 7-5)	Control						
2	9 (7-3)	Thin	March 2002					
2	10 (7-3)	Thin and Burn	March 2002	May 22, 2002		May 4, 2004		
2	11 (8-1)	Burn		May 21, 2002		July 6, 2004		
3	1 (3-3 & 5-5)	Burn		May 15, 2002		April 15, 2004		
3	12 (9-1C)	Herbicide			Oct. 1-2, 2002	April 16, 2003		June 9, 2005
3	13 (9-1C)	Control						
3	14 (9-1E)	Thin and Burn	April 2002	May 1, 2002		April 29, 2004		
3	15 (9-8)	Thin	April 2002					

Thinning Economics

Unit	Pine Sawtimber	Pine Pulp	Hard Hard-woods Pulp	Soft Hard-woods Pulp	Sawtimber Value	Pulp Value	Total
	mbf	cds	cds	cds			
2	3.7	4.2	8.5	0.1	$299.47	$38.04	
3	2.5	2.1	6.2	0	$202.35	$25.17	
9	4.2	3.6	5.8	1.8	$339.94	$33.35	
10	3.5	4.5	2.4	0.9	$283.29	$21.61	
14	1.1	1.6	8.9	0.1	$89.03	$33.02	
15	0.5	2	9.8	3.8	$40.47	$48.89	
Mean	2.58	3	6.9	1.12	$209.09	$33.35	
per acre	1.05	1.21	2.81	0.45	$209.09	$33.35	$242.44

Unit	Pine Sawtimber	Pine Pulp	Hard Hard-woods Pulp	Soft Hard-woods Pulp	Sawtimber Value	Pulp Value	Total
	ton/ha	ton/ha	ton/ha	ton/ha			
2	22.8	11.8	24.1	0.4			
3	15	5.8	17.8	0			
9	25.1	10.1	16.7	5			
10	21.2	12.7	6.8	2.6			
14	6.2	4.4	25.3	0.3			
15	3.3	5.7	27.9	10.8			
Mean	15.6	8.4	19.8	3.18			
per acre	6.31	3.4	8.00	1.29	$189.40	$63.16	$252.56

The herbicide treatments were applied on following dates:

Stand 6-3W (Unit 4) Sept. 23/24/28, 2002
Stand 7-1N (Unit 7) Sept 28.29/30, 2002
Stand 9-1N (Unit 12) Oct. 1/2, 2002

Herbicide was ground applied using solo backpack sprayers. All woody vegetation up to approximately 6 feet was targeted with the exception of longleaf pine seedlings and saplings.

Applied Garlon 4 + timberline 90 surfactant.

Nominal rate: 2 qts Garlon + 9 oz. Timberline 90 per acre in 10-ll gallons of water per acre.

This comes out to approximately a 4.5% solution of Garlon or 20 ounces of Garlon plus 3 ounces of surfactant per backpack (3.5 gallons)

Chemical Cost

Garlon 4 @ $62.50/gallon (in 30 gallon drums)
Timberline 90 @ $12.00/gallon

Garlon $62.50/gallon x .5 gal/acre = $31.50 per acre
Timb. $12.00/gallon x .07 gal/acre= $ 0.84 per acre
Total Chemical Cost: $32.09 per acre

Application Cost: $62.63 per acre

Total Cost Application Plus Treatment: $94.72 per acre

Comparison of vegetation in a control plot (left) with vegetation receiving an herbicide treatment (right.)

DEVELOPING MANAGEMENT OPTIONS FOR LONGLEAF COMMUNITIES OF THE GULF COASTAL PLAIN

Kenneth W. Outcalt, USDA Forest Service, 320 Green Street, Athens, GA. 30602

ABSTRACT: Choosing treatments to reduce fuel loads and readjust structure and composition in longleaf communities of the Gulf Coastal Plains region is difficult because benefits and costs of possible treatment combinations are not fully known. The objective of this research project is to develop management options to reduce fuels and restore the ecosystem that are economically viable and socially acceptable. Research is being conducted in cooperation with Auburn University, which furnished appropriate longleaf stands and has collaborated in data collection on wildlife and soils and logistics support for treatment application. Pretreatment data was collected in 2001 and treatments consisting of thinning, burning and their combination were successfully applied in 2002, in spite of obstacles like a poor timber market and severe spring drought. Post year data collection is proceeding and has already yielded useful information on how to burn recently thinned longleaf stands without excessive crown scorch or tree mortality.

INTRODUCTION

Many U.S. forests, especially those that historically burned at short-intervals, are too dense and/or have excessive quantities of fuels. Widespread treatments are needed to restore ecological integrity and reduce the high risk of uncharacteristically severe and destructive wildfires. Among possible treatments, however, the appropriate balance among cutting, mechanical fuel treatments, and prescribed fire is often unclear. For improved decision making, resource managers need much better information about the consequences of alternative management practices involving fire and mechanical, i.e. fire surrogate treatments.

Longleaf (Pinus palustris) communities of the middle and upper Gulf Coastal Plains historically had an overstory dominated by longleaf pine with pockets of other southern pines and occasional hardwoods, while the understory was grass dominated with lesser amounts of woody shrubs. The open condition and grassy understory were maintained by frequent, every 2 to 5 years, low intensity fires from lightning and native American ignitions. Lack of burning for a number of years during the 1900's allowed hardwoods to increase in the mid and overstory layers while woody shrubs gained understory dominance. These changes have resulted in a variety of impacts from lowered economic returns, to degradation of habitat for numerous species, to more severe wildfires during periodic droughts.

The reintroduction of fire seems like an appropriate treatment to reverse these changes, but the benefits and costs of such treatment is not fully known. The Fire and Fire Surrogate Study recently established on the Solon Dixon Forestry and Education Center, one of 13 nationwide locations, will help fill in these information gaps. The research objective is to develop realistic management options that can be used to treat fuels and restore ecosystems. To accomplish this the initial effects of fire and fire surrogate treatments on vegetation, fuel and fire behavior, soils and forest floor, wildlife, forest insects, tree diseases, and treatment costs and utilization economics will be quantified.

METHODS

The Solon Dixon Forest is representative of the longleaf ecosystem of the Gulf Coastal Plain stretching from Alabama to Louisiana. Currently 1 million acres of longleaf-dominated ecosystem remain in this area with 50 percent in the non-industrial private sector. An additional 2 million acres contain some longleaf pine mixed with other pines and/or hardwoods. Much of the forest in the area is dominated by longleaf pine but other southern pines are also abundant including loblolly (P. taeda), shortleaf (P. echinata), slash (P. elliottii), and spruce pine (P. glabra). In many areas, especially the numerous lower bottoms, there is a substantial hardwood

component dominated by oaks (Quercus spp.). The understory is dominated by woody shrubs with yaupon holly (Ilex vomitoria) the most abundant and lesser amounts of blueberries (Vaccinium spp.) and gallberry (I. glabra).

The design is a randomized block with three blocks of five treatments each. Treatments include an untreated control (no fire or other disturbance), prescribed burn only, with periodic reburns as needed, mechanical removal of excess trees, a combination mechanical removal of excess trees and prescribed burn and a herbicide and burn. Treatment units are operational in size at 30 to 40 acres each.

After a year of pretreatment data collection, trees were marked for thinning in appropriate units. Loblolly, slash and spruce pine and hardwoods, which had increased in abundance during fire control, were targeted for removal during thinning. Tree removal was done through a commercial timber sale. The operator used a feller buncher to cut trees, chainsaws to delimb, and grapple skidders to haul tree length material to the loading areas. The thinning, to reduced basal area to 50 to 60 square feet per acre, was began in January and completed in early April 2002. Prescribed burning was done in April and May by block following thinning operations. Data was collected during and following all burns.

RESULTS AND DISCUSSION

All treatment units were burned using backing, flanking, or spot fires. Unit 2, which took nearly 17 hours to burn, had the slowest moving fire with an average rate of spread of 100 ft/hr (Figure 1). There was significant bole char on trees in this area, but to date tree mortality has been minimal with only a few small pines lost. Units 1 and 10 also had rather slow moving burns, which required 10 hours to complete. The other areas required less time to burn with initial ignitions around 10 am and completion by 2 or 3 in the afternoon. Average rate of spread was influenced by both burning techniques and thinning treatment. Backing fires had a mean spread rate of 100 ft/hr while spot and flank fires spread rate was 170. In thinned units, spread rate was 135 ft/hr versus 200 in burn only stands. The burns in thinned units were also not as uniform because the skid trails interrupted the fire spread while the slash accumulations resulted in greater flame lengths and a longer residence time. Labor and therefore costs of burns were mostly dictated by the size and configuration of burn units rather than the thinning treatments. Both thinned and unthinned units required an average of 2 person hours per acre to install control lines and execute the prescribed burns.

Excessive tree damage was avoided by the pre-fire movement of slash accumulations away from leave trees. It took an average of 1.5 person hours per acre for this slash movement in the two units where many hardwoods were harvested. On the unit that contained mostly pine, no redistribution of slash was necessary prior to prescribed burning. Crown scorch was greater on hardwoods than on pines with no apparent effect due to thinning (Figure 2). Bole char conversely was generally minimal for hardwood stems but averaged about 2.5 m on pines, again with no difference between thinned and unthinned units. The greater crown scorch on hardwoods was likely a function of tree height as there were more short hardwoods than pines. Pre burn litter depth (Figure 3) was the same on burn and thin and burn treatment units, although there was certainly a lot more slash fuel on the thinned areas. Litter consumption was higher on areas thinned before burning, likely because of slash providing addition fuel that increased residence times and therefore litter consumption. Although some places burned down to mineral soil, even on the thinned units the humus layer generally remained with an average litter depth of 1 cm post burn. Herbicide treatment also provide more dead fuel. In addition relative humidity was lower during those burns which resulted in somewhat greater flame lengths.

This study shows that commercial thinning can be used to readjust structure and composition of the mid and overstory layers of longleaf communities of the Gulf Coastal Plains region. These stands can also be treated

with growing season burns soon after thinning to dispose of slash and help control hardwood and woody shrub growth. This requires some movement of logging slash and the burns will be more spotty, but still successful with proper planning and execution. With this slash movement and careful burns, crown scorch for pines can be kept at less than 10 percent. At this low level, there should be little increase in tree mortality and growth loss in subsequent seasons will be minimal (Johansen and Wade 1987). All of the burns were somewhat more time consuming and thus costly than general prescribed burning, but this must be viewed against the minimal damage and mortality to the remaining stand. Once the stand has readjusted to growing season burns, costs will be more typical. Which of the treatments tested is best suited to management objectives of a healthy and productive longleaf community will require additional data collection over a longer time.

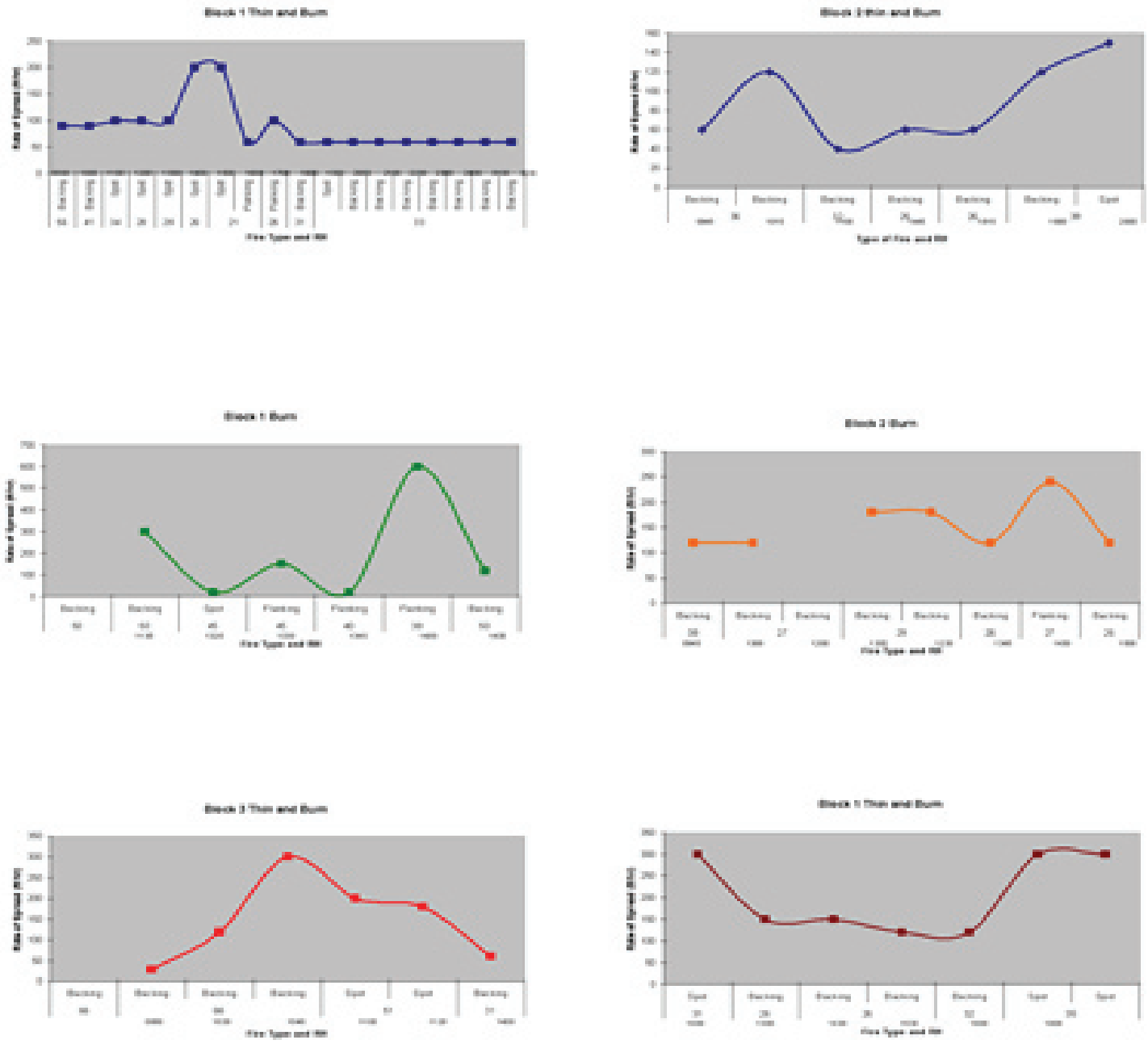


Figure 1. Influence of fire type and relative humidity on rate of spread during prescribed burns of different treatment units at the Solon Dixon Center in southern Alabama. Note unit 11 is two adjoining areas that were burned on consecutive days.

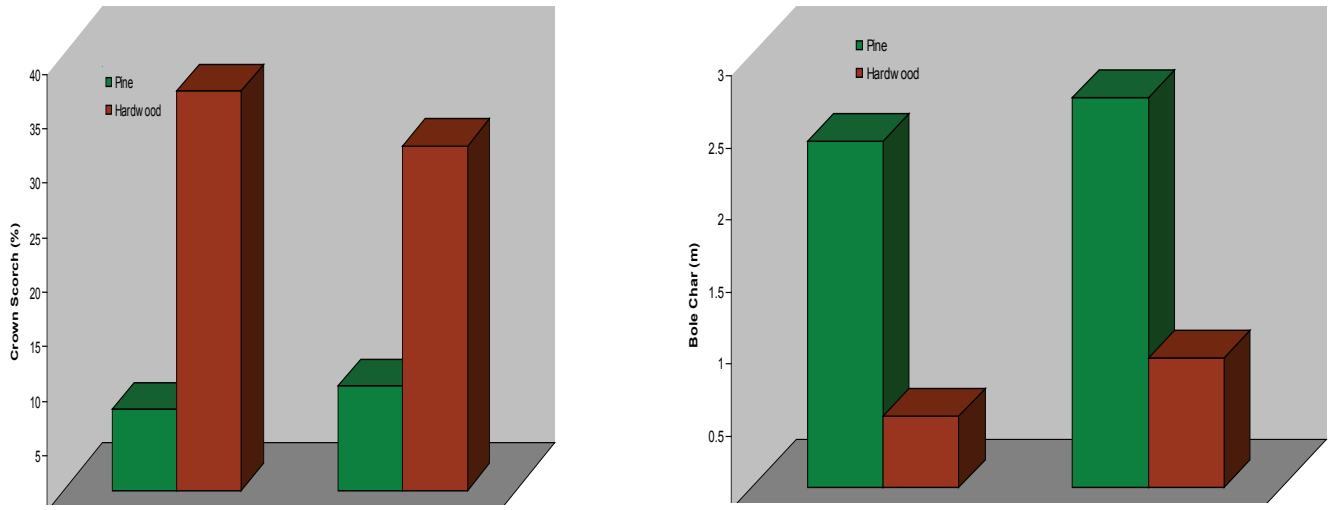


*Figure 2. Crown scorch (a) and bole char (b) of southern pines and hardwoods from prescribed burning in stands, with or without prior thinning, on the Solon Dixon Center in southern Ala*bama.

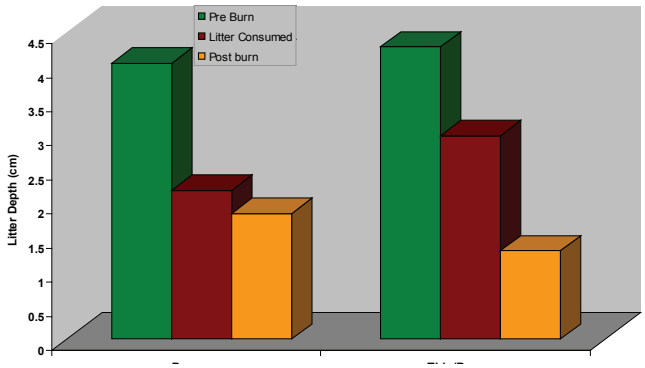


Figure 3. Litter consumption from prescribed burns in stands, with or without prior thinning, on the Solon Dixon Center in southern Alabama.

ACKNOWLEDGEMENTS

This is contribution number 24 of the National Fire and Fire Surrogate Research (FFS) Project. This research was funded by the USDA Forest Service through the National Fire Plan. Although the authors received no direct funding for this research from the U.S. Joint Fire Science Program (JFSP), it was greatly facilitated by the JFSP support of existing FFS project sites. This study would not have been possible without the cooperation of Auburn University School of Forestry and Wildlife Sciences and the Solon Dixon Forestry and Education Center.

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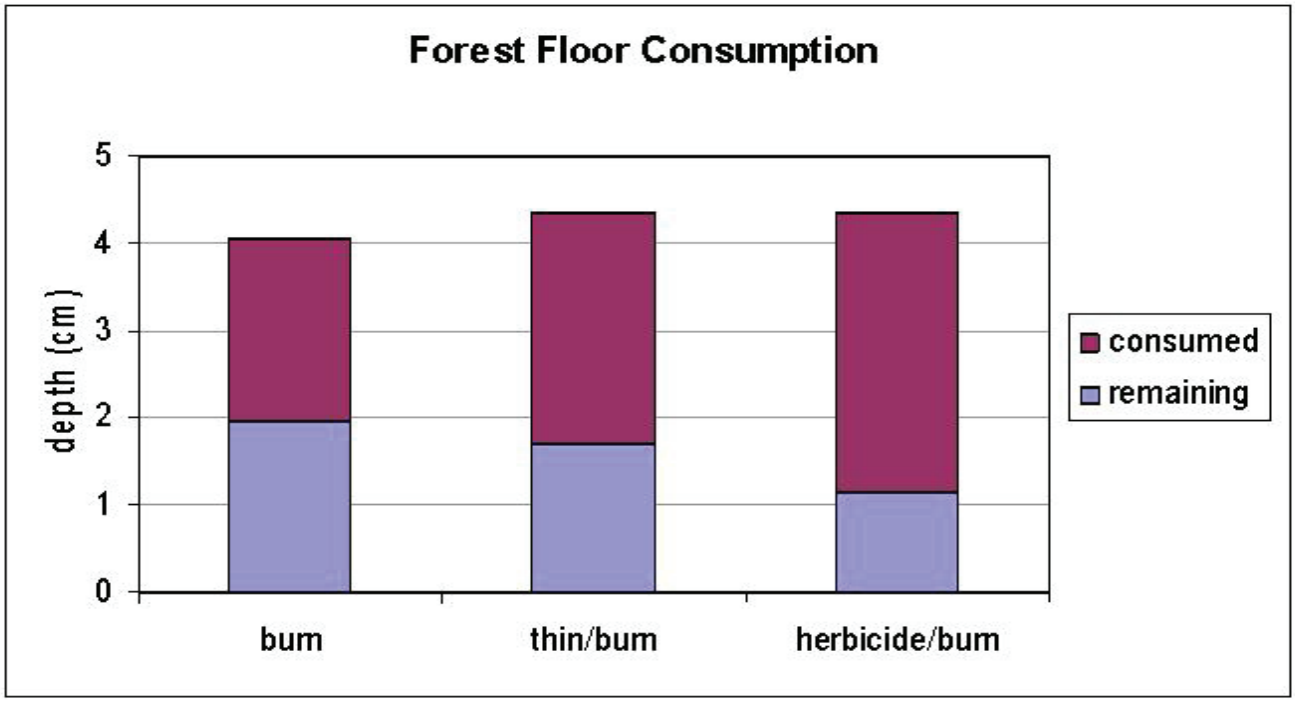
Forest Floor Consumption
depth (cm)
5
4
3
2
1
0
burn
thin/burn
herbicide/burn
consumed
remaining

Fire Behavior

Unit ID	Date of Burn (mmddyyyy)	Time Ignition Began	Time Ignition Completed	Ambient Temperature Range (°C)	Relative Humidity Range (%)	Wind Speed Range (k/h)	Wind Direction	Firing Technique	Spacing of firing method (m)	Flame Length Average (m)	Flame Length Std. Deviation	Rate of Spread Average (m/s)	Rate of Spread Std. Deviation	Fire Zone Width Average (m)	Fire Zone Width Std. Deviation	Residence Time Average (min)	Residence Time Std. Deviation
2	4/5/2002	9:00	2:00	66	21-56	9.6-22.4	N, NE	strip firing		0.5	0.3	0.007	0.004	0.5	0.2	8.3	2.5
6	4/17/2002	10:40	14:30	89	38-50	0-9.6	variable	strip firing		1.1	0.4	0.017	0.019	0.9	0.5	4.8	1.9
14	5/1/2002	8:50	14:00	31.7	31-66	14.4-22.4	S, SW	strip firing		0.7	0.4	0.013	0.008	0.8	0.6	3.8	1.2
1	5/15/2002	9:35	21:00	29.4	26-35	0-4.8	NE	strip firing		0.7	0.3	0.017	0.008	0.4	0.2	3.1	0.7
11N	5/21/2002	9:30	13:00	25.6	27-38	4.8-12.8	N, NE	strip firing		0.5	0.2	0.010	0.000	0.5	0.2	4.0	1.4
11S	5/20/2002	9:00	15:00	25.0	26-29	0-4.8	NE	strip firing		0.7	0.3	0.014	0.004	0.4	0.1	3.8	0.4
10	5/22/2002	9:15	20:00	27.2	25-39	0-8	E	strip firing		0.6	0.2	0.007	0.004	0.5	0.1	5.1	1.5
4	4/15/2003			29.4	25-	1.6-3.2	SE	strip firing		0.7		0.011		0.7		3.8	
12	4/16/2003			28.9	29-	3.2-4.8	S,SW	strip firing		1.6		0.016		0.9		4.3	
7	5/13/2003			29.4	22-	0-8	NE	strip firing									

value is max temp

RESTORING STRUCTURE AND COMPOSITION OF LONGLEAF PINE ECOSYSTEMS OF THE GULF COASTAL PLAINS

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ABSTRACT: Longleaf communities of the middle and upper Gulf Coastal Plains historically had an overstory dominated by longleaf pine (Pinus palustris) with pockets of other southern pines and occasional hardwoods, while the understory was grass dominated with lesser amounts of woody shrubs. The open grassy understory was maintained by frequent, every 2 to 5 years, low intensity fires. The objective of this research project is to develop realistic management options that can be used to manage fuels and restore and maintain this ecosystem. Research is being conducted in cooperation with Auburn University at the Solon Dixon Forestry and Education Center near Andalusia, Alabama. Treatments include an untreated control (no fire or other disturbance), prescribed fire only, mechanical removal of selected trees, and a combination mechanical removal of trees and prescribed fire, and herbicide treatment followed by prescribed burning. Although there was not a large change in either relative composition or diameter distributions, thinning created a more open stand with fewer small hardwoods. Cover of understory shrubs was reduced by both thinning and burning with the combination treatment the most effective. Burning caused the greatest reduction in small understory hardwoods while thinning alone had no effect. For larger midstory hardwoods, however, burning alone resulted in no change while thinning reduced their density significantly. Thus, fire is needed to control understory hardwoods while thinning is needed to reduce larger midstory hardwoods. Therefore, the combination treatment may be the quickest treatment for restoring structure and composition to this ecosystem.

