SPIDER (ARANEAE) RESPONSES TO FUEL REDUCTION IN A PIEDMONT FOREST IN UPSTATE SOUTH CAROLINA

A Thesis

Presented to

the Graduate School of

Clemson University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

Entomology

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by

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May 2003

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ABSTRACT

Prescribed burning and mechanical thinning are common forest-management practices. During 2002, pitfall traps were used in Upstate South Carolina to sample spider populations to determine if the forest-management practices of burning, thinning, and if populations had recovered by 1 yr post burning and thinning combined led to changes in population levels. Control areas were established to allow comparisons of the three different treatments with areas that were not impacted by these practices. The burn only plots were burned during April 2001. Thinning in both thin only and thin and burn plots was conducted during 2001. Burning in the thin and burn treatment occurred in March 2002. Sampling was conducted every two months for one year beginning in January 2002. Spider families collected were Agelenidae, Araneidae, Atypidae, Clubionidae, Gnaphosidae, Hahniidae, Linyphiidae, Lycosidae, Oxyopidae, Pisauridae, Salticidae, Theridiidae, and Thomisidae. Within these families the genera *Agelenopsis* (Agelenidae), *Cicurina* (Agelenidae), *Coras* (Agelenidae) *Cybaeus* (Agelenidae), *Wadotes* (Agelenidae), *Gladicosa* (Lycosidae), *Hogna* (Lycosidae), *Pirata* (Lycosidae), *Schizocosa* (Lycosidae), and *Varacosa* (Lycosidae) were abundant enough to allow analysis. Only one species, *Gnaphosa fontinalis* Keyserling, was analyzed at the species level.

Results indicate that by 1 year post-treatment, spider populations had recovered following the initial burning and thinning in 2001. However in 2002, when first post-

burn samples were compared to pre-burn samples in the thin and burn plots, three taxa, Agelenidae, Linyphiidae, *Wadotes* (Agelenidae), and *Varacosa* (Lycosidae) exhibited a decrease in the mean numbers of spiders collected after the burn in March 2002. After, the first post-burn sample, the mean number of spiders in three of the taxa, Agelenidae, *Wadotes*, and *Varacosa*, remained low during the remaining five sampling periods when compared to the control plots. Linyphiid mean numbers during March/April were also significantly lower than those in the control plots, but during August through December, no significant differences were found between thin and burn, and control plots.

These four taxa, Agelenidae, Linyphiidae, Wadotes (Agelenidae, and Varacosa (Lycosidae) were the only taxa to show detectable responses to the treatments in this study. They, therefore, represent the best candidates for us as indicator taxa in future studies of management-related disturbances.

DEDICATION

I dedicate this work to my Mom and Dad. This thesis exists because of their love, support, and guidance.

ACKNOWLEDGMENTS

I would like to thank Dr. Joesph Culin for his support, guidance, and understanding. Without his patience and assistance this thesis work could not have been accomplished. I thank my committee members Dr. Peter Adler and Dr. Mac Callaham for their direction and assistance on this thesis work. Also, I would like to thank Dr. Hoke Hill for his statistical guidance, and the faculty and staff of the Entomology department for all of their help. A great deal of gratitude goes to Dr. Frederick Coyle for his assistance with spider identification and confirmations. This is contribution number 36 of the National Fire and Fire Surrogate Project (FFS), funded by the U.S. Joint Fire Science Program.

Finally, I would like to thank my family Matt, Sheila, Vickie, Jim, my grandmother and grandfather Noel, and my grandmother and grandfather Vickers for their support and encouragement. I would like to thank my fellow graduate students, especially Laurie, Chris, and Becky, for their friendship and support. Also, I would like to thank my friends Cora Allard, Pete Engle, and Marianne Robertson for their support, encouragement, and friendship throughout the years.

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INTRODUCTION

Prescribed burning and mechanical thinning are common forest-management practices. Prescribed burning is the intentional setting of fire to reduce populations of damaging insects, increase environmental stability, reduce potentially high fuel loads, and alter habitat availability or quality. The practice of prescribed burning has been used mainly in range and agricultural systems (McCullough et al. 1998). Individuals believed that prescribed burning caused a negative impact on the environment, and this belief resulted in a potential end to burning. However, the benefits of prescribed burning are starting to be discovered as scientists study the effects of forest fires and prescribed burning on the environment.

Mechanical thinning is the process of selectively removing trees from a forest environment. Trees that are removed are often selected because of distorted limbs, insect damage, or overgrowth. The selective removal of trees allows for growth and a potential increase in natural and planted tree species populations. Thinning allows for remaining trees to grow in areas with increased sunlight, nutrients, and moisture. Also, thinning provides much needed pulp and fiber products for the paper and construction industries.

Prescribed burning and thinning studies have been conducted in the northwestern boreal forests of the United States and Canada (McCullough et al. 1998). Similar studies have also been conducted in other regions of the world, such as Africa (Heinl 2001), Australia (Collett 1998; York 1999), Europe (Haimi et al. 2000), and the Middle East (Sternberg et al. 2001).

In this study, spiders (Araneae) were examined to determine if there was an effect on populations due to fuel-load management practices. Spider populations were studied from January to December 2002.

Objective:

The goal of this study is to determine if the fuel load management practices of burning, thinning, and thinning and burning have an effect on spider populations in a southern piedmont forest.

Hypotheses:

H_1: Burning will cause a decrease in spider populations in the Clemson Experimental Forest.

H_a: Burning will not cause a decrease in spider populations in the Clemson Experimental Forest.

H_2. Thinning will cause a decrease in spider populations in the Clemson Experimental Forest.

H_a: Thinning will not cause a decrease in spider populations in the Clemson Experimental Forest.

H_3: Thinning and burning will cause a decrease in spider populations in the Clemson Experimental Forest.

H_a: Thinning and burning will not cause a decrease in spider populations in the Clemson Experimental Forest.

LITERATURE REVIEW

Native Americans extensively used fire, and were able to produce fires much different in frequency and intensity than naturally occurring fires caused by lighting strikes. Anthropogenic fires have a different seasonal signature and frequency than fires that occur naturally (Lewis 1985; Brown 2000; Pyne 2000). Native Americans would burn large areas to force deer, elk, and bison into smaller unburned areas for easier capture. Fire, also, was used to surround and collect crickets and grasshoppers so they could be used as food (Williams 2000). Man made fire was used to clear riparian forests and marshes and create areas where grasses and trees could grow to attract game such as beaver, muskrats, moose, and waterfowl (Brown 2000).

Today, fire is used as a way to increase environmental stability, reduce populations of damaging insects and plant pests, reduce potentially high fuel load levels, and alter habitat availability or quality. Altering habitat availability or quality can indirectly reduce pest insect populations (McCullough et al. 1998).

Fire can be divided into different categories based on intensity (relating to the heat energy released by a fire) or behavior (the manner in which a fire reacts to the influence of fuel, weather, and topography). Surface fires are distinguished by low-level burning through grass, shrubs, fallen limbs and logs, leaf litter, and needles. Also, ground-level fires may burn in subsurface organic fuels. Crown fires are unintentional fires that are a result of out of control surface fires and occur in the overstory canopy.

Fuel accumulation, distribution, and moisture content determine the intensity of the fire. Fuels are organic material, such as dead trees, logs, slash (tree-tops, branches, and other logging debris) dead needles, leaves, and litter. In areas that have high level of fuels, fires may burn hotter, move slower, and have more profound ecological effects than fires in areas that have lower fuel accumulation. Besides fuel loads, factors that may affect fire intensity and behavior are wind, aspect (direction of slope orientation), and topography (McCullough et al. 1998).

Effects of Burning and Thinning on Arthropods

Several studies have focused on how forest-management practices affect arthropods. Siemen at al. (1997) found that abundance and species richness of arthropods were reduced in oak savannah and oak woodlands in Minnesota, due to changes in the environment caused by fire. Soil biochemistry can change after a fire and cause changes in species composition of soil and litter arthropods. For example, an increase or decrease in soil pH can change both decomposer communities and the decomposition process itself. Also, increases in soil acidity can cause a change in solubility of nutrients which can result in changes in plant growth rates (Haimi et al. 2000).

Paquin and Coderre (1997) reported that edaphic macroarthropods experienced, on average, a 95.5% reduction in mean abundance caused by fire mortality in a 47-yr-old deciduous forest, a 144-yr-old mixed forest, and a 231-yr-old coniferous forest, in Abitibi, PQ, Canada. However, some organisms survived the experiment. Certain arthropods may be able to survive by moving to different soil depths.

Arthropod activity decreased after two low-intensity prescribed fires in a dry sclerophyll eucalypt forest in west-central Victoria, Australia (Collett 1998). The most common non-insect taxa affected by fires in this study were Acarina (ticks and mites) and Araneae (spiders). The most common insect taxa affected by fires were Coleoptera (beetles), Collembola (springtails), Diptera (flies), and Formicidae (ants). However, the decrease in monthly activity of those organisms caused an increase in other macroarthropods, such as, Dermaptera (earwigs) (Collett 1998). Haimi et al. (2000) reported that macroarthropod numbers decreased in burned plots, while five species of collembolans exhibited a significant increase after a burn. York (1999) reported that low-intensity burning in coastal blackbutt forests in Australia caused an 82% reduction in arthropod numbers. Areas in the forest subjected to low-intensity fires had significantly fewer Araneae, Acari, Isopoda (woodlice), Hemiptera (true bugs), Coleoptera, Pseudoscorpionida (pseudoscorpions), insect larvae, and Hymenoptera (ants and non-ants) found in the leaf litter.

Many arthropod groups decline immediately after a fire, with the magnitude of reduction based upon the intensity of the fire and mobility of the arthropods. Also, niche diversity is affected by burning. Increases in insect populations are related to a species' ability to gain access to newly grown vegetation (Swengel 2000). Species that are able to use the newly created habitat will have a much greater chance of surviving and reproducing.

Few studies have focused on the effects of fire on spider populations. Haskins and Shaddy (1986) found that spider populations were not affected by management practices, such as burning, mowing, and plowing in an old-field ecosystem in Missouri. Lycosidae (wolf spiders) was the most common family found in treatments, except for annually plowed plots where Clubionidae, and Gnaphosidae (running spiders) were predominant. Significantly higher numbers were found in plowed, annually mowed, and burned areas compared to the control areas. Bray-Curtis similarity indices for running spiders, Clubionidae and Gnaphosidae, showed that the treatments that had the highest similarity were mowed and annually burned plots. The mowed and burned quadrants had the highest Lycosidae similarities (Haskins & Shaddy 1986).