INTRODUCTION

Historically, prior to fragmentation of the landscape, lightning ignited fire was a frequent natural occurrence (every two to eight years) across much of the South (Abrahamson & Hartnett 1990, Ware and others 1993). These fires regulated plant composition and favored those species that survived frequent burning. Native American burning augmented these natural fires. This burning kept fuel loads low, thereby reducing the probability of more severe wildfires. The South was one of the first areas where land managers recognized the usefulness and need for frequent prescribed burning to control fuel levels. A large influx of people from other regions of the country where fire is not as prevalent has occurred over recent decades. They do not understand the need for burning and only see the temporary negative aspects of smoke and ash and a blacked area. Increasingly this population growth has occurred on the edge or within forested areas creating a significant amount of wildland to urban interface. This has made prescribed burning much more difficult. Litigation from smoke on highways and an increase in rural highway traffic has also reduced the amount of prescribed burning, especially on private lands.

Reduced burning has resulted in significant changes that are undermining the health and long-term sustainability of many southern communities. Longleaf pine ecosystems for example were once the most prevalent type in the Southeast occupying as much as 23 million hectares, stretching from southeastern Virginia south to central Florida and west into eastern Texas (Stout and Marion 1993). This longleaf pine-grass ecosystem was maintained by frequent fires that inhibited the establishment and growth of competitive but less fire-tolerant species (Clewell 1989). Today longleaf occupies less than 5 percent of its original extent (Outcalt and Sheffield 1996). The continuing reduction of this important forest type threatens a myriad of life forms characteristic of, and largely dependent on, longleaf pine habitat.

Widespread treatments are needed to restore ecological integrity and reduce the high risk of uncharacteristically severe and destructive wildfires in these forests. Among possible treatments, however, the appropriate

balance among cutting, mechanical fuel treatments and prescribed fire is often unclear. For improved decision making, resource managers need much better information about the consequences of alternative management practices involving fire and mechanical, i.e. fire surrogate treatments. The objective of this study is to develop realistic management options that can be used to treat fuels and restore ecosystems. Reported here are the initial effects of these fire and fire surrogate treatments on stand structure and composition in typical gulf coastal plains longleaf stands of southern Alabama.

METHODS

This study is part of the national Fire and Fire Surrogate study funded by the Joint Fire Science Program. This particular location received much of its funding from the National Fire Plan to fill a critical ecosystem type not included in the original nationwide study. It is located about 35 km southwest of Andalusia, Alabama (31o 9' N, 86o 42' W) on the Solon Dixon Forestry Education Center. The center, owned and operated by Auburn University School of Forestry, includes teaching and research facilities and 5,320 acres of forestland. Much of the forest is dominated by longleaf pine but other southern pines are also abundant including loblolly (P. taeda), shortleaf (P. echinata), slash (P. elliottii), and spruce pine (P. glabra). In many areas, especially the numerous lower bottoms, there is a substantial hardwood component dominated by oaks (Quercus spp.). The understory is dominated by woody shrubs with yaupon holly (Ilex vomitoria) the most abundant and lesser amounts of blueberries (Vaccinium spp.) and gallberry (I. glabra).

There are four basic treatments including prescribed burning only, thinning only and their combination along with an untreated control. In addition this site has a fifth local option treatment of herbicide followed by prescribed burning. These were applied utilizing a randomized block design with three blocks. Stands used in the study were selected from all possible areas that were pine dominated with a significant amount of longleaf, were historically longleaf pine dominated, and were at least 12.5 ha. Trees were marked in selected stands at the end of 2001. Selected trees were sold to a commercial logger who began thinning in January of 2002 and finished operations by early April. Equipment using in the logging included a feller buncher, grapple skidders, a loader and haul trucks. Limbing was done near the stump with chainsaws. Logging slash was redistributed by hand to move concentrations away from remaining crop trees. Prescribed burning was done during April and May utilizing backing, flank, and spot fires (Outcalt 2003).

Each stand consists of a core area of 12.25 ha with a surrounding 20m buffer. There are 36 grid points on a 50m by 50m spacing in each stand with ten rectangular 20m by 50m plots established between selected grid points. The overstory tree layer (all trees > 15cm at dbh) was sampled on the entire 20 by 50m plot, while midstory trees (0.1 to 14.9 cm) were sampled on 10 by 50m sub-plots. Diameters and species were recorded for all overstory and midstory stems before treatment application and each growing season post treatment. Cover of understory shrubs greater than 1.37 m tall was determined by ocular estimation before and after treatments on two 10 by 10m sub-plots located at each end of the 20 by 50 plots. Pretreatment data were analyzed with analyses of variance and post treatment data were compared with analyses of covariance using pretreatment levels as the covariate.

RESULTS

There was some variation in stand composition prior to treatments. Total basal area ranged from 15.4 to 23.4 m2/ha. Longleaf pine was the most prevalent species on all sites except stand 15, which was dominated by loblolly pine (Figure 1). Most stands also contained a considerable amount of hardwood, especially oaks. Thinning treatments targeted hardwoods and other pines to reduce their prevalence while increasing the dominance of longleaf pine. However, longleaf pine was also harvested where it was deemed appropriate to reduce stocking and remove inferior trees. On average across all stands thinning removed 10 percent of slash pine

basal area, 15 percent of longleaf, 18 percent of loblolly, and 49 percent of other pines. The most heavily harvested were the hardwoods with oak basal area reduced by 55 percent and other hardwoods by 58 percent.

Midstory hardwoods were present in all stands prior to treatment with an average density from 104 stems/ha in stands that were selected for burning to 240/ha in the thin and burn stands. There were no significant changes in midstory hardwood density in control stands over the first 4 years (Figure 2). Burning alone did not significantly reduce midstory stocking , but rather there was an increase by year 4. Some hardwood stems were harvested during thinning and additional individuals were knocked down by logging equipment. This resulted in a significant decline in midstory density on thinned only and thinned and burned stands. The thinned only stands had returned to pretreatment stocking by year 4 but burning kept thin and burn treatments at a reduced density. Herbicide application followed by burning also reduced midstory hardwoods but not as effectively as thin and burn treatments.

Density of the smallest diameter hardwoods stems (0.01 to 1.00 cm) was not affected by the thinning operation (Figure 3). Burning, however, significantly reduced this size class of hardwood stems with over a ten fold reduction in burn only, thin and burn, and herbicide and burn stands. Density of these small hardwood stems increase the second growing season following treatments, but were reduced again following the next prescribed burns. It appears that thinning may have reduced the density of understory hardwood stems in both the 1.01 to 2.00 and 2.01 to 3.00 cm diameter classes. Without burning however, stocking quickly increased and these treatments were not significantly different from control stands 3 years after treatment application (Figures 4 and 5). The herbicide and burn treatment was very effective at reducing small hardwoods in the 1.01 to 2.00 cm size class.

All treatments significantly reduced tall shrub cover. On thin only plots the shrubs quickly recovered and increased to level equal to the control stands. The combination treatments caused shrub cover to decline temporarily but then shrubs returned to pretreatment levels the following growing season (Figure 6) Burning with or without other treatments kept tall shrubs from expanding and capturing much of the site as happened in non-burned stands.

DISCUSSION

Thinning can be used to readjust structure and composition of the midstory and overstory layers of longleaf communities of the Gulf Coastal Plains region. By selectively targeting species that have increased during the period of reduced fires, a stand can be set on a trajectory to become a more open and fire adapted community where overstory health can be maintained with prescribed burning. These stands can be treated with growing season burns soon after thinning to dispose of slash and reduce wildfire hazard.

The cover of understory shrubs can be reduced by both thinning and burning. Burning is also the most effective means of removing small understory hardwood stems. Larger stems however, i.e. those bigger than 3.0 cm in diameter are quite resistant to burning. Burning did not effectively reduce midstory hardwoods with a single burn. Others have also reported that young hardwoods are also quite susceptible to top kill by fire; and frequent fires can keep hardwood sprouts at low stature in longleaf stands (Komarek 1977; Landers and others 1990). Once stems become larger however, they are more resistant to future surface fires (Rebertus and others 1993). Repeated burning at frequent intervals is required to kill larger hardwoods and reduce the density of hardwood rootstock (Waldrop and others 1987). Therefore, although the combination thinning and burning treatment will be more costly, it is also the quickest method for restoring stand structure and overstory composition to these longleaf pine communities of the Gulf Coastal Plain. It will require continued prescribed burning on a regular basis to maintain these stands and further their development into a more open longleaf

pine dominated overstory with a diverse herbaceous dominated understory.

ACKNOWLEDGEMENTS
This is contribution number ?? of the National Fire and Fire Surrogate Research (FFS) Project. This research was funded by the USDA Forest Service through the National Fire Plan. Although the authors received no direct funding for this research from the U.S. Joint Fire Science Program (JFSP), it was greatly facilitated by the JFSP support of existing FFS project sites. This study would not have been possible without the cooperation of Auburn University School of Forestry and Wildlife Sciences and the Solon Dixon Forestry and Education Center.

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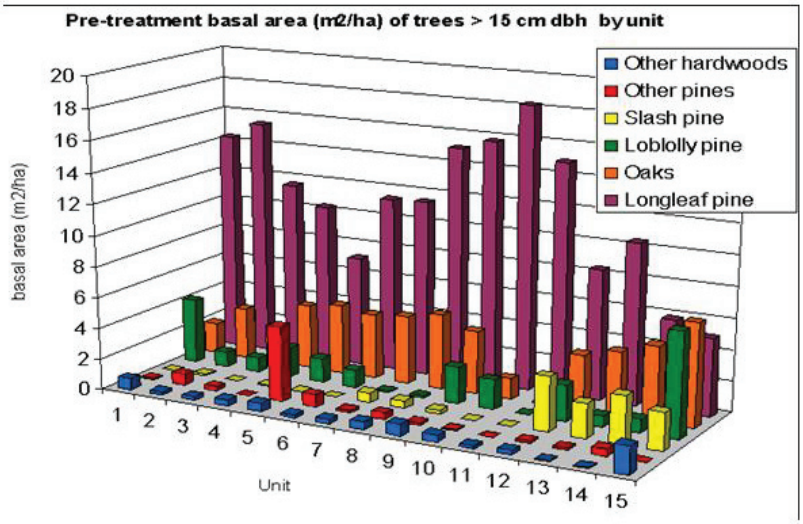

Change in basal area from thinning treatments

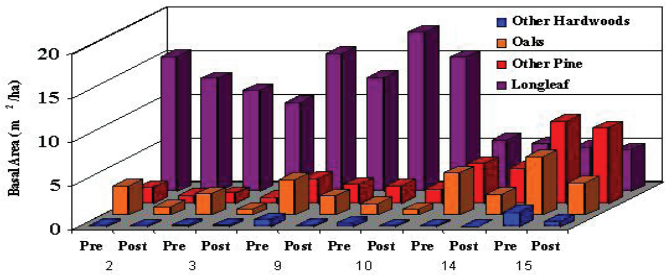

Figure 1.—Pretreatment basal area of overstory trees >15cm diameter by stand and species group.

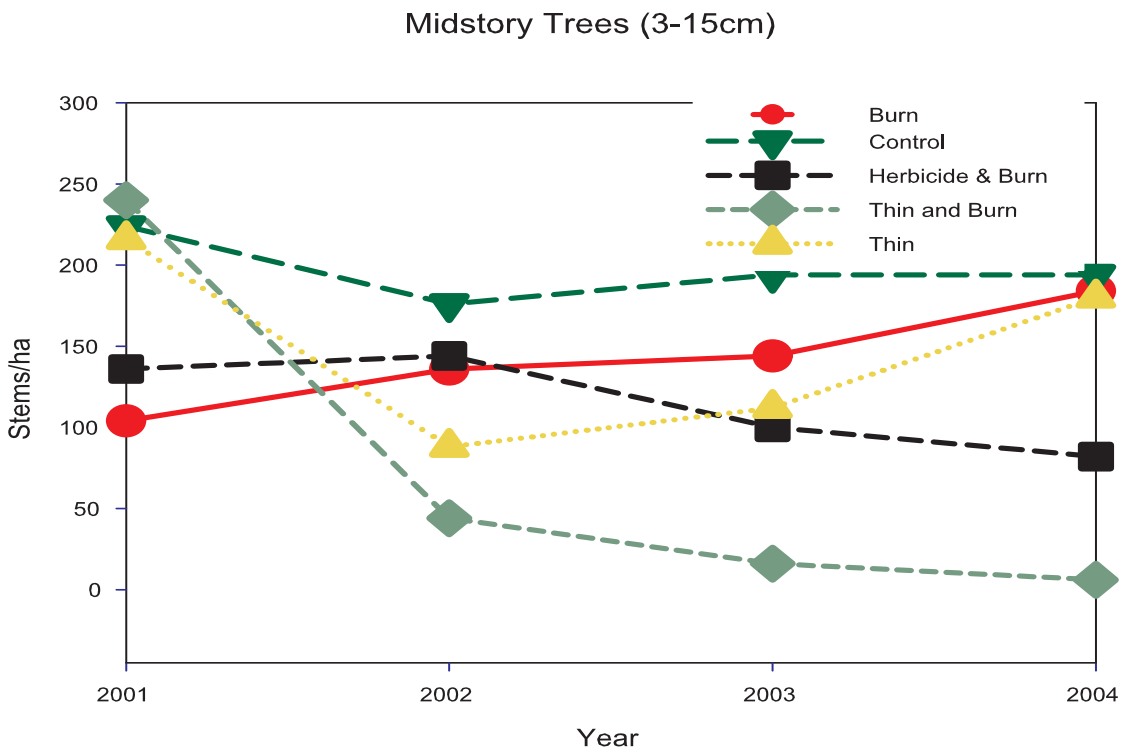

Figure 2.—Density of midstory hardwoods (3.01 –15cm dbh) by treatment and year.

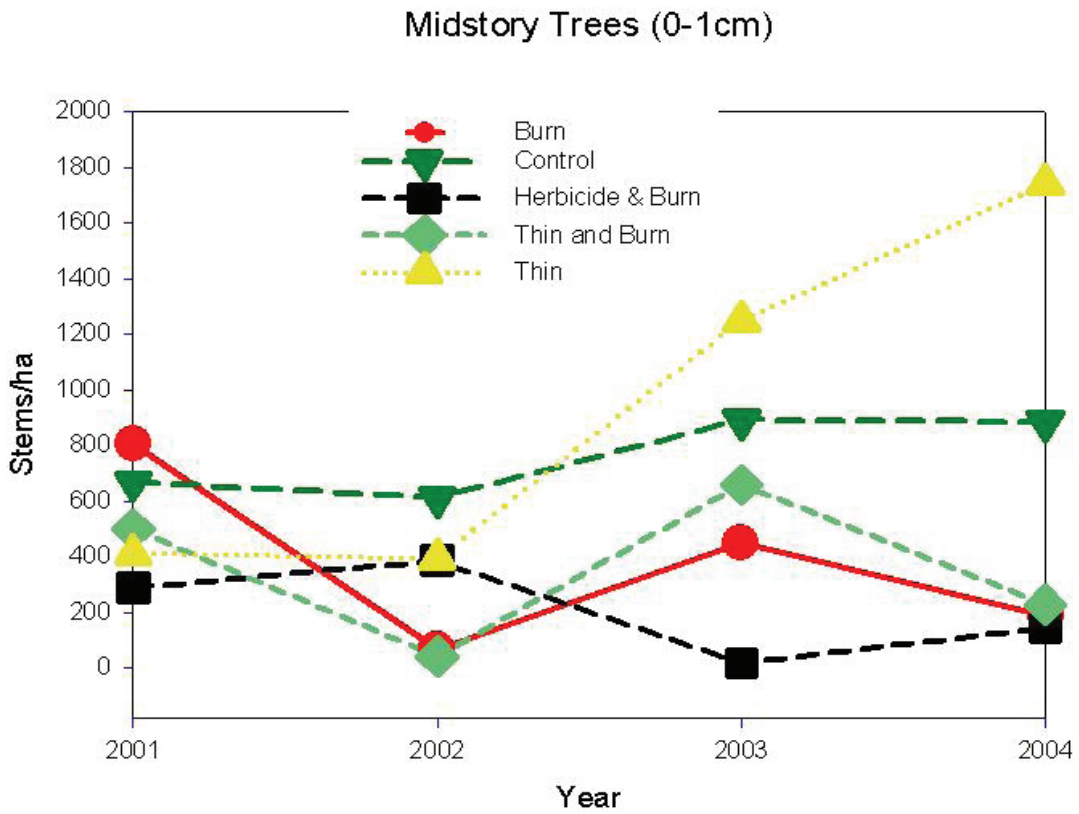

Figure 3.—Density of midstory hardwoods (0.01 –1.00cm dbh) by treatment and year

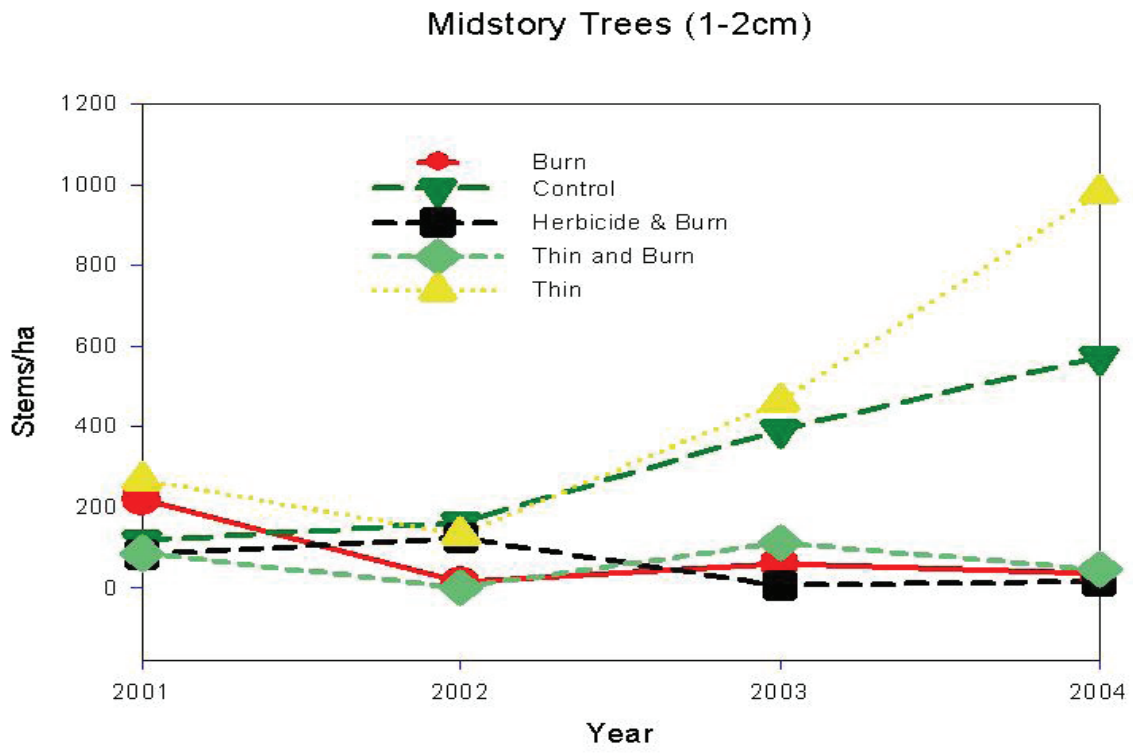

Figure 4.—Density of midstory hardwoods (1.01 –2.00cm dbh) by treatment and year

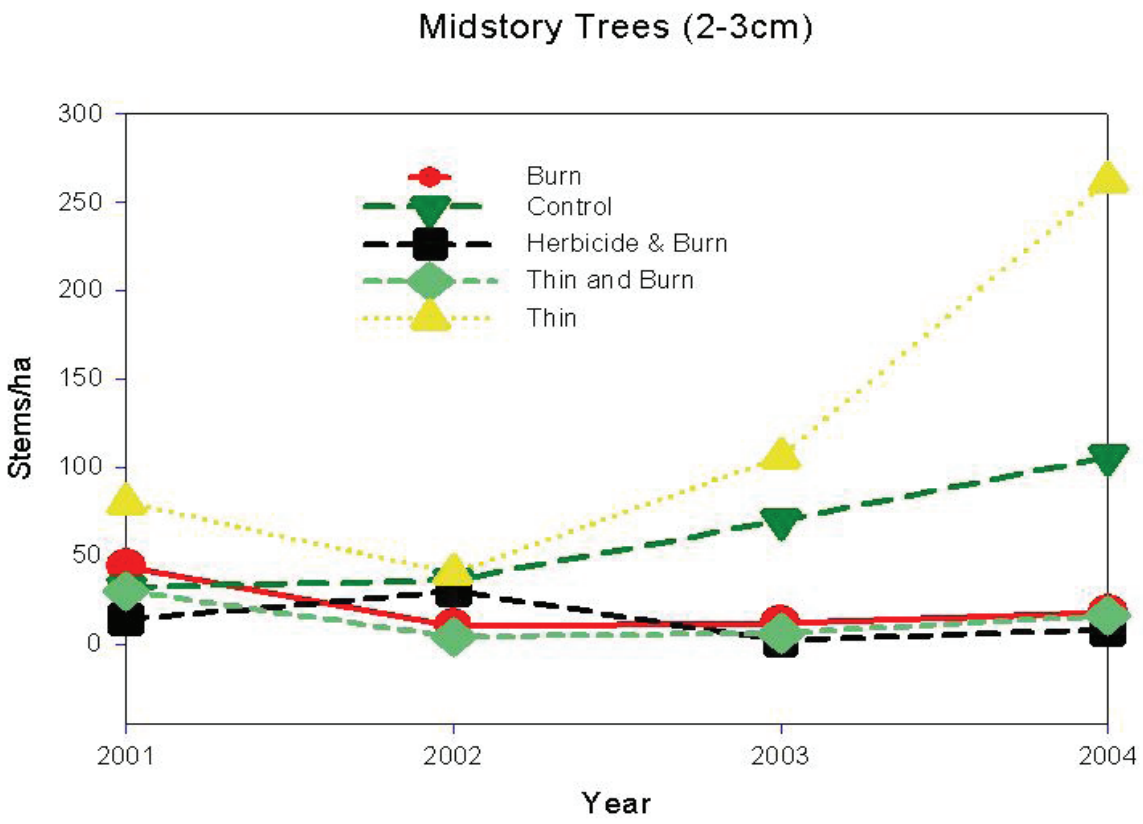

Figure 5.—Density of midstory hardwoods (2.01 –3.00cm dbh) by treatment and year.

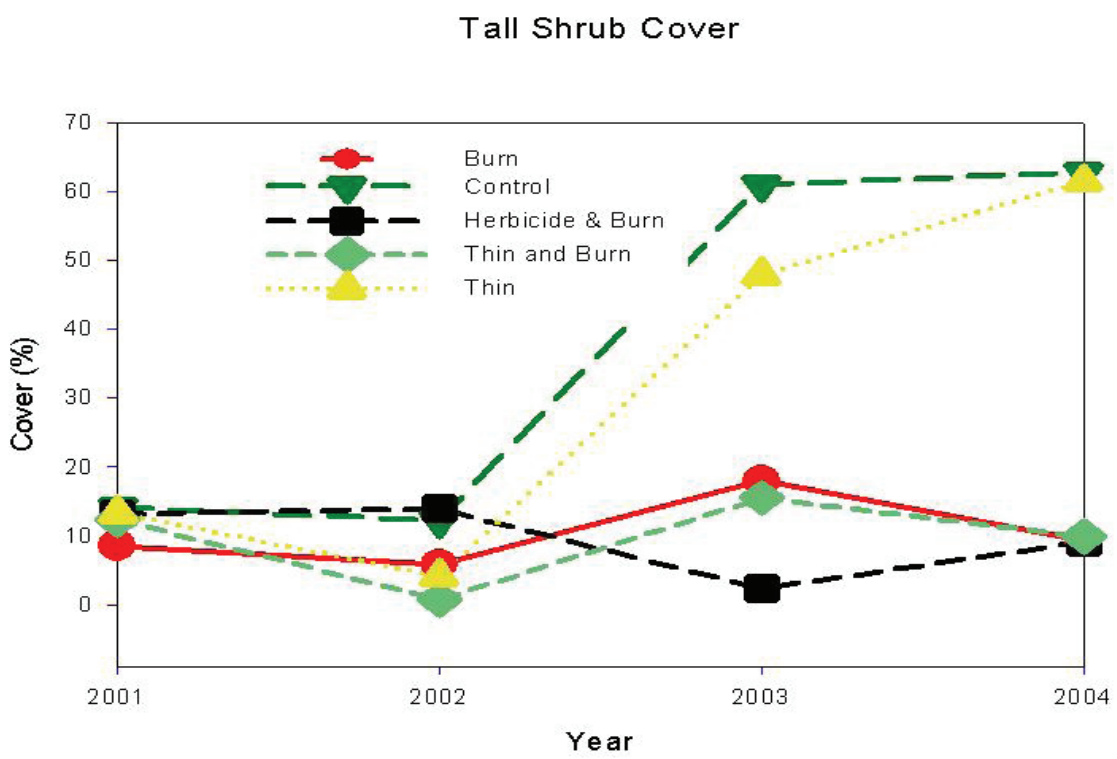

Figure 6.—Cover of shrubs taller than 1.37m by year and treatment.

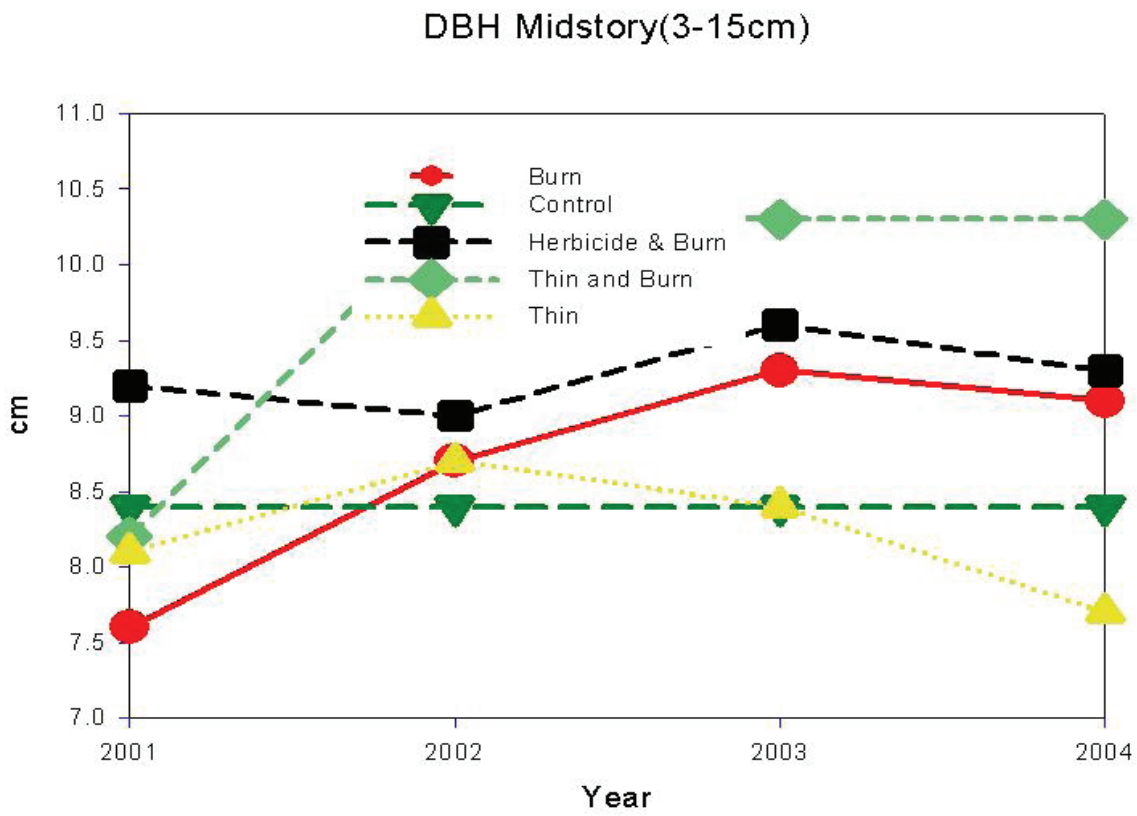

Figure 7.—Average diameter of midstory hardwoods with diameters from 3.01 to 15cm by treatment and year.

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

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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

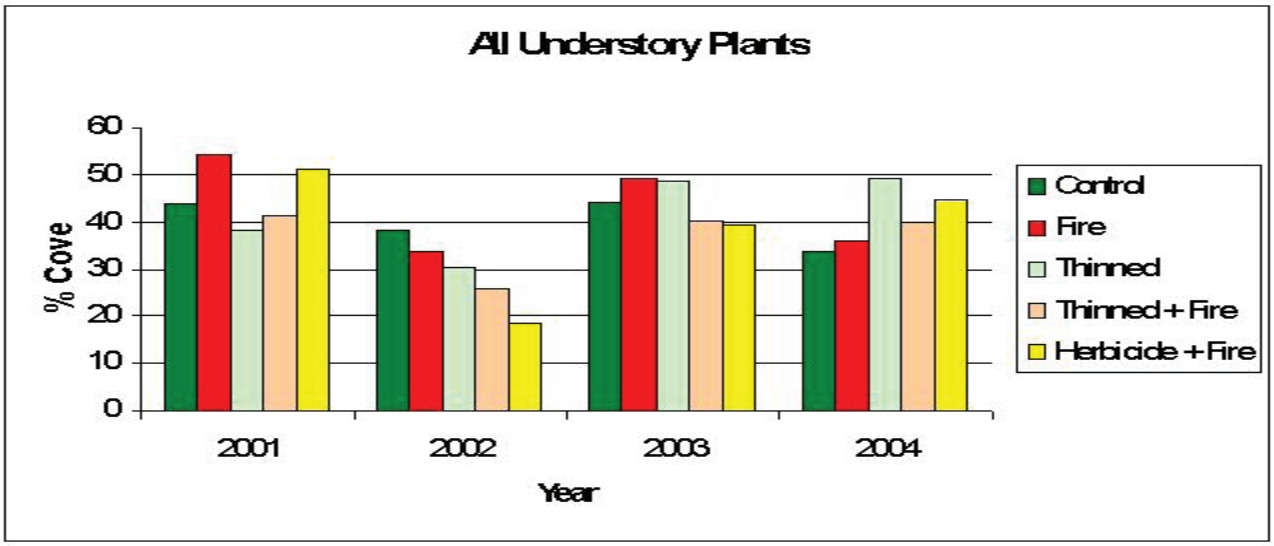
2003	16.9	16.7	11.8	7.9	4.7
2004	12.7	10.9	13.5	6.9	6.6
All Herbs:					
2001	9.6	13.1	4.1	8.5	11.3
2002	4.4	14.7	5.0	9.1	3.5
2003	6.1	15.7	8.1	12.8	20.0
2004	4.9	15.7	6.4	19.2	19.5
Graminoids:					
2001	7.0	9.5	2.8	5.2	7.3
2002	2.5	5.2	2.5	3.1	2.9
2003	4.5	9.2	5.4	7.8	9.8
2004	3.5	8.6	5.1	11.8	14.0
Forbs:					
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

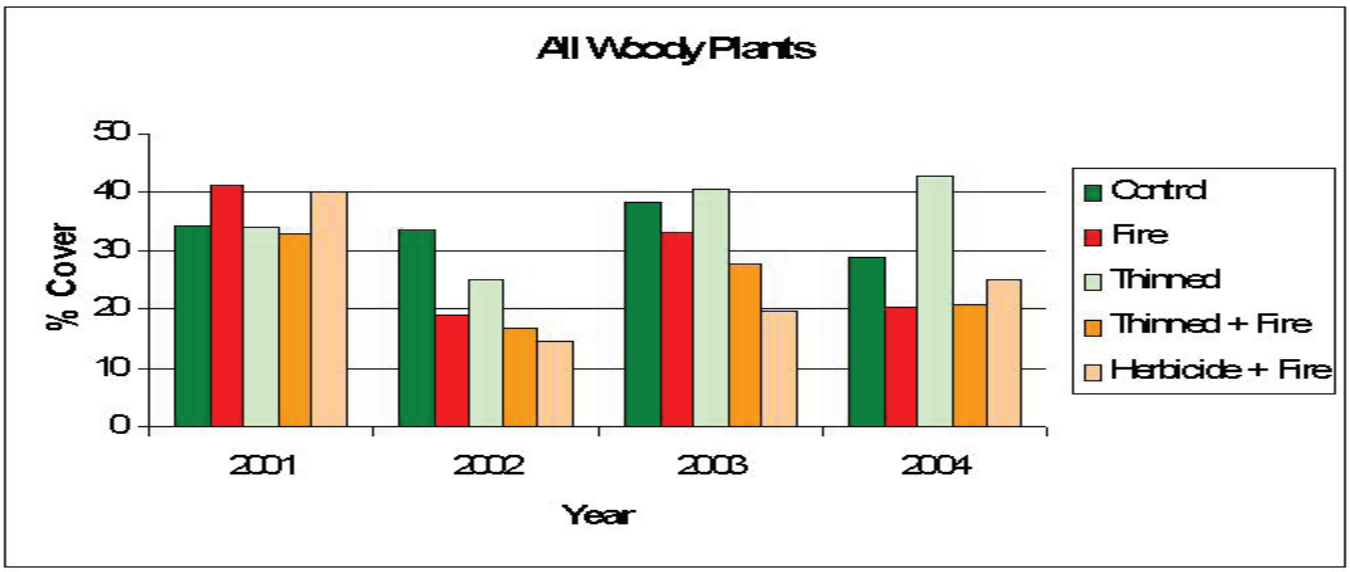
Table 2. Understory Plant Diversity at the Dixon Forest (treatments applied during 2002).

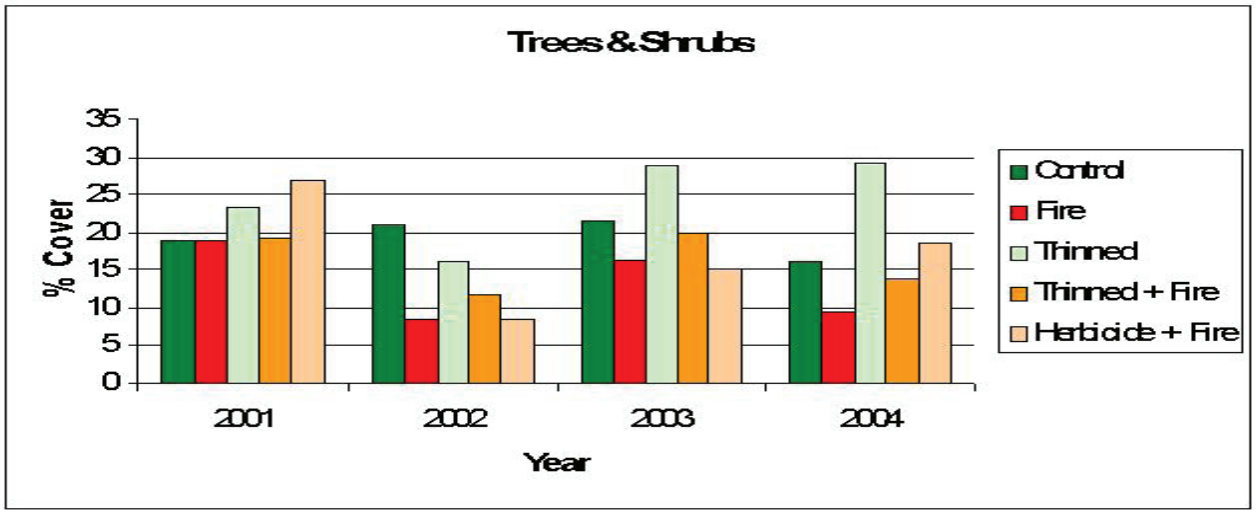
	Control	Fire	Thinning	Thinning Plus Fire	Herbicide Plus Fire
Richness of All Species/m2:					
2001	6.6	6.8	5.1	6.0	7.6
2002	7.2	8.1	6.2	7.0	4.3
2003	6.2	8.2	6.9	8.2	9.0
2004	5.1	8.1	6.4	9.6	8.6
Shannon Diversity of All Species/m2:					
2001	1.84	1.89	1.56	1.71	1.94
2002	1.83	2.05	1.76	1.96	1.41
2003	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

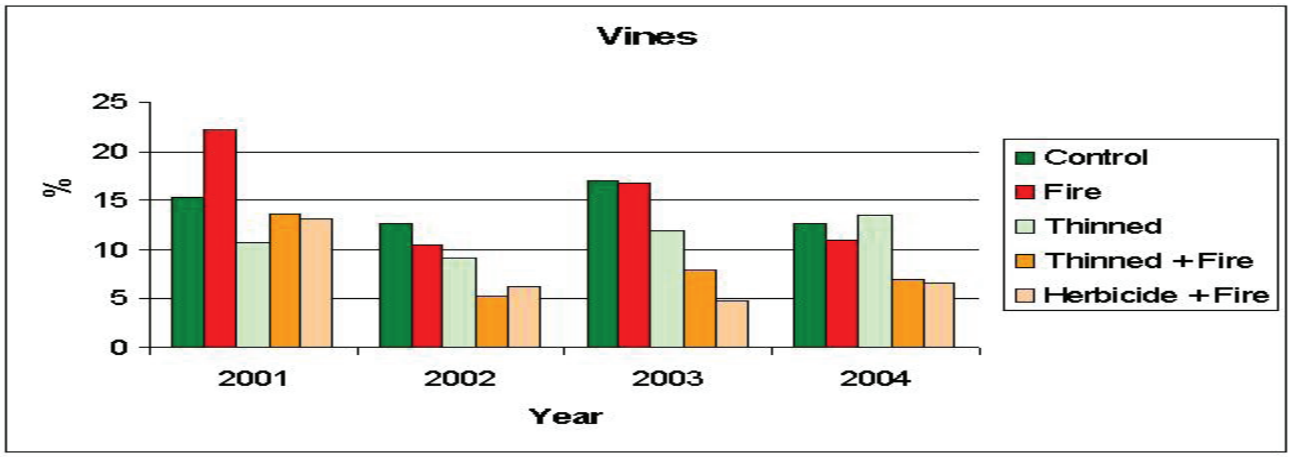
Richness of Herbs/0.1 ha:

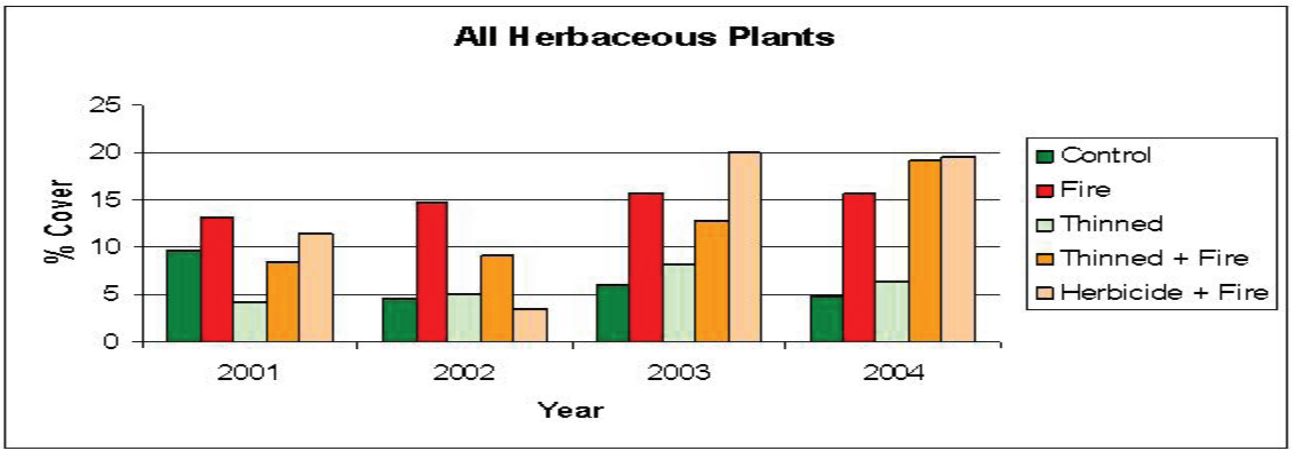
2001	10.5	11.3	6.1	10.8	14.9
2002	13.8	16.9	12.1	17.4	7.5
2003	11.3	17.1	12.7	20.0	25.6
2004	6.5	16.2	8.3	23.4	18.5

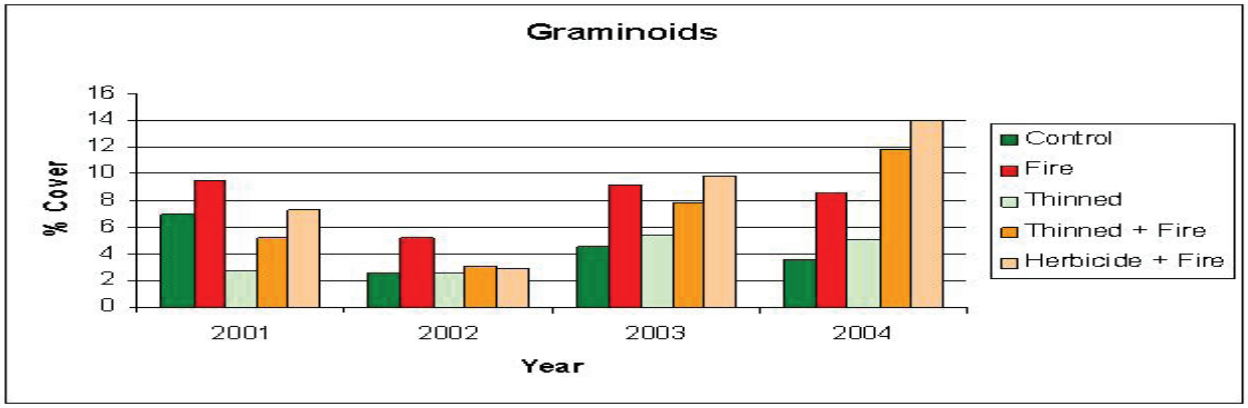


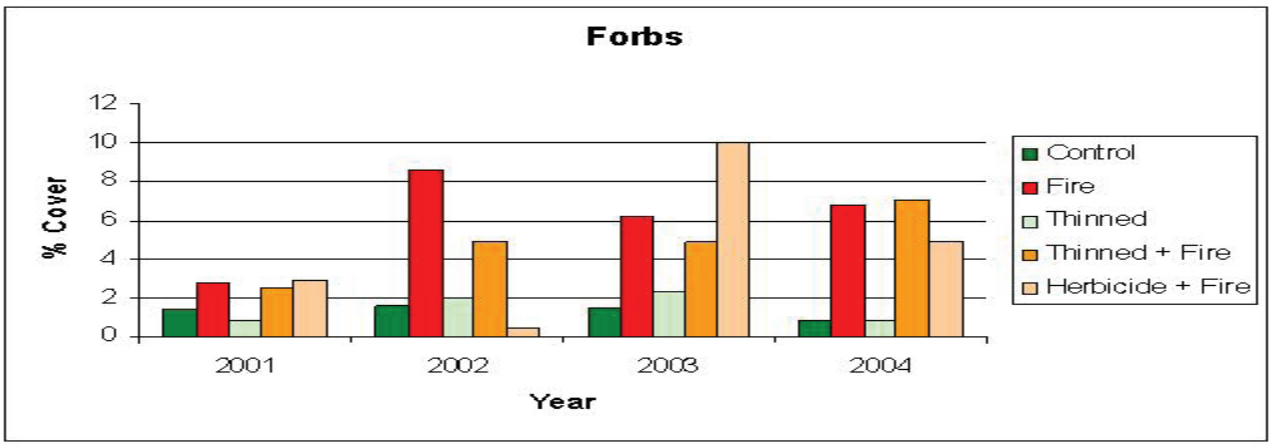


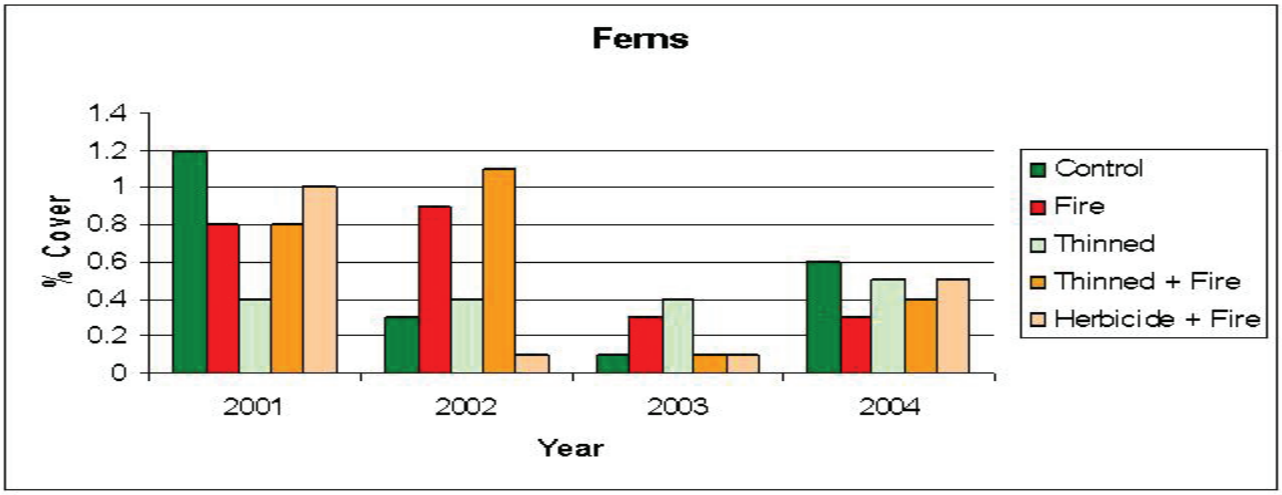

Trees & Shrubs
% Cover
35
30
25
20
15
10
5
0
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire

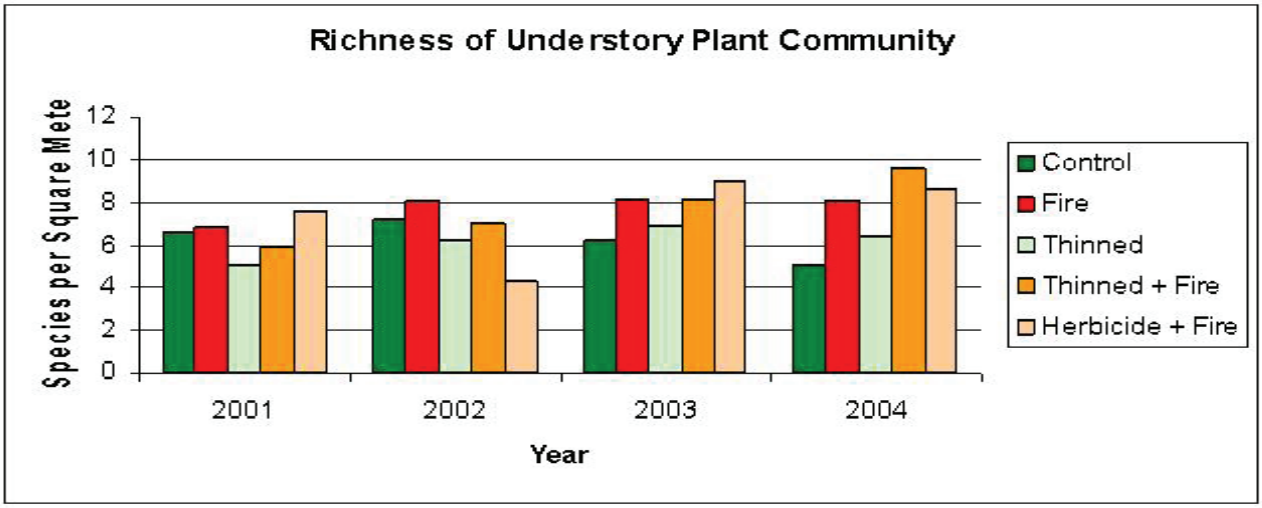

Vines
%
25
20
15
10
5
0
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire

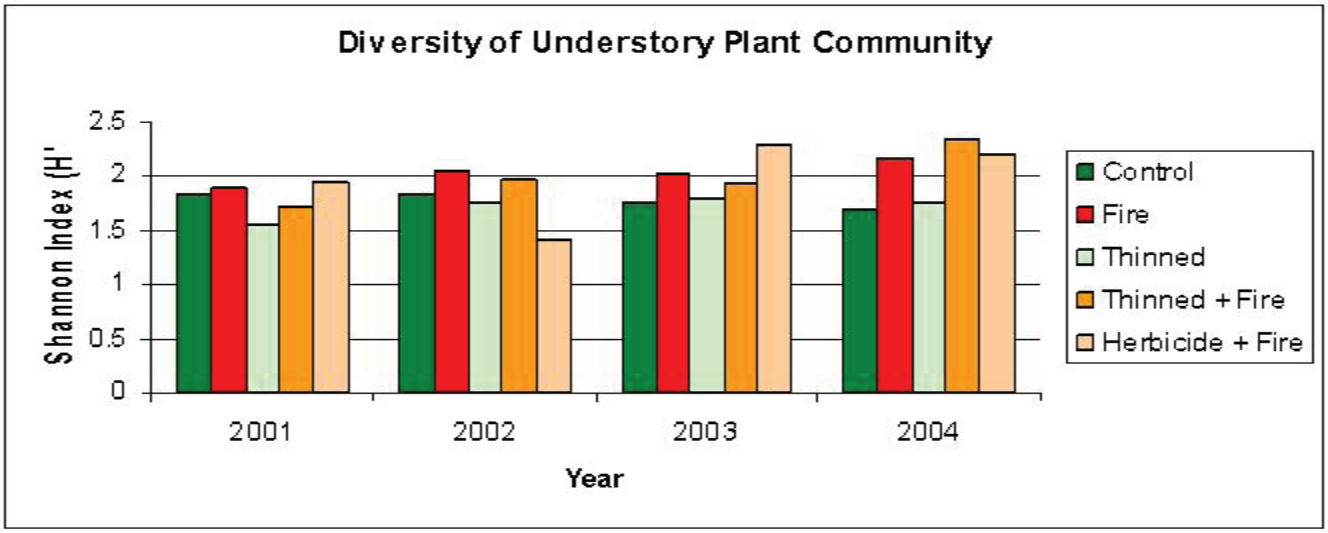

All Herbaceous Plants
% Cover
25
20
15
10
5
0
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire

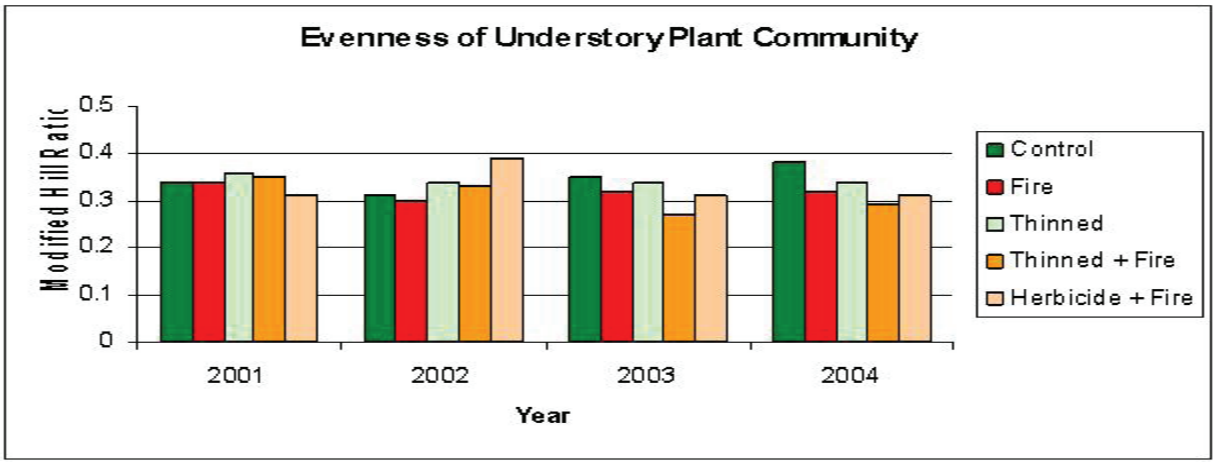

Graminoids
% Cover
16
14
12
10
8
6
4
2
0
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire

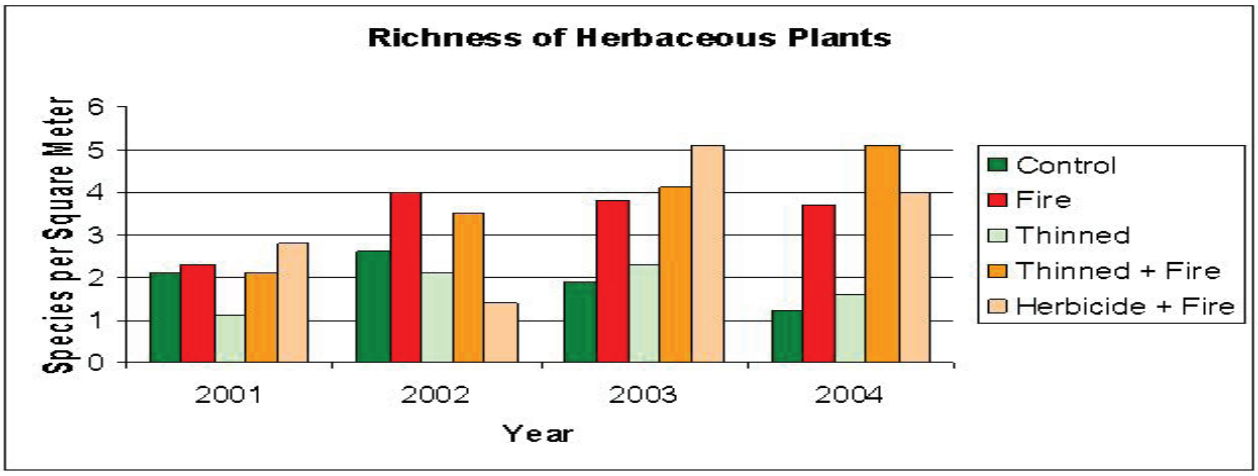

Forbs
% Cover
12
10
8
6
4
2
0
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire

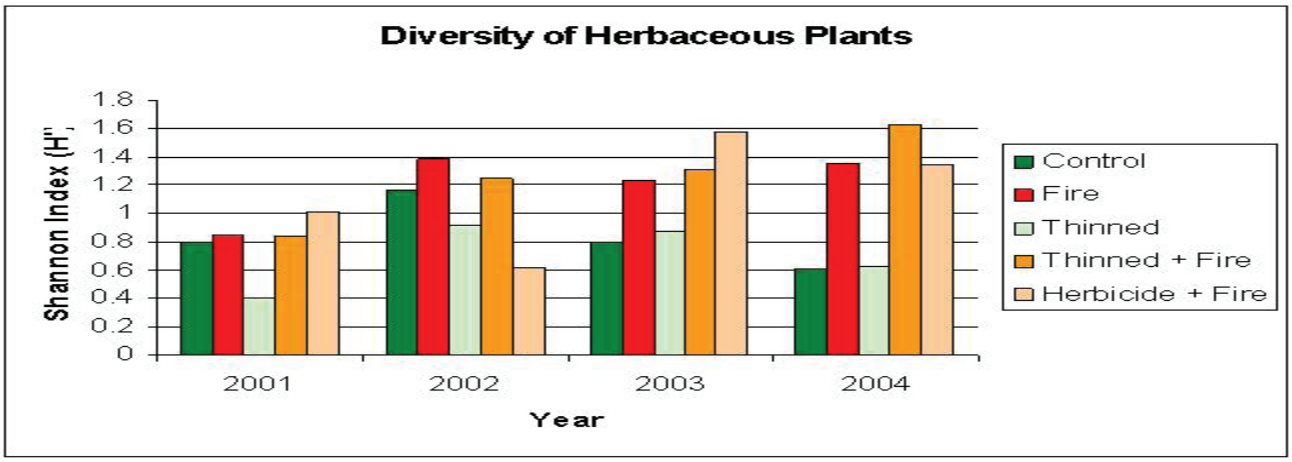

Ferns
% Cover
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire

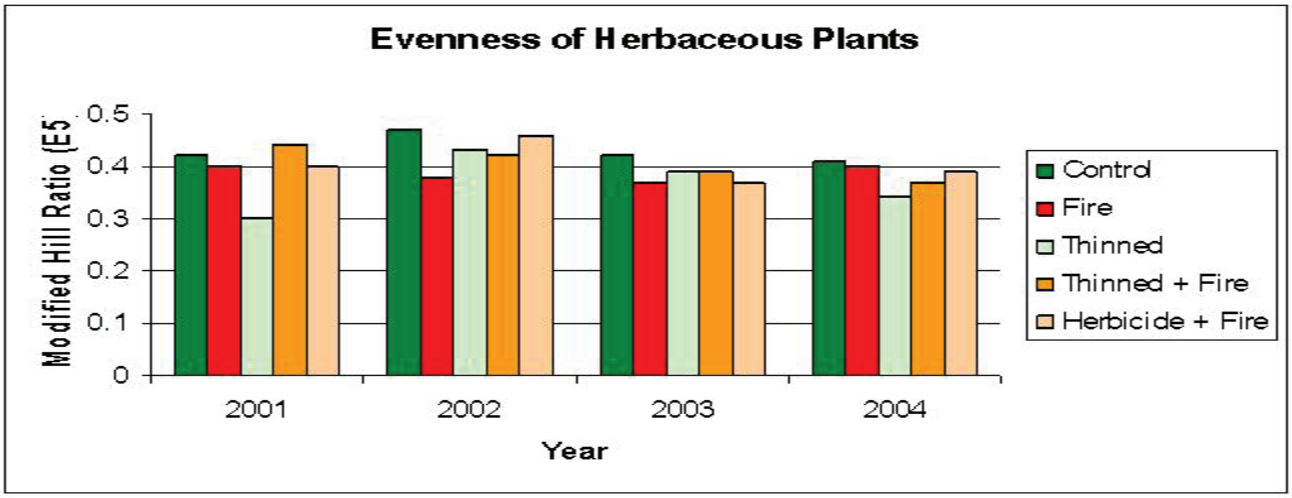

Richness of Understory Plant Community
Species per Square Mete
12
10
8
6
4
2
0
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire

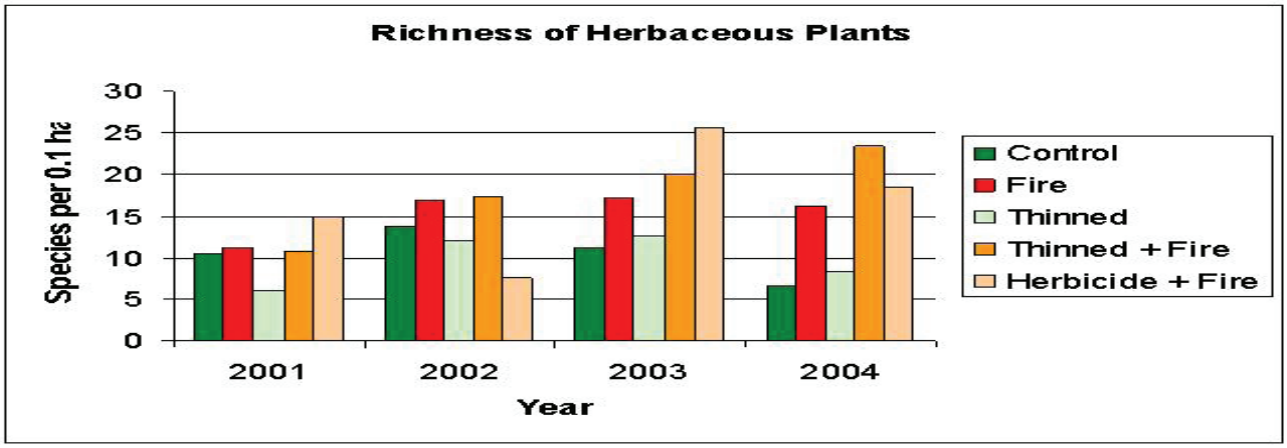

Diversity of Understory Plant Community
Shannon Index (H'
2.5
2
1.5
1
0.5
0
2001
2002
2003
2004
Year
Control
Fire
Thinned
Thinned + Fire
Herbicide + Fire


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

Effects of Prescribed Burning and Alternatives on Pollinators

Josh Campbell, Jim Hanula and Ken Outcalt

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Introduction

Prescribed burning is an important tool for managing pine forests in the southeastern U.S. In addition to its traditional role of reducing fuel loads and controlling midstory vegetation, it is also being used more frequently as a tool for restoring and maintaining understory herbaceous communities in once fire dominated ecosystems. How well it functions in this latter role will be dependent to some degree on how prescribed burning or other treatments affect the pollinating insect community. Nearly 70% of flowering plants depend on insects for pollination. Without them plant populations experience poor seed production and limited gene flow which ultimately limits population growth and viability.

We used several different types of traps to capture pollinating insects to determine how the fire and fire surrogate treatments applied on the Solon Dixon Experimental Forest affected the abundance and diversity of these important insects.

Methods

Trapping was conducted between April and October in 2003 and 2004. Traps consisted of blue, yellow and white 500ml capacity SoloTM plastic bowls filled with water and a malaise trap with 4 cotton cloth (0.3 m2) panels of the same colors attached to catching surfaces. One malaise trap and 15 bowls (5 of each color) were operated on each plot for one week per month.

Results

We caught 10,908 flower visiting insects from 4 orders and 27 families. Hymenoptera (bees and wasps) comprising 8 families and 27 species were the most common and diverse order. We caught 6 families and 26 species of flower visiting Coleoptera (beetles), 10 families and 45 species of Lepidoptera (butterflies), and 3 families and 16 species of Diptera (flies). Overall, we caught approximately equal numbers of flower visiting insects on all treatments. Likewise, treatments had no effect on overall pollinator diversity.

Although the treatments did not have a general effect on overall numbers of flower visitors caught, we did see some treatment effects at the order or family level.

The Hymenoptera, which are probably the most important group of pollinators, were caught in fewer numbers on control plots in 2003 than on the plots that received prescribed burns in either 2002 or 2003 (Figure 1). The thinning treatment alone was not significantly different from either the controls or other treatments. In 2004, the controls had fewer Hymenoptera than the burn only treatment. Although not statistically significant, abundance of Hymenoptera on the thin and burn plots was relatively high. Both the burn only and the thin and burn plots received prescribed burns in the spring of 2004.

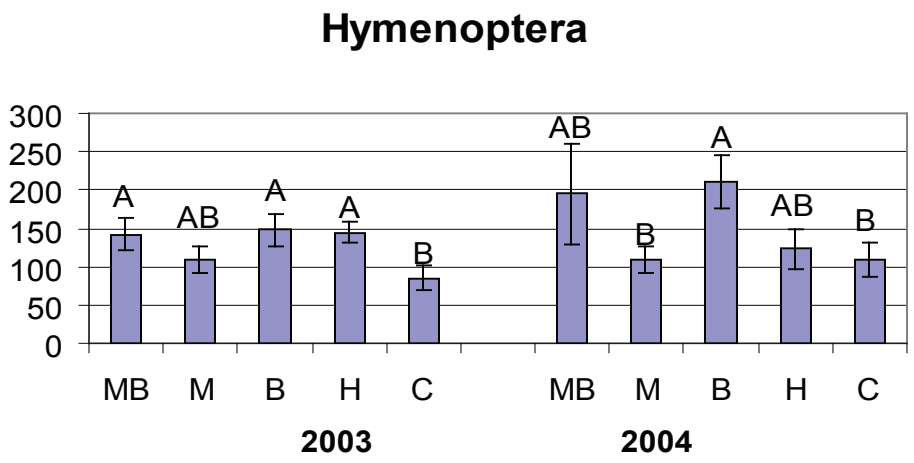


Figure 1. Mean number of flower visiting Hymenoptera captured on fire or fire surrogate treatment plots on the Solon Dixon Experimental Forest near Andalusia, AL. Treatments were thin and burn (MB), thin (M), burn (B), herbicide and burn (H) and untreated control (C). Columns within the same year with the same letter above them are not significantly different.

Most of the differences we observed were driven by the most abundant family, the Halictidae (Figure 2). These bees were caught in lower numbers on the control plots compared to other treatment plots in 2003 and, in 2004, control plots had fewer halictids than the burn only plots. Again, the thin and burn plots had relatively high numbers of halictids compared to the controls. Halictids are primarily ground-nesting bees that like open, exposed bare mineral soil for nests sites. We think that the burning and thinning operations exposed mineral soil either through fire or mechanical disturbance that provide better nesting habitat for these bees.

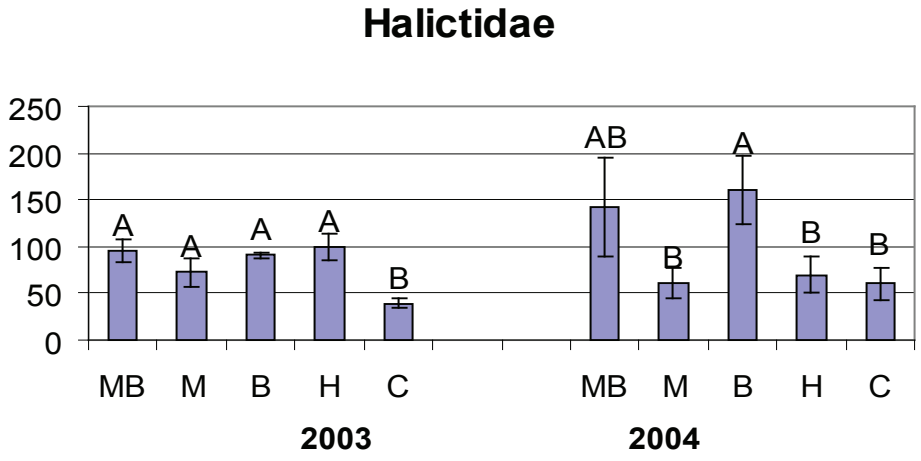


Figure 2. Mean number of flower visiting Halictidae captured on fire or fire surrogate treatment plots on the Solon Dixon Experimental Forest near Andalusia, AL. Treatments were thin and burn (MB), thin (M), burn (B), herbicide and burn (H) and untreated control (C). Columns within the same year with the same letter above them are not significantly different.

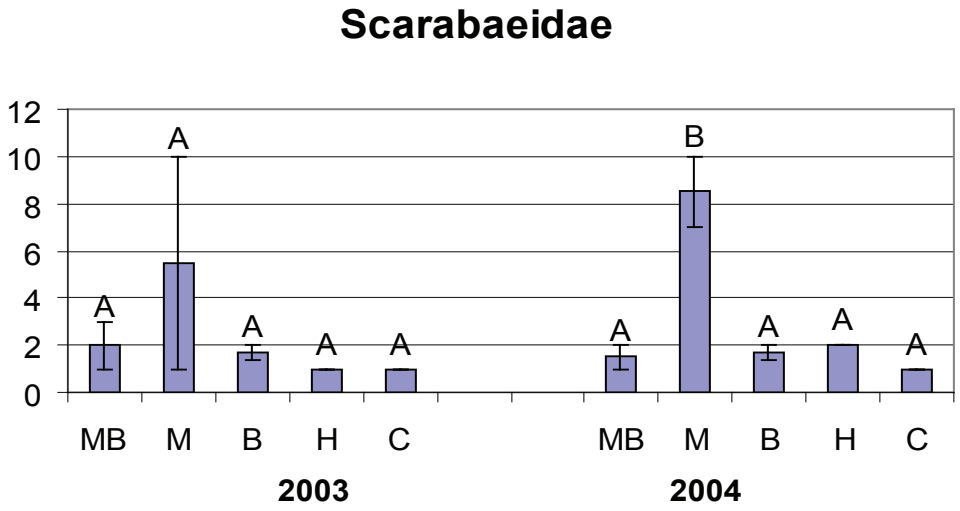


Figure 3. Mean number of flower visiting Scarabaeidae captured on fire or fire surrogate treatment plots on the Solon Dixon Experimental Forest near Andalusia, AL. Treatments were thin and burn (MB), thin (M), burn (B), herbicide and burn (H) and untreated control (C). Columns within the same year with the same letter above them are not significantly different.

The Mordellidae, or tumbling flower beetles, also were affected by the treatments. In 2004, both the thin and burn and the thin only plots had more mordellids than the herbicide and burn and burn only plots. It is unclear why mordellids would respond in this way.