Reichert and Reeder (1972) conducted a study in southwestern Wisconsin prairies, and reported that spiders found on the surface at the time of burning were immediately eliminated, while those species found in surface burrows, under rocks, or in clumps of dense vegetation were not affected by burning. Their pitfall trapping data suggested that spiders moved from burned to unburned patches. After a controlled fire had occurred in a Florida wetland, thousands of wolf spiders (Lycosidae) were observed crawling over remaining grass stubble and ash-covered debris (Vogl 1973).

Merrott (1976) found that pioneer spider species decreased after a fire in a heathland nature reserve. He found that although populations of *Micaria silesiaca* (L.Koch), *Arctosa perita* (Latreille), *Steatoda albomaculata* (DeGeer), *Walckenaera monoceros* (Wider), *Typhochrestus digitatus* (O. Pickard-Cambridge), and *Phaulothrix hardyi* (Blackwell) were drastically reduced by forest fires and were almost absent, shortly after burning, he found that by year 3 there were no longer significant differences among treatments. He reported a trend showing higher numbers of spiders in earlier years (1 through 4) compared to later years (5 through 10). Johnson (1995) found that spider numbers decreased in the canopies of *Spartina pectinata* Link after fires occurred. New and Hanula (1998) reported that after three consecutive years of winter burning, spider populations were highest among soil/litter samples in areas that had been burned 3 years prior to sampling. Of all arthropods sampled (i.e., wood roaches, ants, caterpillars, centipedes, spiders, and beetles), spiders were the only group that increased after a winter burn. Also, spiders and ants were the only taxa to increase after a summer burning. Willett (2001) reported that spider abundance and species richness increased with decreasing logging, litter depth, soil moisture, and increasing herbaceous cover. In general, spider populations decreased after burning and thinning.

Why Study Spiders?

Currently, there are over 44,000 spider species known throughout the world (Marc et al. 1999). All are considered to be predators although there are different types of predatory behavior (Marc et al. 1999; Foelix 1996). For example, wolf spiders (Lycosidae) and jumping spiders (Salticidae) are considered nocturnal wandering spiders. These two families of spiders actively hunt for their prey items. Funnel-web spiders (Agelenidae) create a flat-sheet web in order to capture prey (Foelix 1996).

Spiders are easier to sample and identify than many other macroarthropods because of their large size and well known taxonomy (Willett 2001). The great majority of spiders feed mainly on insects. Spiders have colonized almost all habitat types, and a few species of spiders can be found in fresh water and intertidal zones. Also, spiders are abundant in both cultivated and natural environments.

Spiders as Biological Indicators

Changes in the environment can drastically affect spider populations (Marc et al. 1999). Spiders can be studied at both the population and community levels. The amount of prey ingested in the field can be correlated to growth rates and reproductive rates in natural populations. Marc et al. (1999) conducted two experiments on the effects of heavy metal pollution (atmospheric or soil pollution) in relation to vegetation architecture and the composition of the associated spider communities. Results of the studies indicated a density-dependent relationship between spider and prey populations. Also, spider community composition was highly affected by pollution because of a decrease in vegetation architecture (Marc et al. 1999). As the experiments suggest, changes in the environment can cause changes in spider populations. Using spiders as biological indicators could help land managers and companies to determine if environments are being positively or negatively affected by human impacts.

MATERIALS AND METHODS

During 2002, pitfall traps were used to sample spider populations to determine if the three forest-management practices of burning, thinning, and thinning and burning caused changes in population levels. Control areas were established to allow comparisons of the different treatments with areas that were not impacted by these practices.

Initial Design Setup

Replicated plots of the three different treatments and control areas were located in the Clemson Experimental Forest in Anderson, Oconee, and Pickens Cos., SC (Fig 1a). The research forest is divided into two different areas, the north forest (Fig 1b) and south forest (Fig 1c). The burn, thin and burn, and control plots were replicated three times, and the thin only plots were replicated five times (Fig 2a-e). In each replication, four 20 m x 50 m plots were established (Fig 2a-e). The four 20 m x 50 m plots were selected by a coin being tossed to randomly determine which 20 m x 50 m plot was selected for placement of pitfall traps.

Each 20 m x 50 m plot was divided into ten 10 m x 10 m vegetation measurement subplots. One pitfall trap was placed in the center of each of the five vegetation subplots (Fig 3). A total of 270 pitfall traps were placed throughout the three treatment and control plots.