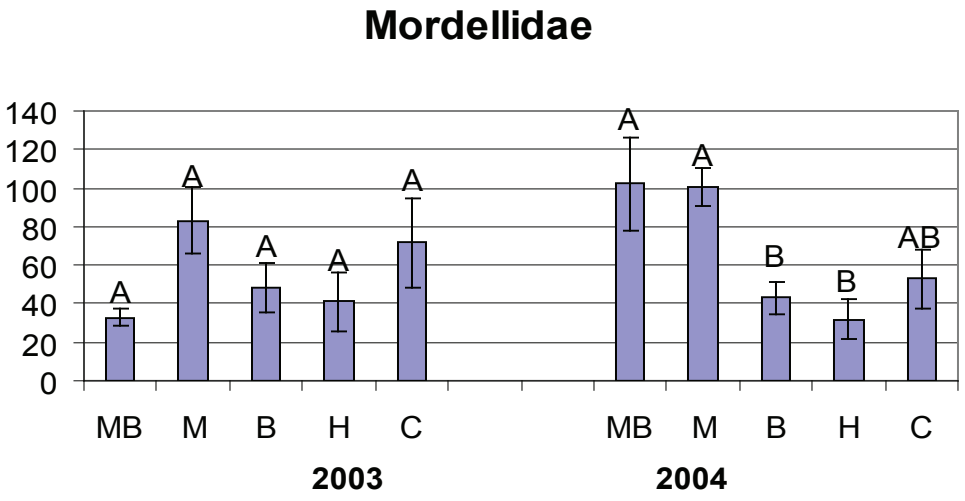
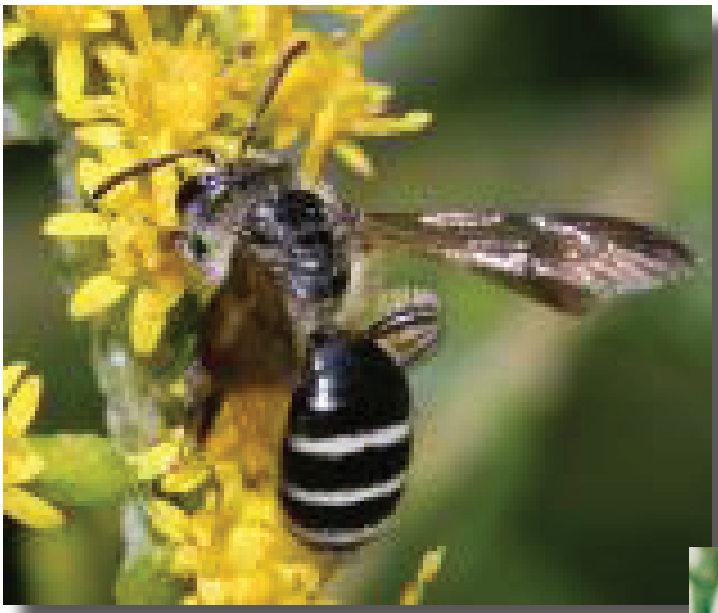


Figure 4. Mean number of tumbling flower beetles (Mordellidae) captured on fire or fire surrogate treatment plots on the Solon Dixon Experimental Forest near Andalusia, AL. Treatments were thin and burn (MB), thin (M), burn (B), herbicide and burn (H) and untreated control (C). Columns within the same year with the same letter above them are not significantly different.

Acknowledgments
This research was funded by the Joint Fire Sciences Program and the USDA Forest Service Fire Plan. We thank Scott Horn and Danny Dyer for their help in this study.



Effects of Prescribed Burning and Alternatives on Tree Mortality

Jim Hanula and Ken Outcalt
USDA Forest Service, Southern Research Station, 320 Green St., Athens, GA 30602-2044

Introduction

Prescribed burning is an important tool for managing pine forests in the southeastern U.S. In addition to its traditional role of reducing fuel loads and controlling midstory vegetation, it is also being used more frequently as a tool for restoring and maintaining understory vegetation. Prescribed burning and potential alternatives to it could increase tree mortality directly or create conditions that favor bark beetle population growth and subsequent tree attacks.

We surveyed the fire and fire surrogate treatment plots on the Solon Dixon Experimental Forest for tree mortality, presence of bark beetles and assigned a cause or reason for the observed mortality.

Methods

We examined all of the trees on each plot for tree mortality approximately twice per year beginning in December 2001, before treatments were applied, and continued through March 2004. A September 2004 survey was planned but Hurricane Ivan caused significant damage and altered the treatment plots so we postponed the survey until November 2004 and used the last survey to assess treatment affects on stand susceptibility to wind damage.

Surveys were conducted by walking the lines along grid points and visually inspecting trees for symptoms of damage. Dead or dying trees were tagged, and the diameter, tree species, cause of death and bark beetle species attacking the tree were recorded.

The data were summed for all years and analyzed using Proc GLM in SAS (SAS 1985). Means were separated using Tukey's test.

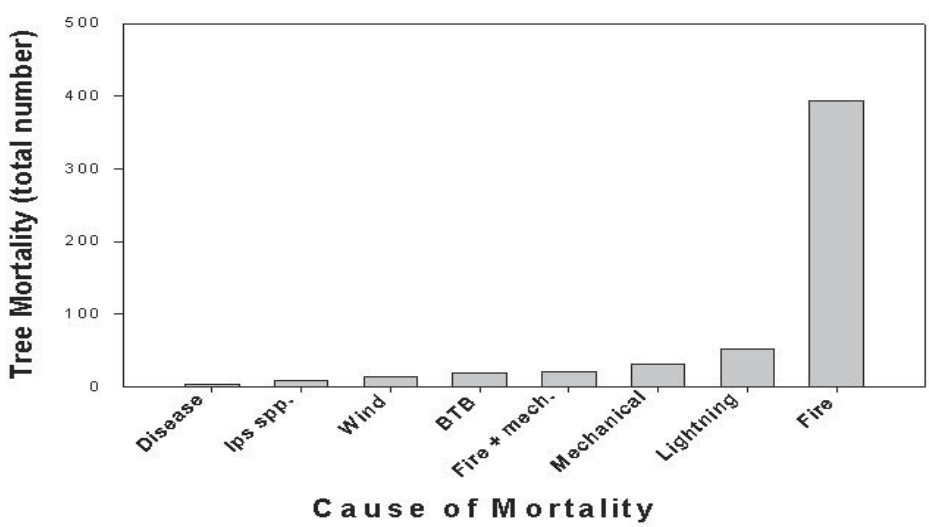


Figure 1. Total tree mortality by cause of death from 2001-2004 on the Solon Dixon Experimental Forest fire and fire surrogate treatment plots.

Results and Discussion

The causes of tree mortality are shown in Figure 1. Fire was the most common cause of tree death causing almost 10 times more tree mortality than lightning, the second most common reason for trees dying. Bark beetles, primarily Ips spp. and black turpentine beetles (BTB) (Dendroctonus terebrans), caused very little direct mortality. Ips spp. were commonly found attacking trees but in most cases we thought fire or some other agent killed the tree and Ips beetles were acting as scavengers. We saw no evidence of southern pine beetle (D. frontalis) attacks during the study which was consistent with the low abundance of this beetle in the southern portion of Alabama from 2002 -2004.

Tree mortality changed over time (Figure 2) primarily on plots that received prescribed burns after either thinning or herbicide treatments to reduce the abundance of youpon holly (Ilex vomitoria). The larger amounts of fuel resulted hotter fires and more tree mortality. Mortality continued to increase following burning on plots that received thinning and prescribed burning for 18 months after the burn. The increased mortality was due to the combination of treatments since we saw very little fire caused mortality in November 2004 despite a second prescribed burn applied to each of the thin and burn plots in April and May 2004. Burning alone and thinning alone caused very little tree mortality.

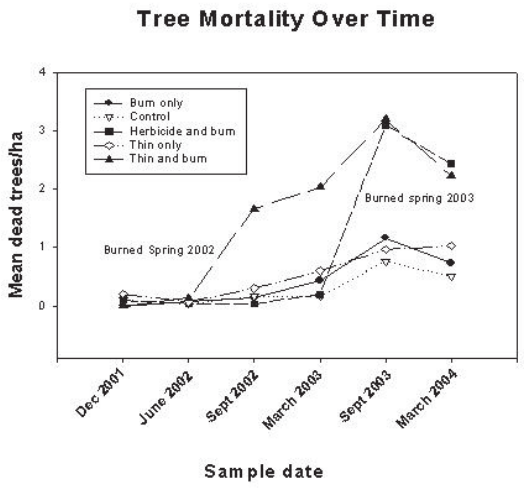


Figure 2. Average number of dead trees per hectare on each sampling date on fire or fire surrogate treatment plots on the Solon Dixon Experimental Forest.

The fire or fire surrogate treatments we tested did result in some tree mortality (Figure 3). Plots that received thinning followed by prescribed burning had the highest numbers of dead trees. The herbicide treatment followed by burning had the second highest tree mortality but they were not different from the undisturbed control plots or the prescribed burn only plots.

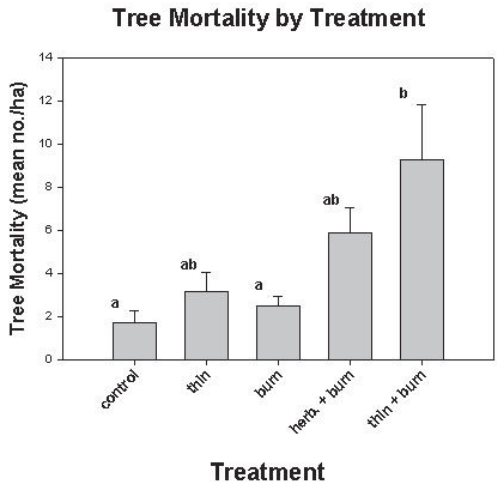


Figure 3. Tree mortality by all causes on fire and fire surrogate treatment plots on the Solon Dixon Experimental Forest from 2002-2004. Columns with the same letter are not significantly different.

Hurricane Ivan caused almost as much mortality as the thinning plus prescribed burning treatments (Figure 4). However, mortality was not associated with any one treatment but was spread equally across the area. Even though the control plots appeared to have received less wind damage the difference was not statistically significant.

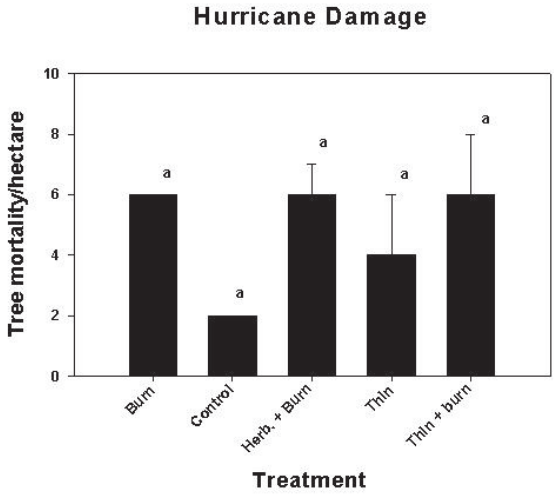


Figure 4. Tree mortality as a result of wind damage from Hurricane Ivan in September 2004 on fire and fire surrogate plots on the Solon Dixon Experimental Forest. Columns with the same letter above them are not different statistically.

Acknowledgments
This research was funded by the Joint Fire Sciences Program and the USDA Forest Service Fire Plan. We thank Scott Horn, Danny Dyer, Mike Ulyshen, and Mike Cody for their help in surveying the plots.

Fuel Reduction treatments in Gulf Coastal Plains

Kenneth W. Outcalt

The longleaf ecosystem of the south, which evolved with and is adapted to frequent low intensity fires, is at risk of uncharacteristically severe wildfires that threaten people's lives and property and the health of this endangered forest community. Widespread fuel reduction treatments are needed to restore ecological integrity and reduce the risk of destructive wildfires. Of particular concern in the South are the rapidly growing urban/wildland interfaces of the Coastal Plains. Prescribed burning has been used for decades in the Coastal Plain to reduce fuel loads, but now is under regulatory pressure. At issue are adverse air quality and transportation safety impacts from smoke of prescribed burning and the potential for property losses if these burns escape in the wildland-urban interface. Alternative fuel reduction treatments are attractive but the appropriate balance among cuttings, mechanical fuel treatments, herbicides, and prescribed fire is unclear.

This study is being conducted in south Alabama on the Solon Dixon Forestry and Education Center operated by Auburn University. Numerous questions are being addressed on operational sized treatment units across broad disciplinary areas. Areas of study include vegetation, fuels, fire behavior, ecosystem structure, soil compaction, nutrient cycling, forest floor dynamics, mammals, herpetofauna, avifauna, entomology, pathology, treatment costs and utilization economics. Resulting information will be used to create a decision matrix to provide resource managers with costs and benefits based on ecological, economic, and social consequences of alternative fuel reduction practices. These results have application to an estimated 10 million acres in the region where they will be used to guide investment of scarce treatment funds to give society the greatest reduction in wildfire risk while improving ecosystem health of the imperiled longleaf pine ecosystem and its host of threatened and endangered species.

Much of the fuel problem in these forests is concentrated in the surface and ground layers. The various components of these fuel types were measured prior to and following treatment applications. Living and dead forbs and grasses are a minor but important part of surface fuels. Forb mass increased the first growing season following burn in all treatments that included fire (Figure 1). The amount of grass increased on all areas between 2001 and 2002 due to accumulation of dead grass leaves (Figure 2). There also appears to be some increase in grass biomass associated with burning. Because of the flashy nature of grass and forb fuels, these small increases have the potential to influence future prescribed burns.

Biomass of vines declined slightly following burn only, thin only, or thin and burn treatments (Figure 3). By the second season however, they had returned to near pretreatment levels. Vines were also significantly reduced by the herbicide and burn treatment. Since this treatment was burned 1 year after the other fires, it is not yet know how much they will recover. It seems reasonable to assume that regular prescribed burning will keep the vines in check and thus prevent a return to pretreatment levels of 2001. This is important because vines serve as ladder fuels to carry flames into the tree crowns.

Live woody material less than 1.37 m tall declined during the second growing season (Figure 4). Its reasonable to expect such a response on treated areas since burning, thinning, and herbicide can all kill some of these stems. The decline on the control sites however, resulted from a substantial number of the stems growing above the sample cut-off height and becoming part of the midstory layer. Dead standing woody material increase substantially after the herbicide application in 2002 (Figure 5). Thinning caused a decline in this fuel because it knocked down many of the dead stems. Burning only was neutral as it consumed or burned off

some dead material but also created new dead stems by killing living tree seedlings and shrubs.

Litter fuel mass, which included all 1 and 10 hr fuels, was reduced by any treatment that included prescribed burning (Figure 6). Similarly, the humus layer was also reduced through partial consumption during prescribed burns (Figure 7). There was some decline on the thin only stands also, from mixing with mineral soil layers during harvest operations. Humus mass was increasing in control areas as they readjusted to annual litter inputs that were not occurring on the burn treatments.

Total down woody fuel as measured in Brown transects was increased by thinning operations. This addition fuel was consumed by the burn in the thin and burn treatment but accumulated in the thin only stands (Figure 8). The mass of 1 hr woody fuel was highly variable but changed little by treatments (Figure 9). Thinning added to 10 hr fuel loads but this extra fuel was consumed in thin and burn stands (Figure 10). Thinning also added 100 hr fuel to the surface layer (Figure 11). Burning following thinning consumed some of these addition fuels but it also exposed fuels in this size class formerly hidden beneath the litter layer. Mass of both sound and rotten 1000hr fuels increased on thin only plots (Figures 12 and 13). Burning consumed enough of this size class to keep them at pretreatment levels.

Overall, any treatment that included burning increased the amount of flashy herbaceous fuel available to carry future burns. The herbicide plus burn treatment appears to be the best for an immediate reduction in vines that serve as ladder fuels. This treatment also performed well in reducing live woody understory fuels. Thinning was the only treatment that significantly added to the down woody surface material. Thus, any of the treatments that included burning were successful at reducing surface and ground fuel loads. This was expected as these treatments have been used by land managers for many years to keep fuel loads in check and reduce wildfire risk in southern pine forests. Therefore, the choice of treatments will be determined by their effect on other significant attributes of longleaf pine ecosystems of the Gulf Coastal Plain region.

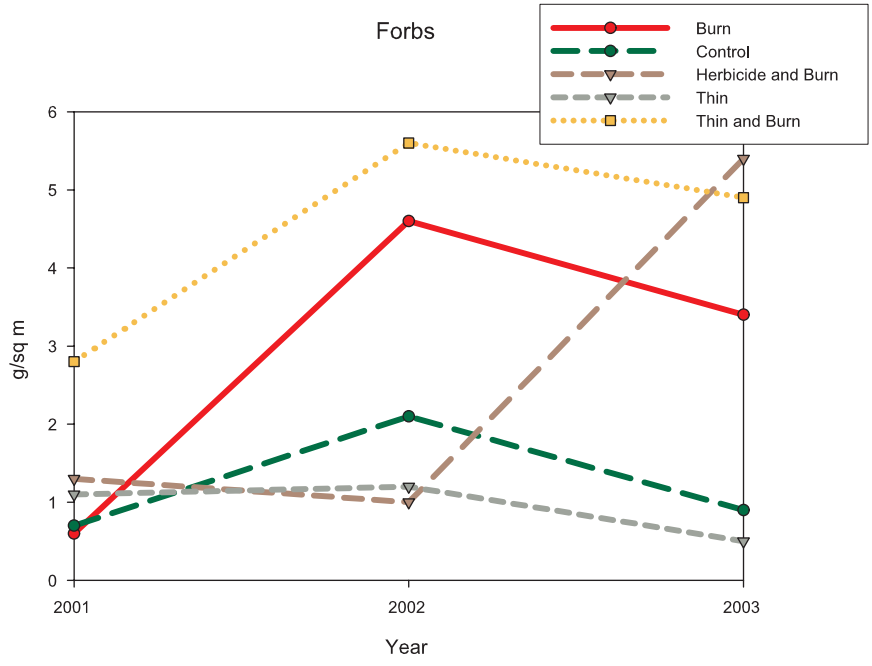


Figure 1. Biomass of forbs before and after fuel reduction treatments in longleaf pine forests of Southern Alabama.

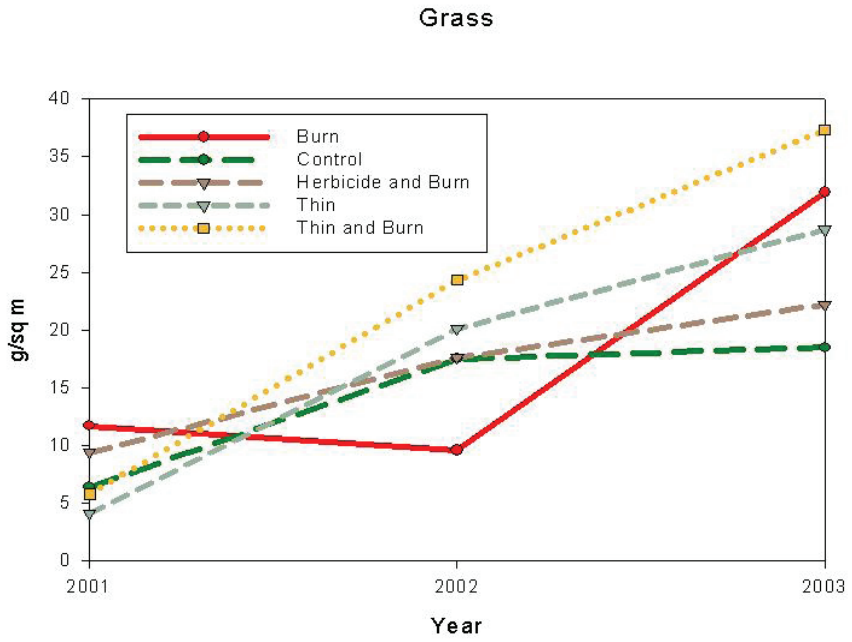


Figure 2. Biomass of grass before and after fuel reduction treatments in longleaf pine forests of Southern Alabama.

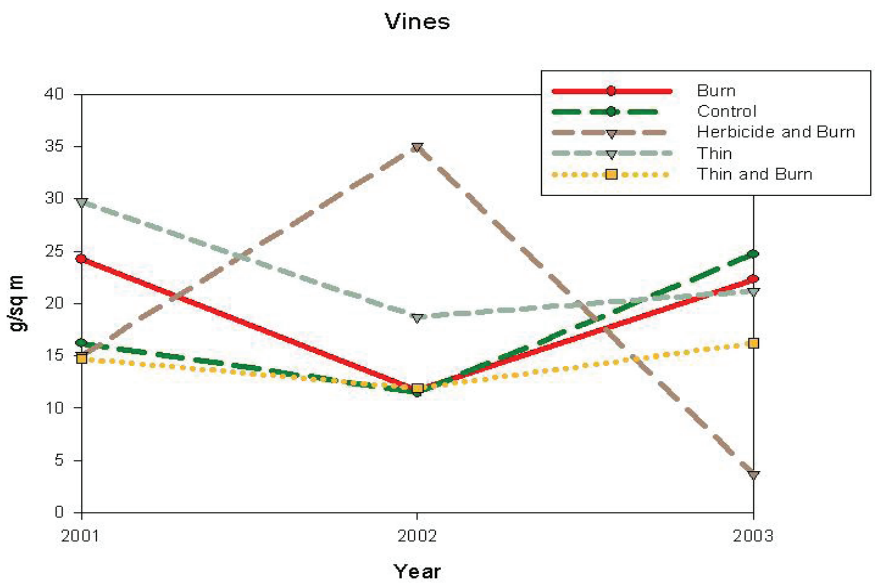


Figure 3. Biomass of vines before and after fuel reduction treatments in longleaf pine forests of Southern Alabama.

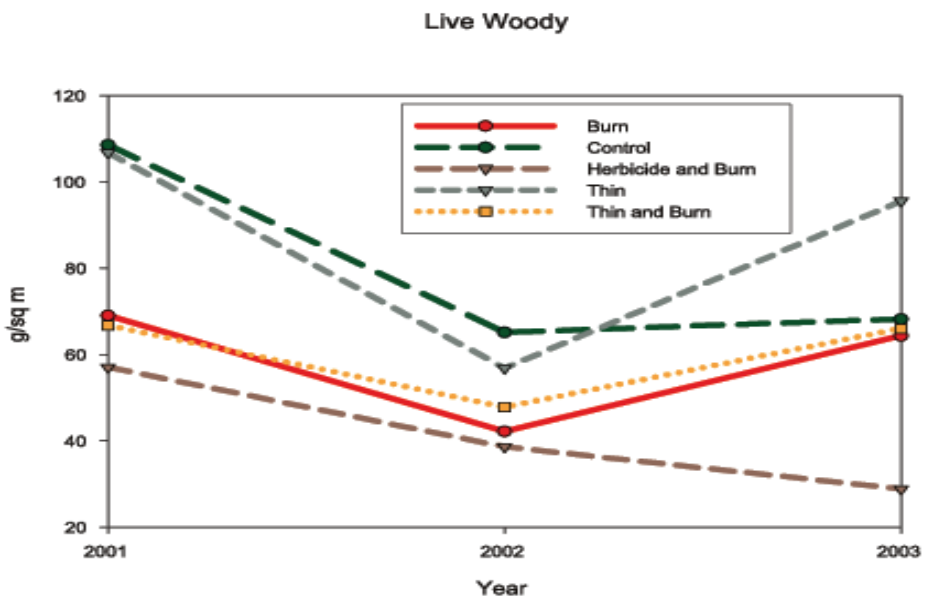


Figure 4. Biomass of dead standing woody stems less than 1.37m in height before and after fuel reduction treatments in longleaf pine forests of Southern Alabama.

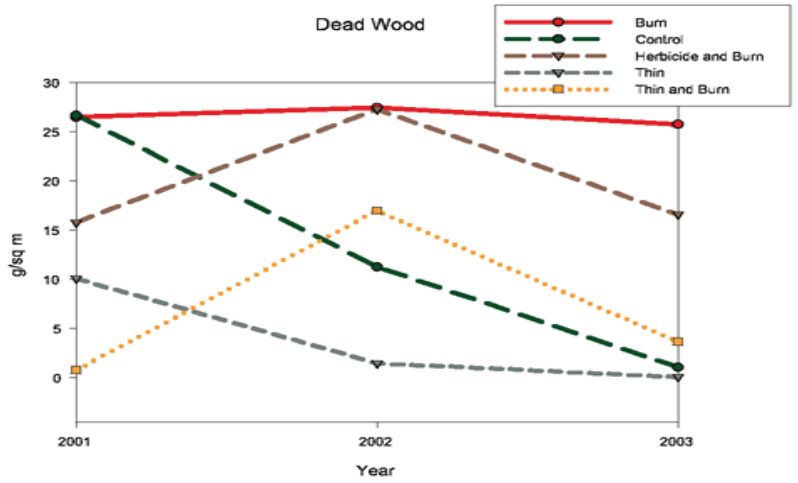


Figure 5. Biomass of live woody stems less than 1.37m in height before and after fuel reduction treatments in longleaf pine forests of Southern Alabama.

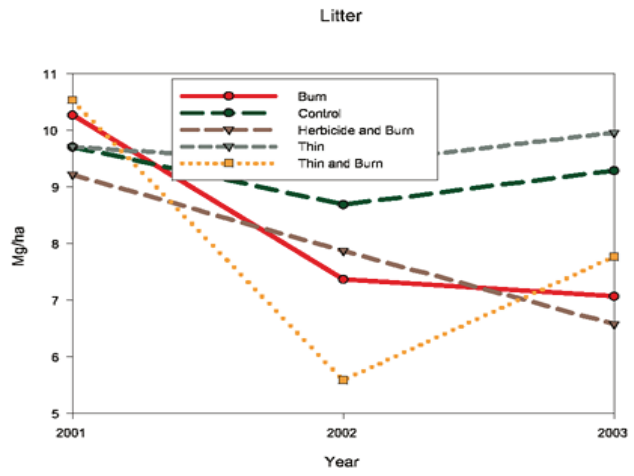


Figure 6. Litter biomass, excluding woody material larger than 1 inch, before and after fuel reduction treatments in longleaf pine forests of Southern Alabama.

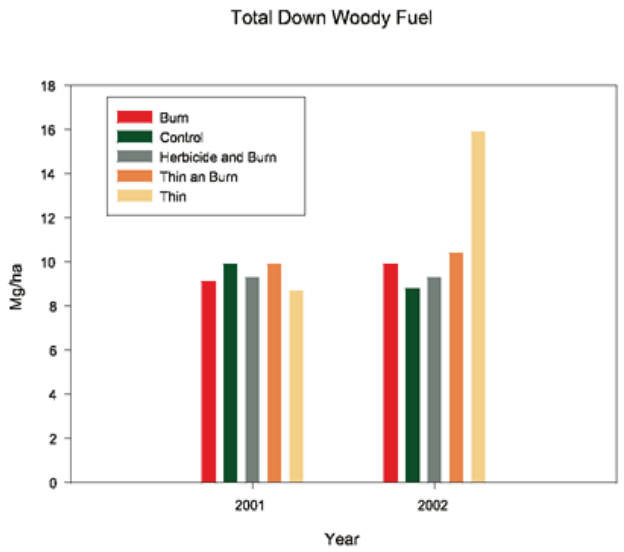


Figure 7. Humus biomass before and after fuel reduction treatments in longleaf pine forests of Southern Alabama.

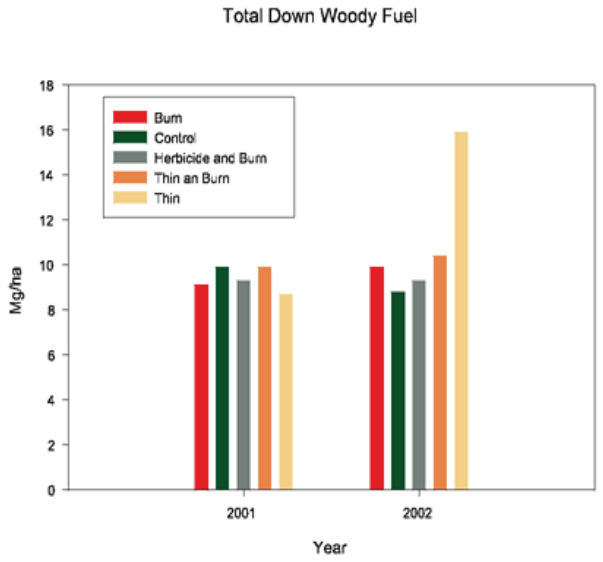


Figure 8. Total down woody fuel biomass before and after fuel reduction treatments in longleaf pine forests of Southern Alabama.

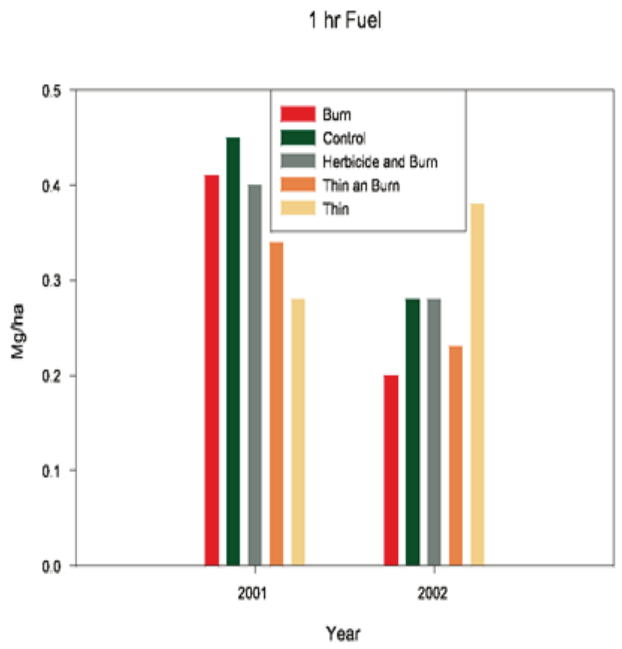


Figure 9. Biomass of woody 1hr fuels before and after fuel reduction treatments in longleaf pine forests of Southern Alabama.

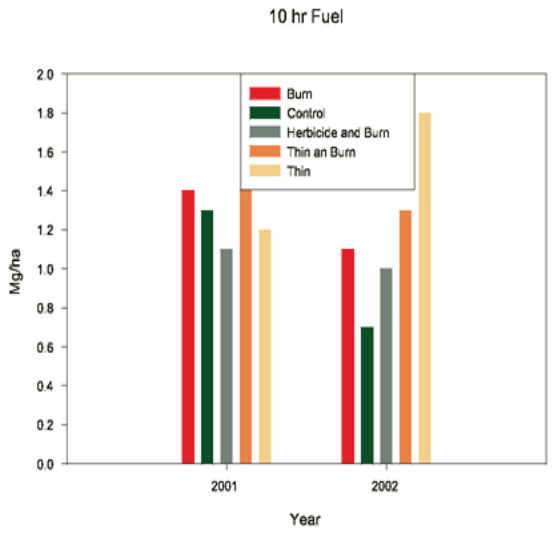


Figure 10. Biomass of 10hr fuels before and after fuel reduction treatments in longleaf pine forests of Southern Alabama.

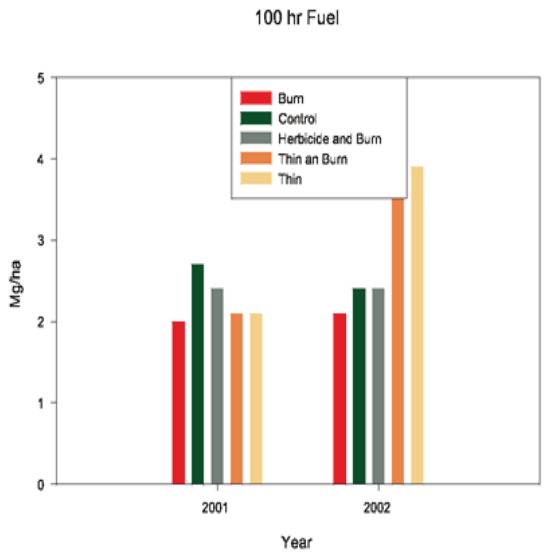


Figure 11. Biomass of 100hr fuels before and after fuel reduction treatments in longleaf pine forests of Southern Alabama.

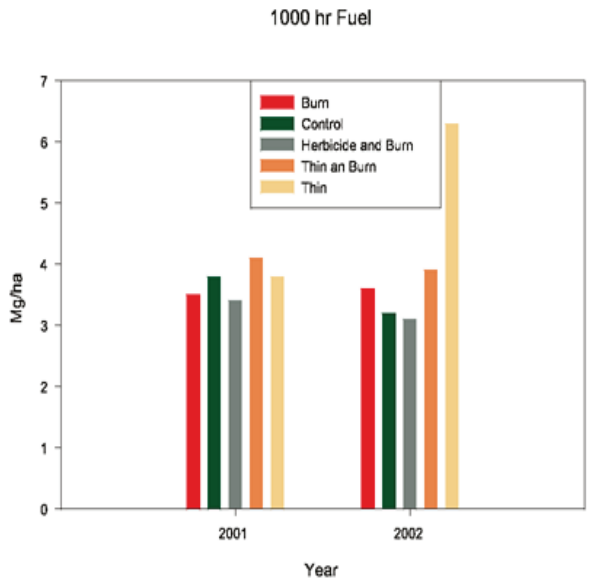


Figure 12. Biomass of sound 1000hr fuels before and after fuel reduction treatments in longleaf pine forests of Southern Alabama.

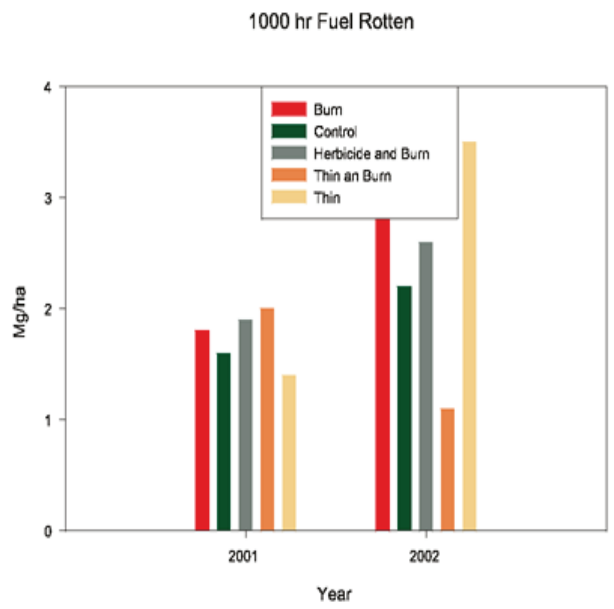


Figure 13. Biomass of rotten 1000hr fuels before and after fuel reduction treatments in longleaf pine forests of Southern Alabama.

Bird research on FFS Project at Solon Dixon
Dr. Douglas Robinson and Ghislain Rompre.

Our study sites were 10-ha longleaf pine plots (N=3 per treatment and 3 "control" plots) in southern Alabama.

We monitored birds with point counts and spotmapping, and estimated breeding success by finding and monitoring nests in 3 years. We had 4 point counts in each unit and visited them 3 – 4 times per year. We found and monitored about 450 nests.

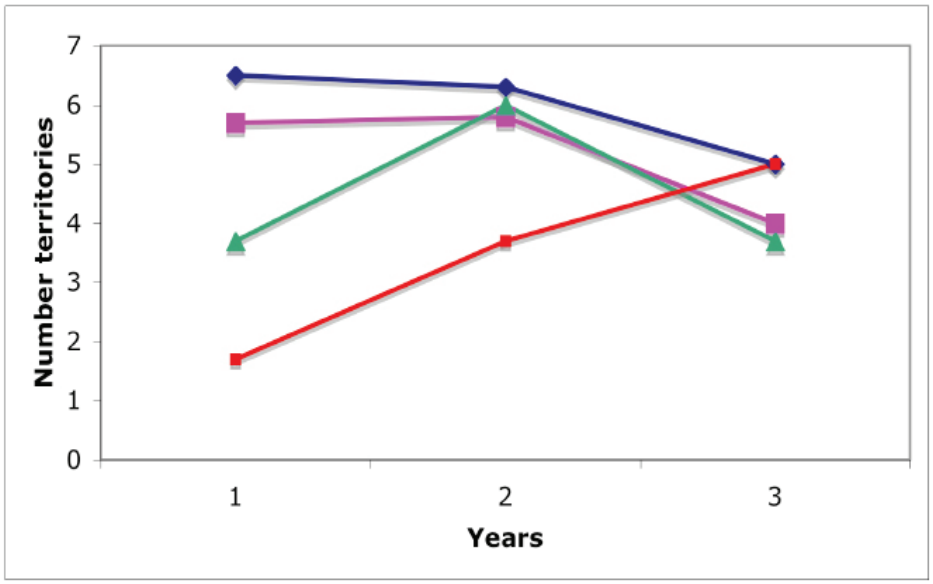
Most understory bird species responded to the treatments while mid-story and canopy species rarely did.

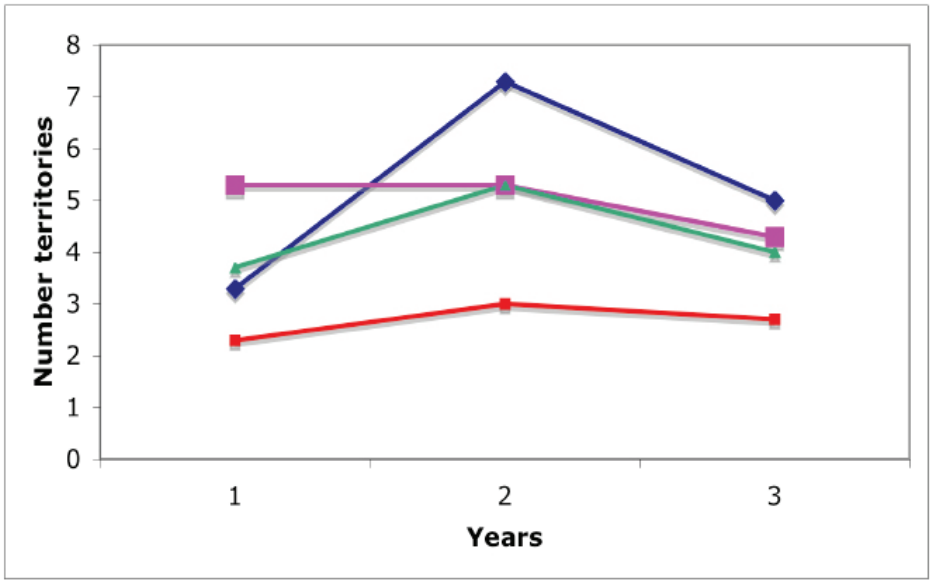
Annual and spatial variation in avian abundances swamped most treatment effects on understory birds (see specimen abundance figures).

The species most sensitive to fire suppression, Bachman's Sparrow Aimophila aestivalis, colonized two units in the study area after fire. Patterns of nesting success varied in species-specific manners and did not appear to be strongly influenced by treatment effects (details not presented here).

We conclude that avian diversity is driven largely by processes occurring across years and at larger spatial scales than our study plots. At scales of 10 ha, most species tolerated all 3 types of understory manipulation. However, fire was the only technique that facilitated colonization by Bachman's Sparrows and therefore allowed the full complement of expected species to occur.
Other result highlights illustrated in the figures:
Numbers of territories of 5 songbird species varied over 3 years (2002-2004), but most changes were attributable to annual variation rather than understory treatment effects.

Significant treatment effects were: Eastern Towhees being less numerous in thinned and burned stands relative to unmanipulated stands in the first 2 years.

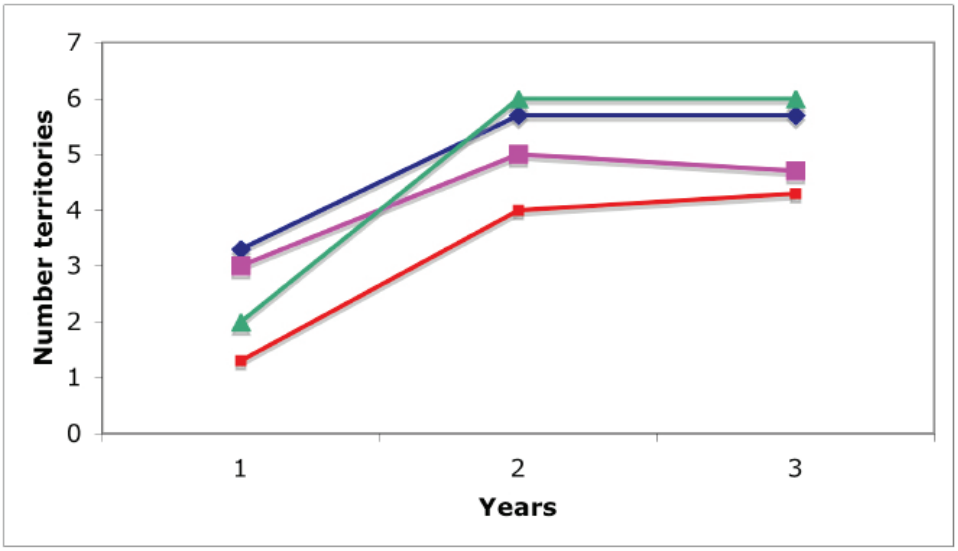




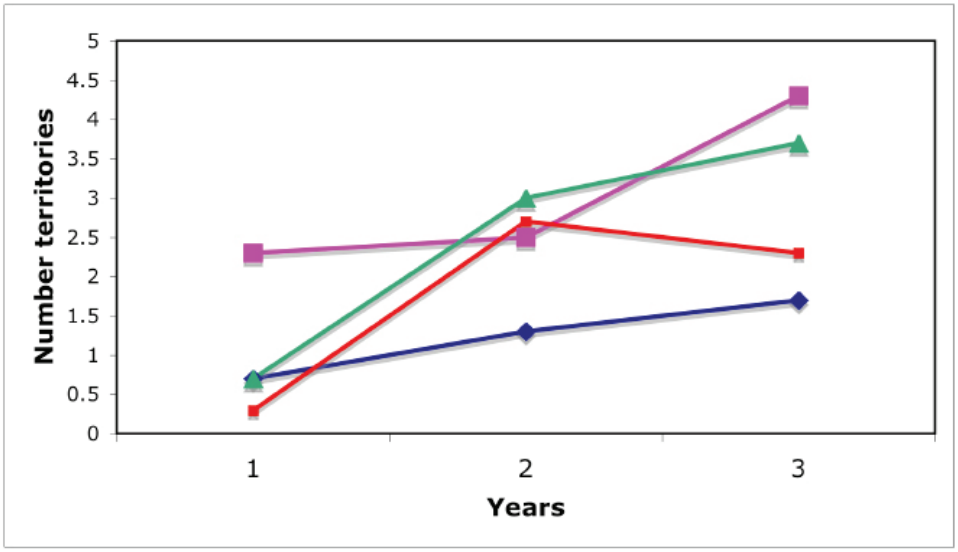
Eastern Towhee (top)

Northern Cardinal (bottom)

Blue = Unmanipulated stands
Green = Thinned
Pink = Burned
Red = Thinned and Burned

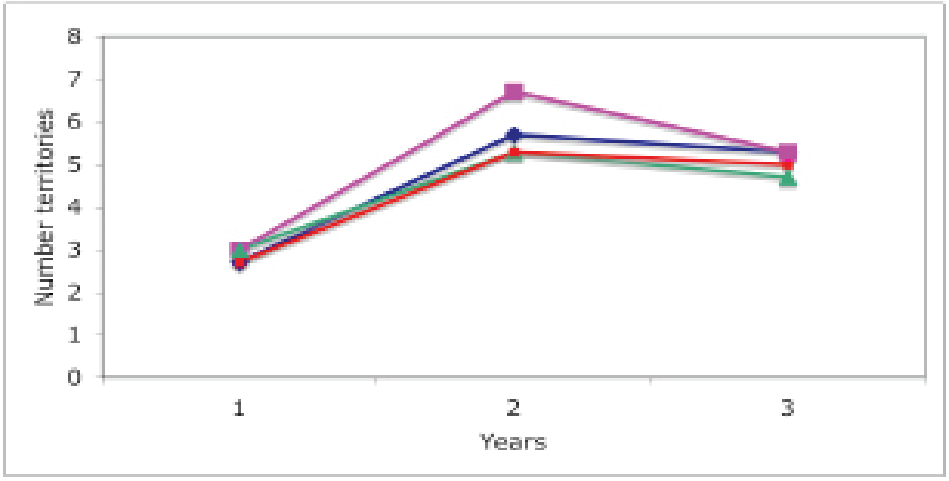


Carolina Wren



Indigo Bunting

Blue = Unmanipulated stands
Green = Thinned
Pink = Burned
Red = Thinned and Burned



Pine Warbler

Blue = Unmanipulated stands
Green = Thinned
Pink = Burned
Red = Thinned and Burned

Changes to Soils and Forest Floor as a Consequence of Fuel Reduction Treatments in Longleaf Pine Ecosystems

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ABSTRACT
The influence of fuel reduction treatments on soil chemistry within a longleaf pine forest of the Gulf Coastal Plain was studied over a 3 year period. Treatments included a prescribed burn only, thin only, thin + burn, herbicide + burn, and control. An apparent large influx of litterfall caused increases in forest floor mass and content of some elements on control plots and may have influenced the minor decrease in forest floor mass and content observed on under the burn-only scenario. Herbicide + burn plots were associated with higher forest floor mass loss, decreases in surface soil (0-10 cm) C:N ratios, contents of nitrogen and organic matter, while P, K, Ca, Mg contents and pH declined. Soil P and pH also increased at 10-20 cm following the herbicide + burn treatment. The thinned-only plots increased in soil C, organic matter, and C:N ratios and the latter increase suggests that these changes were driven by inputs of coarse woody debris residues there. Thinned + burned areas increased in soil C and organic matter only. Results indicate that only the most intense burning treatment (herbicide + burn) resulted in stereotypic changes in soil chemistry that are typically associated with prescribed fires.

1. Introduction

Fire suppression in many forests throughout the United States has become a common practice over the last 60 years. As a result, excessive amounts of fuel have accumulated and risk of catastrophic wildfires has increased. This has led to changes in forest structure and species composition, particularly in ecosystems where fire was historically present, such as the longleaf pine communities (Pinus palustris Mill.) of the Southeastern Coastal Plains (Outcalt 2003).