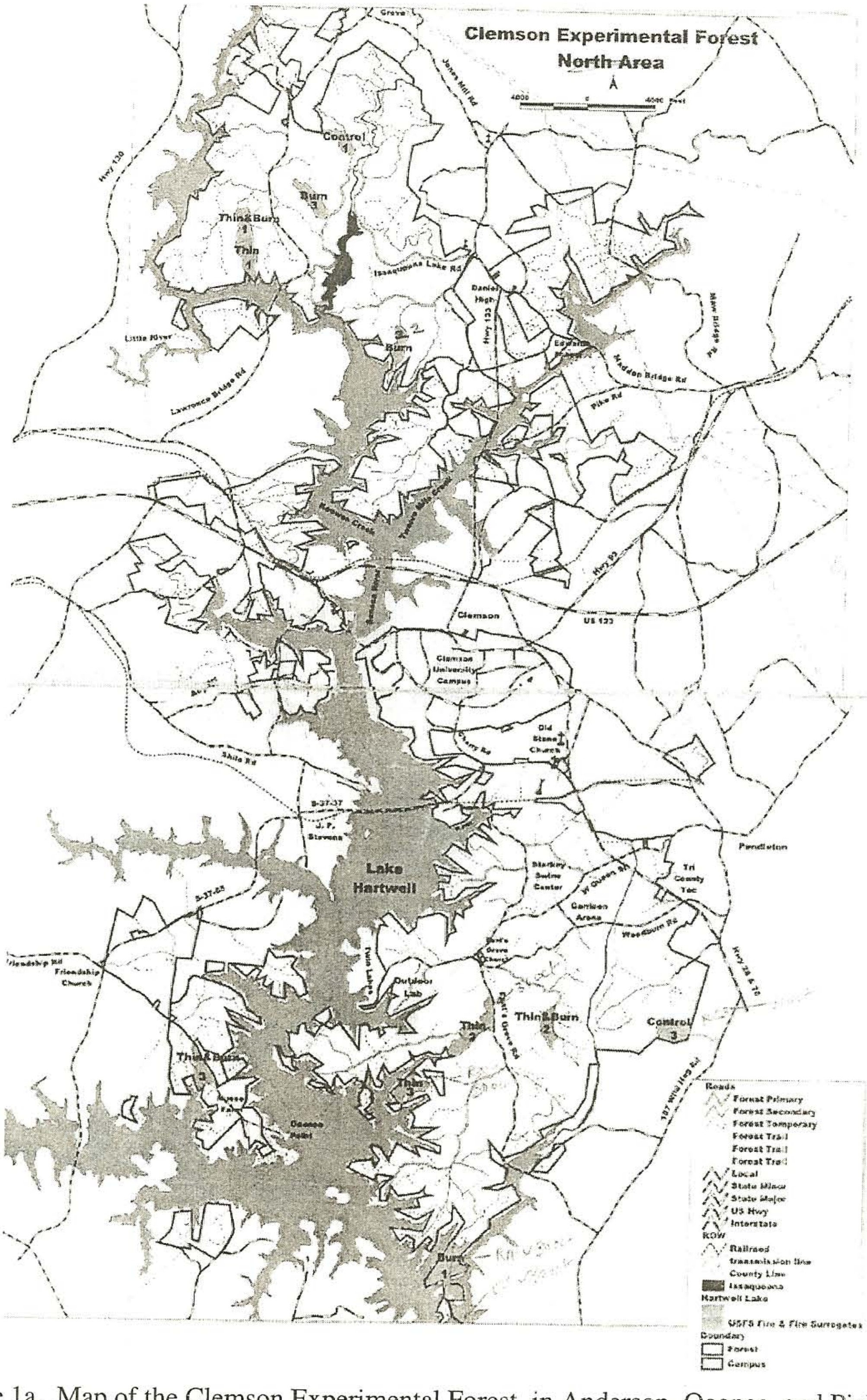

Figure 1a. Map of the Clemson Experimental Forest, in Anderson, Oconee, and Pickens County, South Carolina.

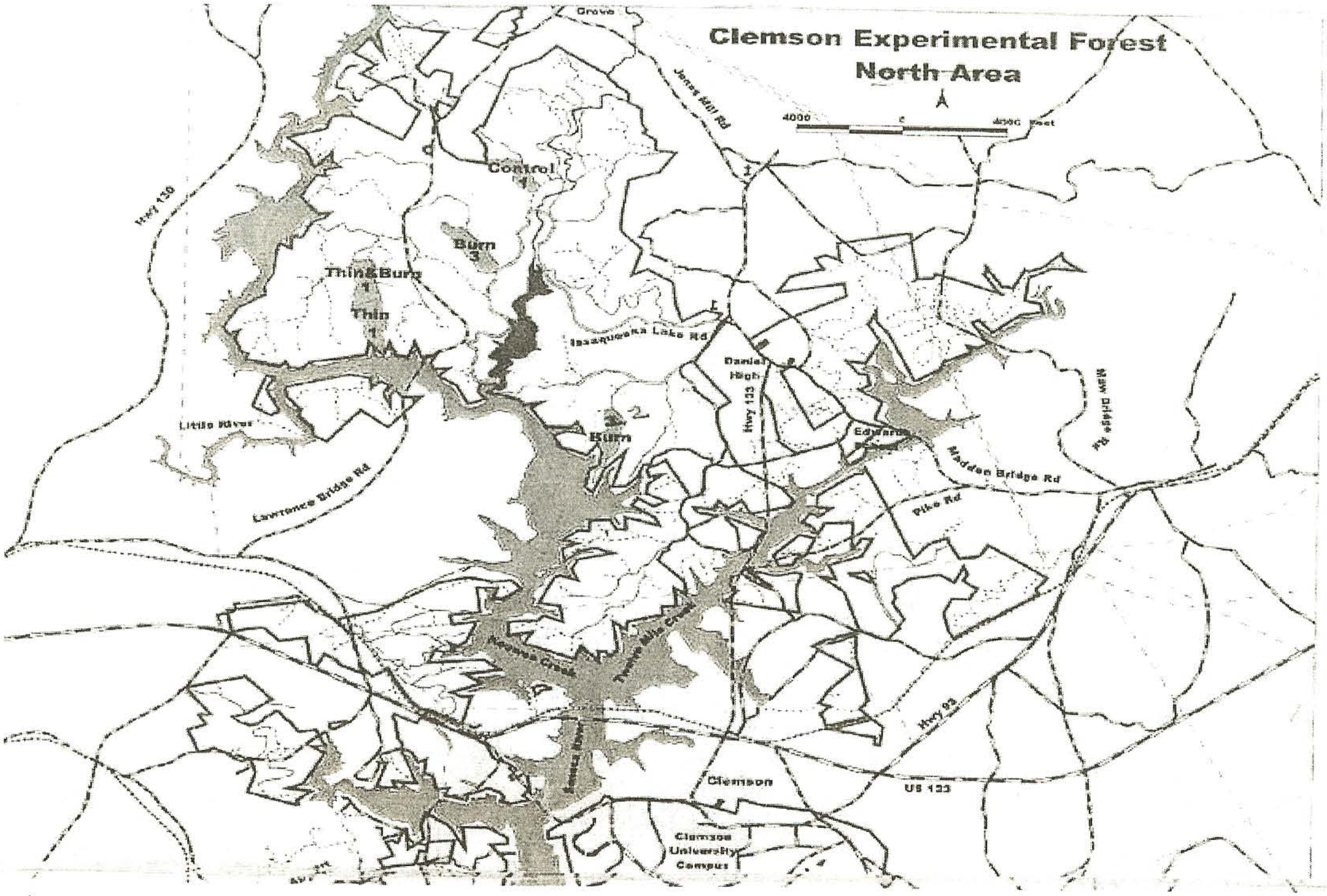

Figure 1b. Replication plots (shaded coloring) located in the northern section of the Clemson Experimental Forest.

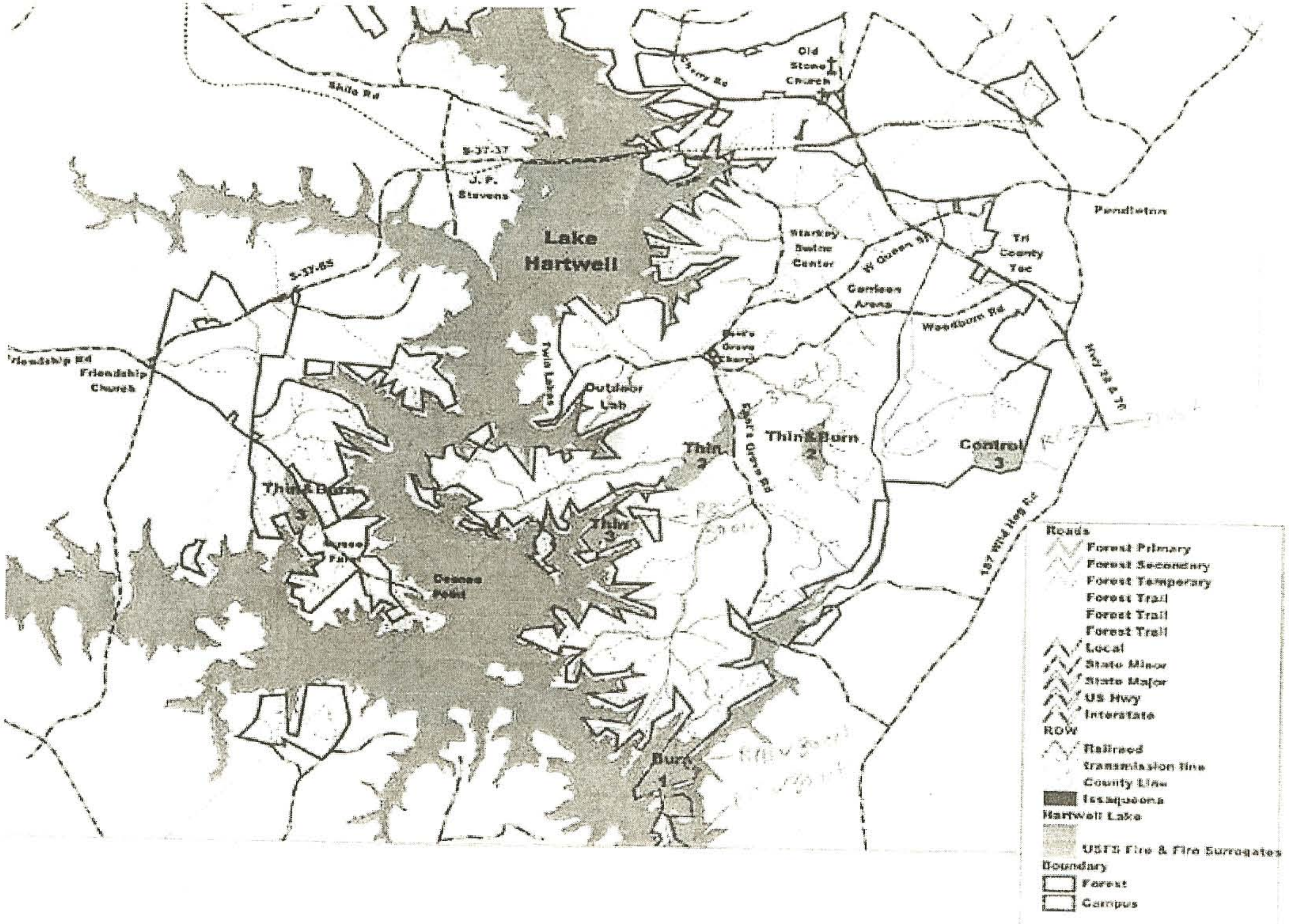

Figure 1c. Replication plots (shaded coloring) located in the southern section of the Clemson Experimental Forest. Note: Thin only plot one is not located on the map.