Treatments currently used to reduce fuel loads including thinning, mechanical fuel treatments, prescribed fire, or a combination of mechanical treatments and burning and are well established and recognized as important practices in restoring ecological integrity and reducing the risk of undesirable wildfire in these ecosystems (McIver et al. 2000). However, the ecological implications of these treatments are not fully understood and much better information is needed in order to improve decision making by resource managers.
Disturbance from silvicultural practices such as prescribed fire and forest harvest are known to alter nutrient availability and microbial dynamics in soils (Entry et al. 1986, Ballard 2000, Phillips et al. 2000a). The overall effects of fire on soil properties are complex and very dependent upon fire intensity, frequency, and season (DeBano et al. 1998). Generally, severe fires have a greater impact on soil physical and chemical properties than lower intensity fires (Covington and Sackett 1992). Low intensity fire may stimulate the growth of understory vegetation, increase nutrient availability through accelerated nutrient cycling, and shape overcrowded forests by thinning (Neary et al. 1999). High intensity fires (wildfires and prescribed fires) can often lead to changes in successional patterns by altering vegetation composition and structure, causing shifts in mineralization rates, C:N ratios, and increasing nutrient losses through volatilization, ash dispersal, and leaching (Neary et al. 1999, Ballard 2000, Fisher and Binkley 2000).

It is critical to understand what fuel reduction treatments mean to nutrient availability, especially on low fertility, sandy soils of longleaf pine ecosystems, where any change in nutrient status may be very important. The Fire and Fire Surrogate (FFS) Study established at the Solon Dixon Forestry Education Center is one of

13 nationwide locations designed to fill this information gap. The primary objective of this study was to examine the effects of four fuel load reduction alternatives – thinning, prescribed burning, thinning followed by prescribed burn, and herbicide application followed by burning – on soil chemistry, net mineralization, nitrification, and standing crops of forest floor.

2. Study Area

The study was conducted at the Solon Dixon Forestry Education Center (SDFEC) which is located in the lower Coastal Plain physiographic province of Alabama, occupying 2,144 ha in Covington and Escambia Counties. Approximately 40% of the Center's lands are occupied by upland mixed pine-hardwoods, 33% even-aged pine plantations, 23% upland and bottomland hardwoods, and 4% regenerating cutovers areas. In addition to the naturally regenerated longleaf pine stands used in this study, the overstory contained Pinus taeda L. (loblolly pine), Pinus elliottii Engelm. (slash pine), Pinus echinata Mill. (shortleaf pine), Pinus glabra Walter (spruce pine), Quercus falcata Michx. (southern red oak), Quercus stellata Wangenh. (post oak), Quercus laurifolia Michx. (laurel oak), and Quercus laevis Walter (turkey oak). The understory is predominately shrubs, mostly Ilex vomitoria Sol. ex Aiton (yaupon hollow), with some grasses (Andropogon spp.).

Soils are highly weathered, low fertility Ultisols that developed in the Coastal Plain. Soil series found within the study area included deep and well drained Dothan and Malbis (thermic Plinthic Kandiudults, and thermic Plinthic Paleudults, respectively) sandy loams, and Bonifay (thermic Grossarenic Plinthic Paleudults) loamy fine sands.

3. Methods

The study design consisted of three blocks with five treatments. Treatments were randomly assigned in each block and included: thin only, burn only, thin + burn, herbicide + burn, and a control. A total of 15 experimental units were included in the study. Each treatment unit consisted of a core area of 12.25 ha and a surrounding 20 m buffer, giving a total size of 15.2 ha. Units were comprised of 10 subplots, each with 2 gridpoints and totaling 20 gridpoints per unit. All units were sampled during August, 2001 of the pre-treatment year. Post-treatment samples using the same procedures and same units were sampled in August, 2002, except for those designated for the herbicide treatment. Herbicide + burn units were sampled during July, 2003.

3.1 Treatments

Levels of thinning and prescribed burning used in this study were the same prescriptions used by SDFEC personnel in their management of longleaf pine in order to reduce fuels satisfactorily so that most overstory trees (≈ 80%) would survive a wildfire. Apart from the herbicide + burn treatment, burning operations were conducted in April and May 2002 by Solon Dixon personnel. All plots in the burn + thin and burn only treatments burned almost completely in uniform and moderate intensity fires.

Implementation of thinning operations occurred from February to April 2002 and was conducted by Posey-Kilcrease (a timber company). The thinning treatment was a commercial thinning. Selection removal included any merchantable hardwoods, badly formed/diseased trees, and loblolly pine. The target residual basal area was 12-14 m2 ha-1.

Herbicide application was conducted in September 2002 by Longleaf Foresters, Inc. Garlon 4 (The Dow Chemical Company, MI.) was applied as a foliar spray at a rate of 3.8 – 4.2 kg ha-1. The active ingredient in Garlon 4 herbicide is tryclopyr, which effectively controls most woody species. These plots were burned in April and May, 2003.

3.2 Soil Chemistry and Nitrogen Mineralization

Three soil samples for chemical analyses were collected at each gridpoint at two depths (0-10 cm, 10-20 cm) during each sampling period. The three samples representing a given depth were composited. Collection

dates were Aug 20-22, 2001, Aug. 28, 2002, and July 7, 2003. Soil samples were placed in metal trays and air-dried until weight stability was reached. The dried samples were then ground and sieved through a 10-mesh. Soil was analyzed for extractable P, and exchangeable K, Mg, Ca (Johnson et al. 1984), total C and total N (LECO CHN-600; LECO Corporation, St. Joseph, MI.), pH using the Adams-Evans buffer on a MP-80D pH meter (TPY Pty Ltd, Australia), and percent organic matter. Phosphorus was determined on soil extracts (double acid Mehlich 1) using ascorbic acid and read on a B & L Spectronic 100. Potassium was determined by atomic spectroscopy with Ca and Mg determined using a C2H2/air flame in a lanthanum solution. Total C and N was determined using total combustion (LECO CHN-600; LECO Corporation, St. Joseph, MI.), (Nelson and Sommers 1996).
Nitrogen mineralization was estimated using the in-situ methodology of Hart et al. (1994). Two nitrogen mineralization (NMIN) samples were collected per gridpoint to a depth of 7.5 cm. Each sample was separated into two subsamples. One of the subsamples was placed in a polyethylene bag and returned to the soil for in situ incubation while the other subsample was sent to the laboratory for extraction of N-NH4 and N-NO3. After one month, the two NMIN samples were retrieved from the field and analyzed for N-NH4 and N-NO3. All nitrogen mineralization samples were kept refrigerated upon return to the laboratory. Collection dates Aug. 20, 2001 initial to Sept 17, 2001 final, July 22, 2002 initial to Aug. 19, 2002 finals, and July 7, 2003 to Aug. 11, 2003). Samples were wet sieved to pass a No. 10 sieve. A subsample was weighed and oven-dried at 105oC to calculate moisture content. All samples were extracted using a 2 M KCl solution, shaken for one hour, filtered using a Whatman #42 filter, and then read on a Biorad Model 680 microplate reader to determine N-NH4 and N-NO3. Net mineralization was calculated as the difference in total inorganic N (N-NH4 + N-NO3) between the initial sample and those incubated in situ for 20-30 days. Proportional nitrification was calculated as the net difference in NO3 concentration between the initial and incubated samples, divided by the total NH4 available for nitrification (i.e. initial NH4 + net mineralization).

3.3 Forest Floor Mass and Elemental Content

Forest floor samples were collected by placing a grid frame (30 cm2) on the ground and then removing all litterfall to the surface of the mineral soil. Three forest floor samples were collected per gridpoint, then samples were composited, placed in bags and transported to Auburn for laboratory analysis. Collection dates were Aug 27, 2001, Aug 9, 2002, July 7, 2003. Forest floor samples were oven-dried at 70oC until dry. Samples were ground in a Wiley mill to pass a 20-mesh sieve and analyzed for C, N and P. All samples were dry-ashed, then extracted using the vanadomolybdate method (Jackson, 1958). Extracts were read for total P on a Spectronic 501 spectrophotometer (Milton Roy Co., Rochester, NY). Total Carbon and N were determined using thermal combustion (Perkin-Elmer 2400 series II CHNS/O analyzer; Perkin-Elmer Corp., Norwalk, CT, USA)-(Nelson and Sommers, 1996).

4. Statistical Analyses

All analyses were performed using the Statistical Analysis System (SAS Institute, Inc., 1999-2001). One-way analysis of variance (ANOVA) was used with a post hoc Tukey's Studentized range to evaluate pre- versus post-fuel reduction treatment differences. Post-treatment comparisons among treatments were made on adjusted data using an analysis of covariance with pre-treatment data as the covariate. All differences between pre- versus post-treatment application and among treatments were considered significant at the 0.05 level.

5. Results and Discussion

5.1 Soil Chemistry and Nitrogen Mineralization

In the 0-10 cm soil depth, among the four macronutrients, P was the most sensitive to treatments (Table 1). With the exception of thin + burn plots, P content increased significantly following fuel reduction in all plots. In herbicide + burn plots, content of all macronutrients was significantly higher post-treatment. An increase in soil pH was observed for thin + burn and herbicide + burn plots only.

Treatment effects on soil macronutrients were less evident in the 10-20 cm soil depth. As an example, while a significant increase for P, K, Mg, and Ca content was observed in the 0-10 cm zone in herbicide + burn plots, none was observed at 10-20 cm. Again, P was the most responsive with significant increases in control, thin only, and burn only plots. Magnesium decreased significantly in burn only plots while pH declined in both burn only and thin only treatments. However, an increase in pH was observed in the herbicide + burn plots.

At the upper depth, C content increased significantly post-treatment in control, thin only, and thin + burn plots (Table 2). Nitrogen contents were significantly higher in control and thin + burn plots following treatment application, while OM content was significantly greater in control and thin only plots. No significant differences were observed on burn only plots. Decreases in C:N ratios were also observed in control and herbicide + burn plots, while ratios increased in thin only plots. A high influx of litterfall on control plots (described in the Forest Floor Mass and Elemental Content section) may account for the significant increases in C, N, and organic matter observed in the 0-10 cm zone there. At that depth, the only other increases occurred for C on thin-only and C and N on thin + burn. The latter increases may be related to inputs of logging slash from the thinning and / or increases in bulk density (Tables 9 and 10).

At the 10-20 cm soil depth, differences were observed in control and thin + burn for all variables for all variables. With few exceptions, response variables displayed a significant increase at the time of the post-treatment sampling. Exceptions included a significant decrease in C:N ratios on control plots.

Comparisons of post-treatment soil macronutrients and pH among treatments are presented in Table 3. At the 0-10 cm depth, no differences were observed for P content. At the 10-20 cm depth, P content significantly decreased in herbicide plots and no differences were observed for K content. Calcium, Mg, and soil pH were significantly lower in thin only and burn only plots.

Soil C, N, OM, and C:N ratio differences among treatments followed similar trends at both depths (Table 4). Carbon content and OM were significantly lower in herbicide + burn plots. In general, N content was higher in thin + burn plots while C:N ratios were higher in both thin + burn and thin plots.

Net mineralization increased significantly in burn only and thin + burn plots post-treatment (Table 5). No other significant differences were observed for mineralization. However, significant increases in proportional nitrification were observed in thin + burn plots. Compared among treatments, net mineralization was significantly higher in thin + burn plots but no differences among treatments were observed for proportional nitrification (Table 6).

Generally, a prescribed fire might be expected to increase P, K, Ca, and Mg availability in surface soils (along with a corresponding increase in pH) due to the presence of these elements in residual ash (Fisher and Binkley 2000). As an example, Slay et al. (1987) found these patterns following a site preparation burn in Louisiana. In the present study, expected effects were only consistently noted among the burn treatments for the herbicide + burn treatment at the 0-10 cm depth. The soils of the burn-only plots increased in P while those of the thin + burn increased in both Mg and pH. Due to the extra traffic on thinned treatments, significant increases in bulk density were recorded and may have been responsible for the higher P and Mg content noted on thin-only and thin + burn plots respectively. Apart from treatment influences, control plot data indicated that elemental contents at the 0-10 cm depth were not stable between the two sampling periods.

Comparisons among treatments (Table 3) at the 0-10 cm depth indicate no differences for P and increases for K, Ca, and Mg for the herbicide + burn. Changes on the burn-only and thin+ burn soils did not reflect the expected responses to fire. The apparent anomaly between the typical responses on the herbicide + burn vs. those of the burn-only and thin + burn is interesting. It is possible that (1) the fire was more intense on the herbicide + burn due to heavier fuel loads (i.e. from dead vegetation) and the increased intensity generated the stereotypic effect or (2) the typical response occurred on the burn-only and thin + burn but the longer period between treatments and post-treatment measurement on those areas compared to that of the herbicide + burn allowed the effect to dissipate. In support of (2), the sandy nature of the soils would likely promote leaching of readily available elements from ash. Also, some combination of (1) and (2) may also be

at play. Lack of soil chemical changes due to fire have been reported elsewhere in the Southeast (Vose et al. 1999, Phillips et al. 2000b).

Comparisons among treatments for C, N, and organic matter soil content (Table 4) indicated that the herbicide + burn soils were significantly lowest at both depths. Again, these responses on the herbicide + burn treatment suggest that the influence of either greater fire intensity or a shorter interim between treatment and measurement. These plots, along with the controls and burn-only, were also significantly lower in C:N ratios than the thin only and thin + burn. However, increases in N mineralization rates (Table 5) did not track decreases in C:N ratios as might be expected. The burn-only and thin + burn were highest in mineralization and the thin + burn showed greater nitrification tendencies. Comparisons among treatments (Table 6) indicated that only the thin + burn was significantly greater than the control (i.e. the lowest value).

5.2 Forest Floor Mass and Elemental Content

Significant increases in forest floor mass, and contents of N, P, and C were observed for control and thin only plots post-treatments (Table 7). In contrast, the same variables decreased significantly in herbicide + burn while mass and C content only decreased in the thin + burn treatment. Within burn plots, significant decreases were observed only for N content. Although C:N ratios increased on burn only plots, those ratios declined for the other four treatments.

When comparisons were conducted among treatments (Table 8), forest floor mass, N, P, and C contents in general were significantly higher in control and thin only plots, and significantly lower in herbicide + burn plots. Ratios of C:N were significantly higher in burn plots, followed by thin + burn, control, thin only, and herbicide + burn.

Increases in forest mass and nutrient content in the control plots were unexpected (Table 7) but are confirmed by pre- and post comparisons of ground and surface fuels by US Forest Service personnel (Dr. D. Kennard, U.S. Forest Service, Personnel Communication). Together, these data suggest that an unusually high input of litterfall occurred between the August 2001 and spring 2002 on controls. This accounts for the significant increase in N and C content of the forest floor within controls and, possibly, C, N, and P content on thin-only plots if the high litterfall occurred there as well.

The possibility that a large litterfall influx also occurred on the other treatments may account for the minor mass losses noted in the burn-only (N.S.) and thin + burn (-22%). However, the herbicide + burn showed a more substantial decrease in floor mass (-70%). These may be compared to 46% and 64% declines noted by Waldrop et al. (2004) for burn-only and thin + burn treatments respectively in the South Carolina Piedmont.

Similarly, increases of forest floor N, and P of 82, and 7.0 g/m2 respectively were noted in controls for the post-treatment measurement (Table 7). Apart from the thin-only treatment which increased in N and P by 58.0 and 6.8 g/m2 respectively and the thin + burn which showed no change, the other treatments generally decreased in content.

As examples, the N contents of the forest floors in the burn-only and herbicide + burn treatments declined by 13 and 26 g/m2 (x 10 = kg/ha) respectively. Fisher and Binkley (2000) and Knight (1966) cite ranges of N loss due to one-time prescribed fires of 10-40 and 30-80 kg/ha. Similarly, Vose et al. (1999) reported litter N losses of 52.9 kg/ha following a restoration fire in the Southern Appalachians. Binkley et al. (1992) calculated that nearly 85% (approximately 300 kg/ha) of total forest floor N was lost following annual prescribed fires over a 30 year period in a SC study. As previously described, high losses in the herbicide + burn plots may have been driven by greater fire intensity there as a result of the presence of larger fuel loads following the herbicide treatment.

6.0 Conclusions

Only the herbicide + burn treatment caused stereotypic changes in soil chemistry and this may reflect the transient nature of burn effects on sandy soils and/or a greater fire intensity on this particular treatment.

Herbicide + burn plots also exhibited greater forest floor mass losses, and decreased soil C:N ratios, nitrogen, and organic matter contents. Increases in elemental content of surface soils on plots that included thinning may be related to increases in bulk density on these treatments or greater elemental inputs resulting from burning the logging slash.

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Table 1. Pre- versus post-treatment comparisons of soil macronutrients (P, K, Mg, Ca) and soil pH at two soil depths.

Treatment	P	K	Mg	Ca	pH
	----------g m^{-2}----------				
0-10 cm					
Pre-control	0.09b† ± 0.10	1.81a ± 0.11	1.19b ± 0.10	9.42a ± 1.31	4.7a ± 0.04
Post-control	0.28a ± 0.02	1.82a ± 0.10	1.82a ± 0.24	13.44a ± 2.11	4.7a ± 0.05
Pre-thin	0.17b ± 0.03	1.71a ± 0.13	1.20a ± 0.11	7.47a ± 0.90	4.5a ± 0.04
Post-thin	0.31a ± 0.03	1.56a ± 0.10	1.50a ± 0.22	8.11a ± 0.96	4.6 a± 0.04
Pre-burn	0.20b ± 0.01	1.93a ± 0.09	1.82a ± 0.21	9.26a ± 0.96	4.6a ± 0.04
Post-burn	0.31a ± 0.02	2.03a ± 0.13	1.50a ± 0.10	8.23a ± 0.69	4.5a ± 0.03
Pre-thin+burn	0.22a ± 0.08	1.84a ± 0.14	1.39b ± 0.15	8.77a ± 1.09	4.6b ± 0.03
Post- thin+burn	0.35a ± 0.03	2.13a ± 0.22	2.08a ± 0.20	15.72a ± 3.70	4.7a ± 0.05
Pre-herb+burn	0.19b ± 0.01	1.76b ± 0.10	1.63b ± 0.13	12.14b ± 1.11	4.7b ± 0.03
Post- herb+burn	0.36a ± 0.03	2.36a ± 0.17	2.34a ± 0.21	17.83a ± 1.94	5.0a ± 0.05
10-20 cm					
Pre-control	0.05b ± 0.01	1.14a ± 0.06	0.78a ± 0.07	4.27a ± 0.52	4.8a ± 0.03
Post-control	0.17a ± 0.01	1.08a ± 0.06	0.98a ± 0.13	6.03a ± 1.03	4.8a ± 0.03
Pre-thin	0.12b ± 0.02	1.03a ± 0.07	0.87a ± 0.12	5.18a ± 0.73	4.8a ± 0.04
Post-thin	0.21a ± 0.03	0.96a ± 0.05	0.76a ± 0.07	3.44a ± 0.32	4.7b ± 0.02
Pre-burn	0.12b ± 0.01	1.12a ± 0.07	1.58a ± 0.30	4.87a ± 0.44	4.8a ± 0.02
Post-burn	0.18a ± 0.01	1.17a ± 0.07	0.83b ± 0.05	3.91a ± 0.41	4.7b ± 0.02
Pre- thin+burn	0.23a ± 0.13	1.22a ± 0.10	0.87a ± 0.08	5.38a ± 0.62	4.8a ± 0.02
Post- thin+burn	0.20a ± 0.02	1.15a ± 0.08	0.94a ± 0.08	5.02a ± 0.51	4.8a ± 0.02
Pre-herb+burn	0.11a ± 0.01	1.08a ± 0.08	0.93a ± 0.07	6.10a ± 0.53	4.8b ± 0.02
Post- herb+burn	0.14a ± 0.01	1.13a ± 0.09	1.00a ± 0.10	5.74a ± 0.59	5.1a ± 0.03

†Column means followed by different lowercase letters indicate significant differences in pre versus post comparisons at the 0.05 probability level

Table 2. Pre- versus post-treatment comparisons of soil C, N, OM, and C:N ratio at two soil depths.

Treatment	C	N	OM	C:N
	----------g m^{-2}----------			
0-10 cm				
Pre-control	1705b† ± 109.5	46.5b ± 3.10	3228b ± 207.2	39.0a ± 1.52
Post-control	2238a ± 142.8	67.7a ± 3.94	3842a ± 245.3	33.4b ± 0.77
Pre-thin	1553b ± 104.0	46.7a ± 3.71	2958b ± 197.8	37.2b ± 1.51
Post-thin	2022a ± 149.0	52.4a ± 5.64	3475a ± 254.6	66.4a ± 7.89
Pre-burn	2059a ± 103.9	58.4a ± 2.48	3794a ± 158.1	36.6a ± 1.71
Post-burn	2241a ± 135.9	65.4a ± 4.04	3854a ± 233.8	34.9a ± 0.70
Pre-thin+burn	1836b ± 138.0	52.6b ± 4.58	3484a ± 263.9	39.9a ± 1.74
Post- thin+burn	2137a ± 164.7	85.3a ± 12.76	3683a ± 282.1	43.9a ± 4.24
Pre-herb+burn	1682a ± 94.9	50.2a ± 3.15	3192a ± 181.3	35.0a ± 0.92
Post- herb+burn	1676a ± 86.6	53.0a ± 2.75	2888a ± 148.8	32.2b ± 0.64
10-20 cm				
Pre-control	972b ± 51.1	26.4b ± 1.78	1849b ± 97.5	42.4a ± 2.30
Post-control	1386a ± 73.1	40.6a ± 2.07	2380a ± 125.2	35.1b ± 1.03
Pre-thin	841b ± 55.6	28.7a ± 1.93	1609b ± 106.5	32.5b ± 1.80
Post-thin	1284a ± 82.1	31.2a ± 3.33	2209a ± 140.9	95.1a ± 16.71
Pre-burn	1053b ± 71.3	33.1b ± 1.88	2003a ± 135.1	32.90a ± 1.48
Post-burn	1310a ± 62.5	38.6a ± 1.82	2248a ± 108.0	34.2a ± 0.77
Pre- thin+burn	1043b ± 76.0	29.6b ± 1.89	1978b ± 145.0	37.0b ± 1.85
Post- thin+burn	1387a ± 92.0	68.7a ± 15.48	2389a ± 159.0	58.61a ± 8.95
Pre-herb+burn	945a ± 74.7	28.9a ± 2.44	1801a ± 141.4	36.8a ± 1.96
Post- herb+burn	891a ± 57.7	26.6a ± 1.34	1534a ± 99.6	33.4a ± 0.98

Table 3. Comparisons among treatments following fuel reduction for soil macronutrients (P, K, Mg, Ca) and soil pH at two soil depths.

Treatment	P	K	Mg	Ca	pH
	----------g m^{-2}----------				
	0-10 cm				
Control	0.29a† ± 0.02	1.84bc ± 0.13	1.97ab ± 0.18	13.60ab ± 2.05	4.6c ± 0.04
Thin	0.30a ± 0.03	1.59c ± 0.15	1.57b ± 0.21	9.44b ± 2.38	4.6c ± 0.04
Burn	0.31a ± 0.02	1.98b ± 0.13	1.28c ± 0.19	8.42b ± 2.09	4.5c ± 0.04
Thin+burn	0.35a ± 0.02	2.16ab ± 0.13	2.17a ± 0.18	16.87a ± 2.06	4.7b ± 0.04
Herbi+burn	0.35a ± 0.02	2.42a ± 0.13	2.27a ± 0.18	15.87a ± 2.02	4.9a ± 0.04
	10-20 cm				
Control	0.17a ± 0.01	1.06a ± 0.06	1.00a ± 0.08	6.34a ± 0.60	4.8b ± 0.02
Thin	0.19a ± 0.01	1.02a ± 0.07	0.71b ± 0.10	3.21b ± 0.69	4.7c ± 0.03
Burn	0.19a ± 0.01	1.16a ± 0.06	0.70b ± 0.09	3.75b ± 0.61	4.7c ± 0.02
Thin+burn	0.20a ± 0.01	1.13a ± 0.06	0.96a ± 0.08	5.04a ± 0.60	4.8b ± 0.02
Herbi+burn	0.14b ± 0.01	1.15a ± 0.06	1.02a ± 0.08	5.44a ± 0.59	5.0a ± 0.02

†Column means followed by different lowercase letters indicate significant differences among treatments at the 0.05 probability level

Table 4. Comparisons among treatments following fuel reduction for soil C, N, OM, and C:N ratio at two soil depths.