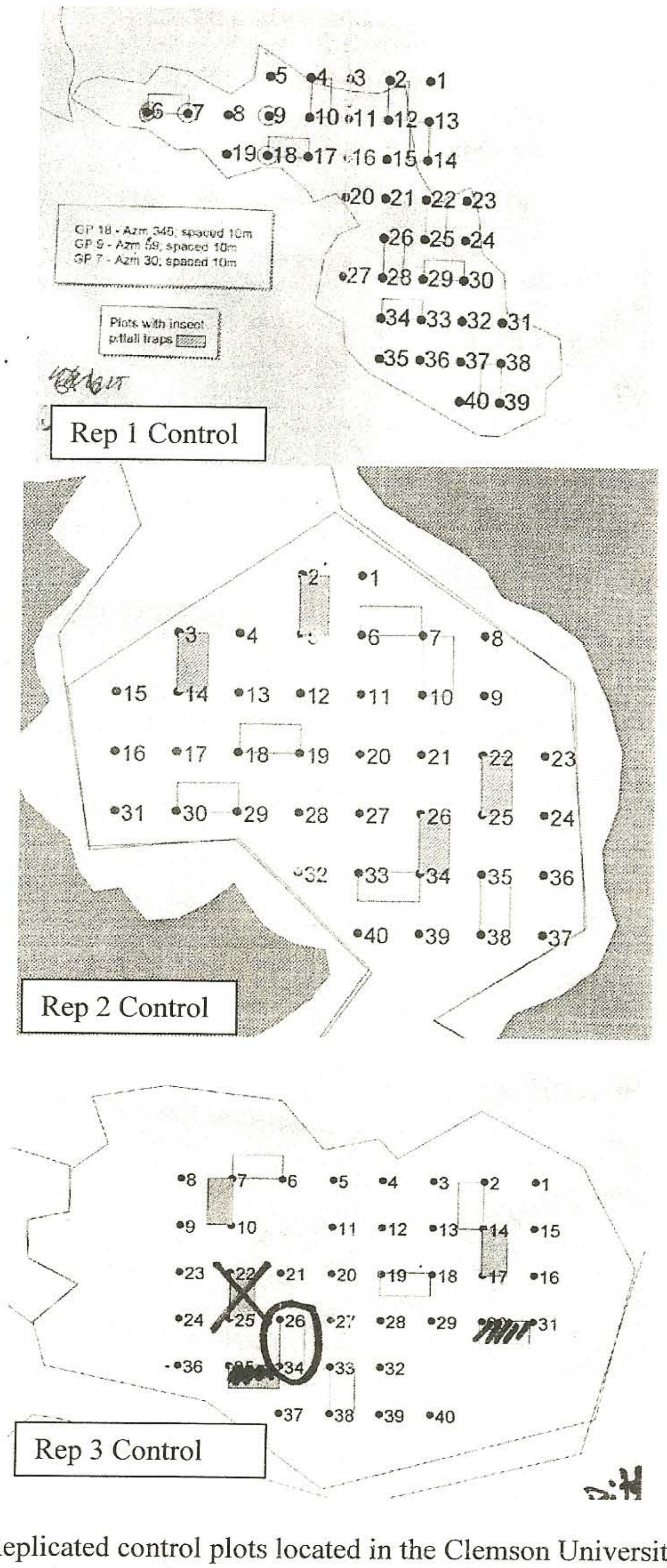

Figure 2a. Replicated control plots located in the Clemson University Experimental Forest. Darkened squares indicate 10 m x 10 m vegetation subplots.

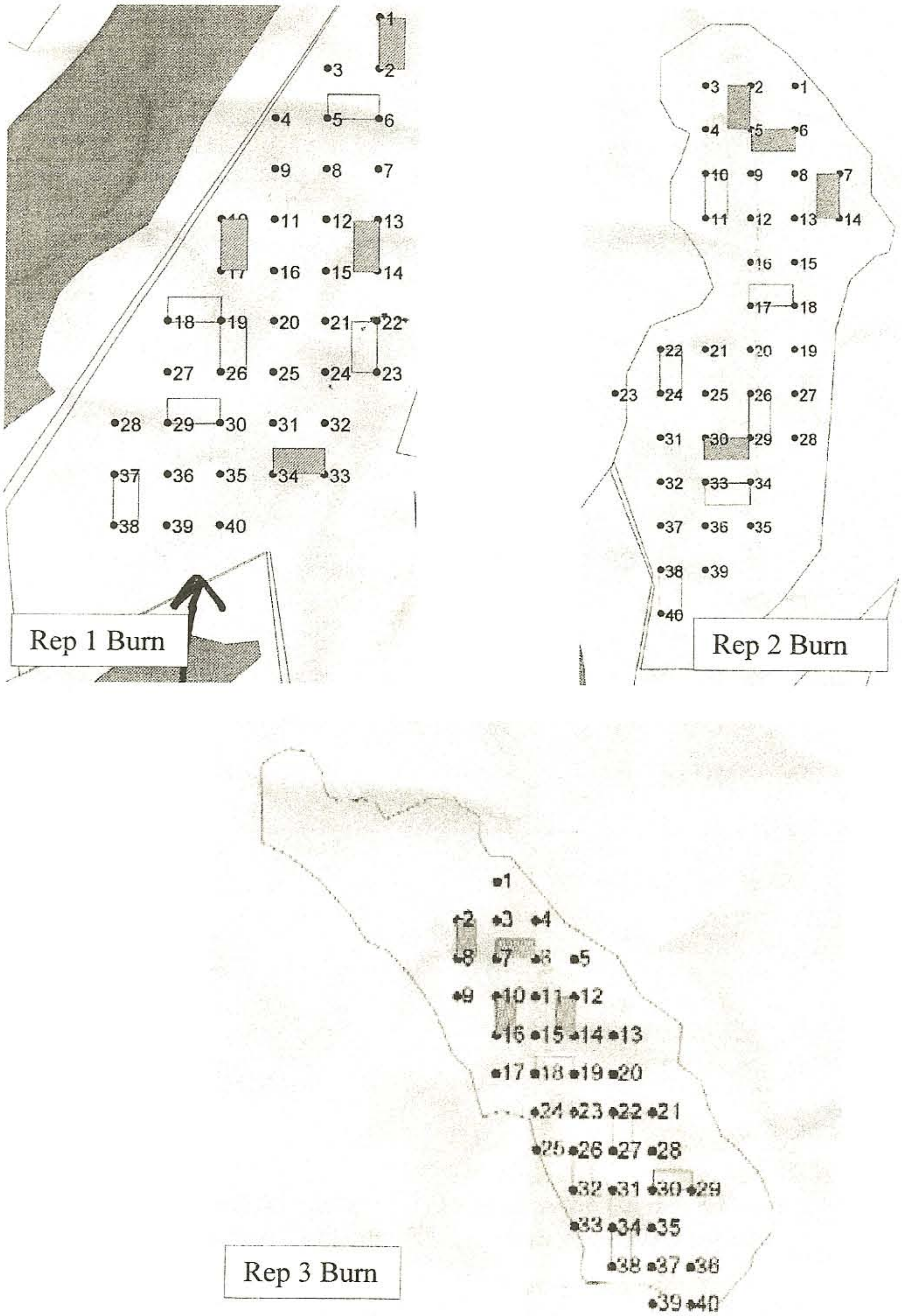

Figure 2b. Replicated burn plots located in the Clemson University Experimental Forest. Darkened squares indicate 10 m x 10 m vegetation subplots.