Treatment	C	N	OM	C:N
	----------g m^{-2}----------			
	0-10 cm			
Control	2289a† ±120.0	70.59ab ± 5.91	3922a 9206.5	33.19b ± 2.43
Thin	2177a ±137.5	62.95ab ± 6.72	3719a ±236.6	47.02a ± 2.76
Burn	2174a ±123.1	62.75ab ± 6.01	3774a ±211.2	35.63b ± 2.44
Thin+burn	2171a ±119.8	78.22a ± 5.87	3731a ±206.3	43.11a ± 2.43
Herbi+burn	1735b ±117.1	54.49b ± 5.72	2982b ±201.5	32.93b ± 2.36
	10-20 cm			
Control	1386a ±66.1	40.65b ± 6.11	2383a ±114.1	36.40b ± 4.46
Thin	1365a ±76.2	38.83b ± 6.96	2345a ±131.6	56.75a ± 4.97
Burn	1292a ±67.4	37.79b ± 6.23	2218a ±116.4	34.65b ± 4.42
Thin+burn	1401a ±66.2	58.39a ± 6.08	2413a ±114.2	56.87a ± 4.34
Herbi+burn	902.8b ±64.4	26.75b ± 5.92	1554b ±111.2	33.34b ± 4.22

†Column means followed by different lowercase letters indicate significant differences among treatments at the 0.05 probability level.

Table 5. Pre- vs. post-treatment net mineralization and proportional nitrification comparisons.

Treatment	Net mineralization (mg kg^{-1})	Proportional Nitrification
Pre-control	1.67a† ± 0.29	0.29a ± 0.07
Post-control	2.29a ± 0.51	0.17a ± 0.03
Pre-thin	3.19a ± 0.52	0.13a ± 0.02
Post-thin	4.43a ± 0.58	0.18a ± 0.04
Pre-burn	1.44b ± 0.27	0.10a ± 0.03
Post-burn	4.22a ± 0.77	0.16a ± 0.04
Pre-thin+burn	2.90b ± 0.41	0.09b ± 0.02
Post- thin+burn	5.31a ± 0.65	0.28a ± 0.03
Pre-herb+burn	2.80a ± 0.39	0.13a ± 0.03
Post- herb+burn	3.13a ± 0.80	0.14a ± 0.02

†Column means followed by different lowercase letters indicate significant differences in pre versus post comparisons at the 0.05 probability level.

Table 6. Comparisons among treatments following fuel reduction for net mineralization and proportional nitrification.

Treatment	Net mineralization (mg kg^{-1})	Proportional Nitrification
Control	2.35b† ± 0.97	0.14a ± 0.04
Thin	4.62ab ± 0.88	0.12a ± 0.04
Burn	3.85ab ± 1.00	0.17a ± 0.04
Thin+burn	5.34a ± 0.78	0.22a ± 0.04
Herbi+burn	3.70ab ± 1.25	0.11a ± 0.04

†Column means followed by different lowercase letters indicate significant differences among treatments at the 0.05 probability level

Table 7. Pre vs. post treatment comparison of forest floor mass and elemental content.

Treatment	Mass	P	N	C	C:N
	----------g m^{-2}----------				
Pre-control	10818b† ± 412.1	5.77b ± 0.21	44.35b ± 2.46	5301b ± 208.5	133.49a ± 6.35
Post-control	19210a ± 810.2	12.80a ± 0.66	126.70a ± 11.83	8591a ± 381.1	81.38b ± 4.47
Pre-thin	11376b ± 467.0	6.36b ± 0.31	60.75b ± 2.99	5547b ± 239.4	97.51a ± 3.97
Post-thin	16363a ± 874.3	13.24a ± 0.94	118.80a ± 8.32	7587a ± 441.2	70.70b ± 3.29
Pre-burn	12551a ± 590.6	6.32a ± 0.34	65.57a ± 3.89	5907a ± 293.9	101.22b ± 5.88
Post-burn	11296a ± 706.4	7.05a ± 0.54	52.07b ± 4.33	5404a ± 329.8	120.09a ± 6.88
Pre-thin+burn	11076a ±572.5	6.61a ± 0.37	65.46a ± 5.23	5298a ± 271.0	112.50a ± 10.00
Post- thin+burn	8630b ± 557.1	6.06a ± 0.46	53.92a ± 4.00	4148b ± 272.0	83.98b ± 3.24
Pre-herb+burn	9967a ±407.5	5.80a ± 0.25	52.79a ± 2.70	4822a ±209.2	101.09a ± 5.42
Post- herb+burn	2913b ±152.7	2.46b ± 0.15	27.23b ± 1.68	1440b ±81.77	56.54b ± 2.15

†Column means followed by different lowercase letters indicate significant differences in pre versus post comparisons at the 0.05 probability level.

Table 8. Comparisons among treatments following fuel reduction for forest floor mass and elemental content.

Treatment	Mass	P	N	C	C:N
	----------g m^{-2}----------				
Control	19294a† ± 679.1	13.09a ± 0.61	133.56a ± 7.22	8613a ± 327.8	79.21bc ± 4.27
Thin	16337b ± 667.1	13.17a ± 0.60	117.83a ± 6.91	7555b ± 322.4	71.25c ± 4.14
Burn	11179c ± 695.0	6.83b ± 0.62	48.99b ± 7.16	5332d ± 333.6	122.0a ± 4.25
Thin+burn	8642d ± 666.9	5.89b ± 0.60	51.28b ± 6.96	4167d ± 322.0	83.79b ± 4.13
Herbi+burn	3068e ± 674.0	2.61c ± 0.60	29.10c ± 6.93	1547e ± 325.2	56.92d ± 4.13

†Column means followed by different lowercase letters indicate significant differences among treatments at the 0.05 probability level.

Table 9. Pre- versus post-treatment comparisons of soil bulk density.

Treatment	Bulk Density (g cm^{-3})
Pre-control	1.23a† ± 0.02
Post-control	1.25a ± 0.02
Pre-thin	1.28a ± 0.02
Post-thin	1.37b ± 0.02
Pre-burn	1.24a ± 0.02
Post-burn	1.22a ± 0.02
Pre-thin+burn	1.27a ± 0.02
Post- thin+burn	1.40b ± 0.02
Pre-herb+burn	1.28a ± 0.02
Post- herb+burn	1.25a ± 0.02

†Column means followed by different lowercase letters indicate significant differences in pre versus post comparisons at the 0.05 probability level.

Table 10. Comparisons among treatments following fuel reduction for soil bulk density.

Treatment	Bulk Density (g cm^{-3})
Control	1.25b† ± 0.02
Thin	1.37a ± 0.02
Burn	1.22b ± 0.02
Thin+burn	1.40a ± 0.02
Herbi+burn	1.25b ± 0.02

†Column means followed by different lowercase letters indicate significant differences among treatments at the 0.05 probability level.

Herpetofaunal responses to fire and fire surrogates at the Dixon Forest Education Center

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Introduction

Like many habitats within the temperate zone, frequent low-intensity fires once maintained the longleaf pine forests of the Coastal Plains of the southeastern United States. Such fires are thought to have created a disturbance to the understory plant community, thereby allowing for unusual species richness in this portion of the habitat and creating an open park-like aspect to the forest. Suppression of fire by humans has altered this disturbance regime, allowing the forested areas to become dominated by shrubs and hardwoods. Shading in such areas results in reduced species richness of plants and an altered assemblage of animal species. Because these kinds of changes are so pervasive, many animals species native to old-growth longleaf pine forests are imperiled.

Amphibians and reptiles are important components of the longleaf pine community because they perform a variety of important functions and because they can represent a large percentage of the vertebrate fauna. For example, the gopher tortoises is thought to be a keystone species of the longleaf pine forest and amphibians breeding at temporary ponds in this habitat can serve as a vital source of food for predators.

Reintroduction of fire into uplands of the southeastern United States has become an essential tool for restoring habitat for game species and for conserving sensitive taxa. This is especially true for amphibians and reptiles that are endemic to longleaf pine forests. Unfortunately, some aspects of fire, especially the creation of hazardous smoke conditions, preclude its use across the entire landscape. Therefore, land managers need alternative management tools that can create the same ecosystem effects as fire while minimizing the deleterious effects of this feature. Two such tools are thinning and use of herbicides. Thinning of timber stands has the effect of removing fuel from the habitat and opening the area to increased sunlight. The latter has the effect of allowing sunlight to penetrate to the forest floor, thereby allowing increased growth of understory plants. Such changes are thought to be generally beneficial to native amphibians and reptiles of the longleaf pine forests because of improved foraging and nesting opportunities. Similarly, use of herbicides can mimic the effects of fire by eliminating shrub growth, thereby releasing understory grasses and herbs from shading. Again, such changes to the environment should benefit native amphibians and reptiles of the longleaf pine community. However, this management tool might carry a deleterious effect if the chemicals released into the environment alter physiological pathways of the animals, such as those associated with reproduction, that change patterns of recruitment within populations.

In this study the effects of fire, stand thinning, and use of herbicides are examined by comparing the species richness and taxonomic composition of amphibians and reptiles on reference sites receiving no management practices with experimental sites receiving fire, herbicide, and thinning as treatments singly or in combination. If these tools are beneficial, then increased species richness, especially of taxa that are specialists of the longleaf pine forests, should occur on experimental sites. If species richness on plots that are thinned or treated with herbicide is similar to or increased relative to plots that are burned, then thinning or use of herbicides would be valuable management tools, from a herpetological perspective.

Methods

The study was located on the Solon Dixon Forestry Education Center lands in Covington County, Alabama. The study design consisted of five treatments replicated three times each. The five treatments were (1) burn (three plots treated with a dormant season fire during April and May of 2002), (2) herbicide (three plots treated during Sept of 2002), (3) thin (three plots thinned during Feb-Mar of 2002), (4) thin and burn (three plots thinned and burned during Feb-Mar of 2002), and (5) control (three plots receiving no fire, thinning, or herbicide). Each plot was 9 ha in size and the shape of the plot was configured to include areas with initial conditions that were as similar among sites as possible.

We established one drift fence array on each plot during the fall of 2001. Each array consisted of a central 5 gal bucket, buried so that the top of the bucket was flush with the ground and from which three 50 foot sections of 16 inch aluminum flashing radiated. Each section of flashing was imbedded into a 4 inch trench dug into the ground. Each trench was back-filled so that the flashing created a barrier to movement of small vertebrates. At the distal terminus of each section of flashing a 5 gal bucket was buried flush to the ground. The lid of each bucket was propped off of the ground so that small amphibians and reptiles could crawl into the bucket and so that the lid shaded each bucket's interior. Mid way along each section of flashing two funnel traps were placed, one on each side of the fence. These traps were made of aluminum window screening and consisted of a 6 inch diameter barrel with a funnel-shaped insertion of screen at each end. The funnels were oriented so that the small opening (1 inch diameter) was oriented towards the center of the trap. Bucket and funnel traps were checked daily from May 27 through Aug 1, 2002.

Time constrained visual encounter surveys were also performed on each site. During each survey, an investigator walked for 15 minutes searching for visible amphibians and reptiles. The species identity of each individual encountered was recorded. This sampling procedure was designed to inventory large species that were unlikely to be captured by the drift fences. One survey per plot was conducted each week from May 27 through Aug 1, 2001.

Because Bufo terrestris was a common species on all sites, we marked these individuals by toe-clipping them. When an animal was removed from a trap, we recorded whether it was newly captured or represented a recapture. These data will be analyzed to examine the population-level response of this widespread species to the treatments.

Results and Discussion

Pre-treatment (2001)

The time required to establish the drift fence arrays took much longer than was anticipated. Because of this, the final array was not established until September of 2001. Soon thereafter, some of these had to be removed and then reestablished because of the burn treatments. Therefore, the only pretreatment data that will be available from this project are those from the control and herbicide plots. We plan to analyze these separately. In that comparison, data from 2002 will be compared with those gathered during 2003 on control and herbicide plots. Comparisons during 2002 will be used to assess how different the plots were before treatments were applied and will be used to estimate the size of effect required in all other treatment plots to allow the effect to be attributable to treatments.

Post-treatment (2002)

A total of 823 individuals representing 31 species were recorded on the 15 plots. These included 15 species of amphibians (12 anurans, 3 caudatans) and 16 species of reptiles (9 snakes, 4 scincimorphs, 2 iguanians, and 1 turtle; Table 1). The number of individuals was dominated largely by amphibians (680 individuals), of which most were Bufo terrestris (290 individuals) or Gastrophryne carolinensis (342 individuals).
The taxonomic content of each treatment (replicates pooled) was fairly consistent (Table 1). One notable exception is frogs of the genus Rana. These appear haphazardly among plots, probably in response to the relative proximity of some plots to creeks. The captured ranids were all juveniles that were presumed to be dispersing. Therefore, interpretation of treatment effects on his group is likely to be confounded by this confounding variable. With the exception of Rana, the species composition of the control and herbicide treatments was similar. We interpret this to indicate that the upland herpetofauna was fairly uniformly distributed before treatments were administered.

To examine possible treatment effects, we compared species richness among sites. Because these data consisted of counts of numbers of species on each plot, we used a log-linear contingency table analysis. To date, no effect of treatment on species richness can be documented for the herpetofauna at the Solon-Dixon Center ($G = 3.92$; $df = 8$; $p = .86$; Table 2). Additionally, the number of individuals among common taxa does not differ among treatements ($G = 14.35$; $df = 20$; $p = .81$; Table 3). There was a significant difference in the abundance of Bufo terrestris among treatments ($G = 14.62$; $df = 4$; $p = .006$; Table 3), although this main effect was complicated by significant variation among replicates within treatments ($G = 82.22$; $df = 8$; $p < .0001$). The treatment effect was associated with reduced toad abundance on control, herbicide, and thinned sites. Because the herbicide was not administered during the time period over which our surveys were conducted, we conclude that thinning has no effect on the numbers of Bufo terrestris that are sampled by drift fences. Thinning of a burned plot had no additional effect. This indicates either that toads became more abundant due to the burn treatment or that toads became more trappable. Additional data on changes in body size should allow us to distinguish between these two explanations. If abundance increased, then either immigration increased (reduced probability of recapturing an adults on burned plots) or activity patterns were altered (increased probability of recapture on burned plots). To date we have insufficient data to test these two ideas, but such comparisons should be feasible over the next two years.

Overall, a response of the herpetofauna to the treatments cannot be documented. This is not surprising because amphibians and reptiles are characterized by having reduced mobility, relative to birds and mammals, and are less sensitive than birds and mammals to the effects of habitat quality. There is some indication that Bufo terrestris is becoming more abundant or more trappable on burned sites. Because fires are the natural disturbance that maintained the ancestral habitat, this is the treatment that is expected to have the strongest influence on herpetofaunal diversity and the abundance of common species. Herbicide is the primary tool being advocated for use where fire cannot be used. Additional data are required to document the utility of this management tool. However, for Bufo terrestris, thinning a site to reduce fuel load and create a more open aspect does not yet appear to have the effect that appears to be emerging on burned plots.

Table 1. Species lists for amphibians and reptiles collected on the five treatments (replicates pooled). Abbreviations are Northern Cricket Frog (Acr cre), Southern Cricket Frog (Acr gry), Southern Toad (Buf ter), Oak Toad (Buf que), Narrowmouthed Toad (Gas car), Green Treefrog (Hyl cin), Pinewoods Treefrog (Hyl fem), Squirrel Treefrog (Hyl squ), Bullfrog (Ran cat), Bronze Frog (Ran cla), Southern Leopard Frog (Ran sph), Spadefoot Toad (Sca hol), Mole salamander (Amb tal), Eastern Newt (Not vir), Slimy Salamander (Ple glu), Green Anole (Ano car), Eastern Fence Lizard (Sce und), Six-lined Racerunner (Cne sex), Five-lined Skink (Eum fas), Broadheaded Skink (Eum lat), Ground Skink (Sci lat), Copperhead (Agk con), Cottonmouth (Agk pis), Scarlet Snake (Cem coc), Black Racer (Col con), Eastern Hognose Snake (Het pla), Scarlet Kingsnake (Lam tri), Coachwhip (Mas fla), Pine Snake (Pit mel), Crowned Snake (Tan cor), and Gopher Tortoise (Gop pol).

		CONTROL	**HERBICIDE**	**BURN**	**THIN**	**THIN & BURN**
AMPHIBIA						
	ANURA	Acr cre Buf ter Gas car Hyl cin Ran cla Ran sph Sca hol	Acr gry Buf ter Gas car Sca hol	Buf ter Gas car Ran cat Ran sph Sca hol	Acr cre Buf ter Buf que Gas car Hyl cin Ran cla	Acr gry Buf ter Buf que Gas car Hyl cin Hyl fem Hyl squ Ran cla Sca hol
	CAUDATA		Not vir	Not vir	Amb tal Not vir Ple glu	Ple glu
REPTILIA						
	IGUANIA	Ano car Sce und	Ano car Sce und	Ano car Sce und	Ano car Sce und	Ano car Sce und
	SCINCOMORPHA	Cne sex Eum lat Sci lat	Eum lat Sci lat	Cne sex Eum lat Sci lat	Cne sex Eum fas Eum lat Sci lat	Cne sex Eum lat Sci lat
	SERPENTES	Agk pis Cem coc Col con Tan cor	Agk con Cem coc Col con Mas fla Tan cor	Col con Het pla Tan cor	Agk con Col con Lam tri Tan cor	Agk con Cem coc Mas fla Pit mel Tan cor
	TESTUDINES		Gop pol			

Table 2. Number of species of amphibians and reptiles present on each of 15 plots on the Solon Dixon Forestry Education Center.

TREAT	REPLICATE	NUMBER OF SP.
CONTROL	1	10
CONTROL	2	9
CONTROL	3	8
HERB	1	7
HERB	2	10
HERB	3	7
THIN	1	9
THIN	2	9
THIN	3	5
BURN	1	8
BURN	2	10
BURN	3	8
T&B	1	16
T&B	2	7
T&B	3	9

Table 3. Numbers of individuals of amphibians and reptiles on 15 plots on the Solon-Dixon Forestry Education Center.

TREAT	REPLICATE	TAXON					
		BUFO	GAST	OTHER	IGUAN	SCINCO	SERPENTES
CONTROL	1	57	17	0	9	9	1
CONTROL	2	5	24	2	4	10	1
CONTROL	3	21	29	2	2	4	5
HERB	1	5	27	0	2	10	3
HERB	2	7	11	1	4	3	4
HERB	3	23	23	4	6	2	0
THIN	1	14	24	2	2	2	2
THIN	2	5	9	0	2	2	0
THIN	3	15	9	2	1	1	3
BURN	1	16	23	16	3	4	1
BURN	2	18	18	3	5	7	1
BURN	3	30	29	1	3	3	2
T&B	1	33	59	5	4	8	1
T&B	2	27	10	1	2	5	0
T&B	3	14	27	9	2	9	5

Fire / Fire Surrogate Study:
Small Mammal Project Status Report
October 3, 2002
Nicholas W. Sharp

The nationwide Fire/Fire Surrogate study is a multidisciplinary effort to study the effects of restoring fire to historically fire dependent ecosystems and to determine if alternatives to fire can mimic those effects. The study underway at the Solon-Dixon Center focuses on the longleaf pine ecosystem. Our goal is to examine the effects of the various treatments on the small mammal community of this ecosystem. To that end, we are sampling the population with a mark-recapture study so that changes in population demographics may be ascertained. Since the overall goal of the project is to learn how to return the ecosystem to a natural state, we must define that natural state or "Desired Future Condition (DFC)" (named in the Proposal to the Joint Fire Science Program). In an effort to define the DFC for the small mammal population, we expanded our trapping efforts to Conecuh National Forest, an area resembling the "classic" wire grass understory longleaf pine ecosystem.

Work continued in the summer of 2002 with Nicholas Sharp assuming the MS student position. The protocol from the previous summer was repeated. There were two trapping cycles; during each cycle every stand was sampled one time. Trap cycle one ran from May 5 through June 26th. Trap cycle two began July 2 and continued through July 31. A summary of all data collected thus far follows.

Sampling in Conecuh National Forest again followed the same protocol. Three grids were installed in compartment 58 (US Forest Service notation), an approximately 300 acre stand of mature longleaf pine with a mixed grass/herbaceous understory. Trapping proceeded from July 31st through August 7th. Vegetation sampling was conducted by means of assisting PhD student Travis Folk, who also has a study in compartment 58 and offered to share his data. Due to the ad hoc nature of this additional sampling, this data will not be as robust as that of the major study, but should provide insights into the small mammal community composition. I suspect that as habitat is converted from a yaupon shrub understory back to a grass/herb understory the community structure will change (e.g. the cotton rat, Sigmong hispidus, will become a larger component of the community and the golden mouse, Ochrotomys nuttalli, will drop out of the communitaltogether.) Preliminary data suggests this may be the case (see below).

Currently, I am preparing for a round of trapping this winter. Trapping will begin in early December. Previous efforts to sample the squirrels of the habitat were unsuccessful. I am reviewing appropriate sampling methods and a new protocol will be written. I anticipate placing Mosby box traps on the ground and affixing Sherman traps to trees by use of a wooden sleeve. Other researchers have found these methods successful. The traps and sleeves were built this past summer. Data entry is also underway.

Summer 2001

Species	# Captured
Peromyscus gossypinus	198
Ochrotomys nuttalli	13
Sigmodon hispidus	2
Glaucomys volans	2
Oryzomys palustris	1
Total	216

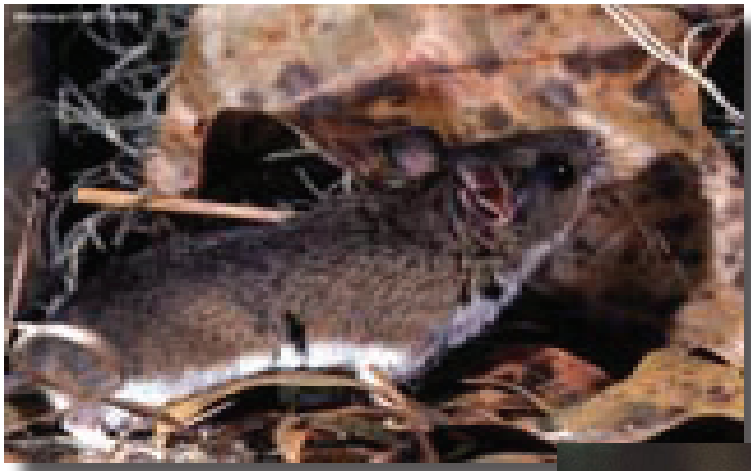
Total # captures =	928
Total trap nights =	÷21,000
Total capture rate =	4.42%

Summer 2002

Species	# Captured
Peromyscus gossypinus	268
Ochrotomys nuttalli	41
Mus musculus	2
Sigmodon hispidus	1
Glaucomys volans	1
Microtus pinetorum	1
Rattus norvegicus	1
Total	315

Total # captures =	1,684
Total trap nights =	÷21,000
Total capture rate =	8.02%

Conecuh National Forest

Species	# Captured
Peromyscus gossypinus	46
Sigmodon hispidus	7
Total	53

Total # captures =	219