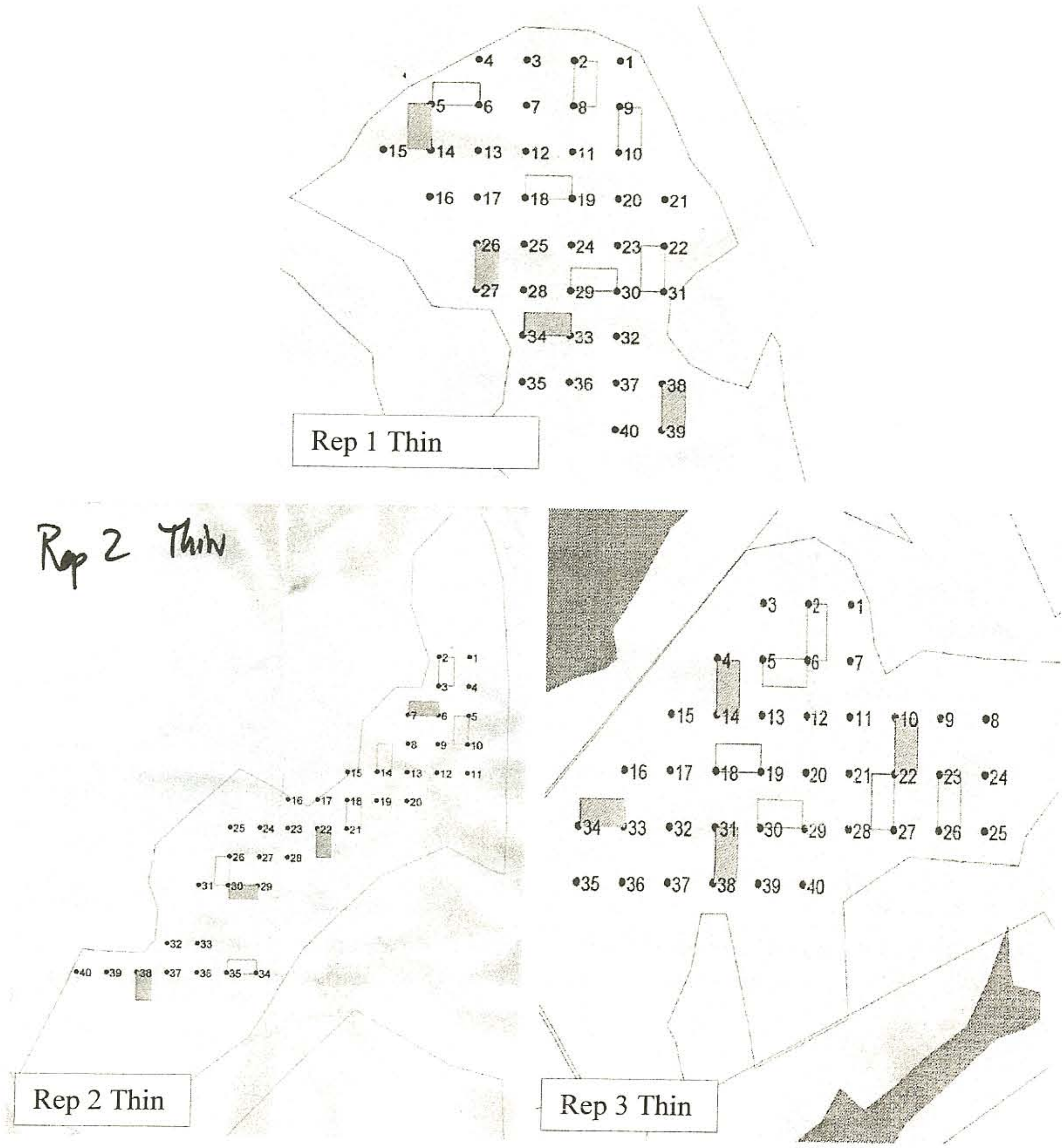

Figure 2c. Replicated thin plots (1-3) located in the Clemson University Experimental Forest. Darkened squares indicate 10 m x 10 m vegetation subplots.

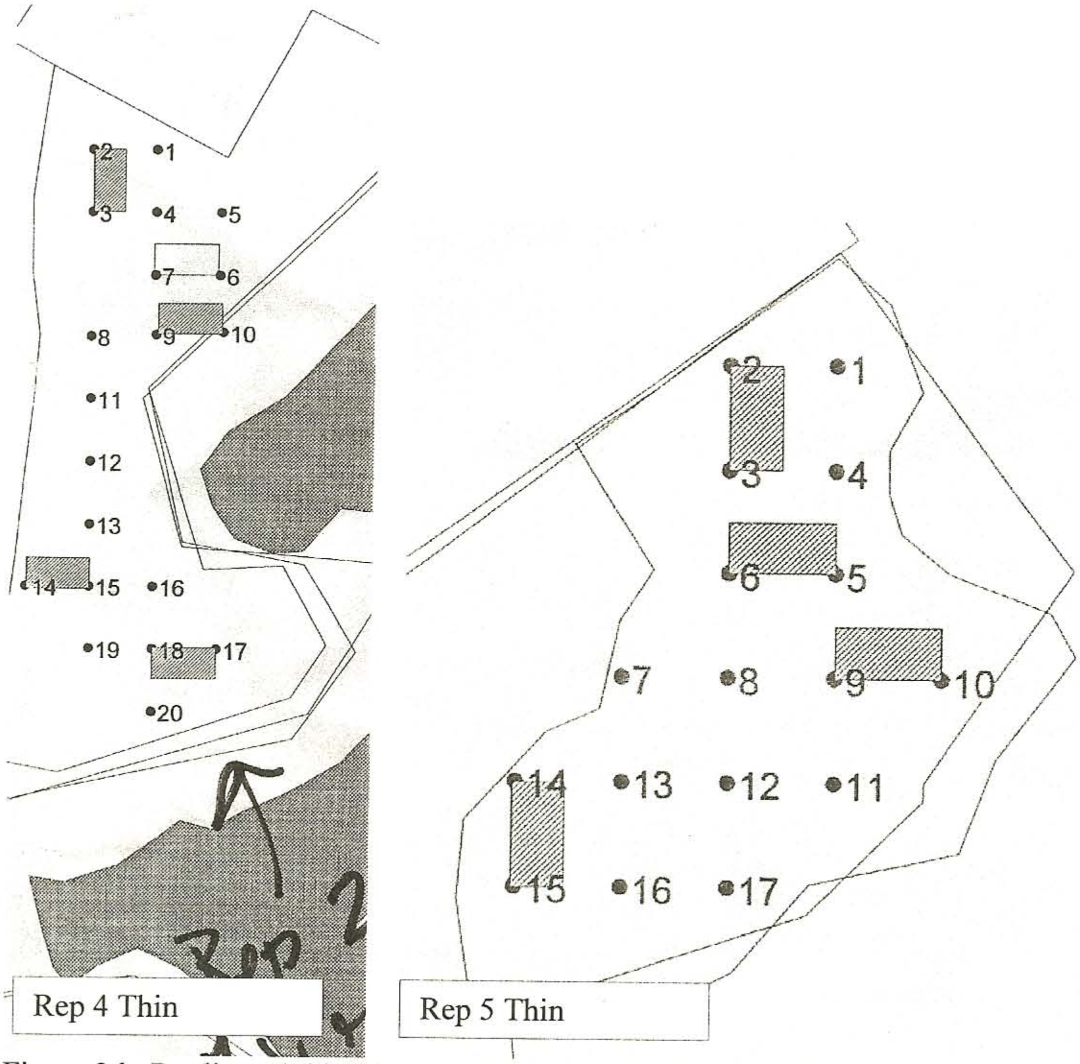

Figure 2d. Replicated thin plots (4-5) located in the Clemson University Experimental Forest. Darkened squares indicate 10 m x 10 m vegetation subplots.

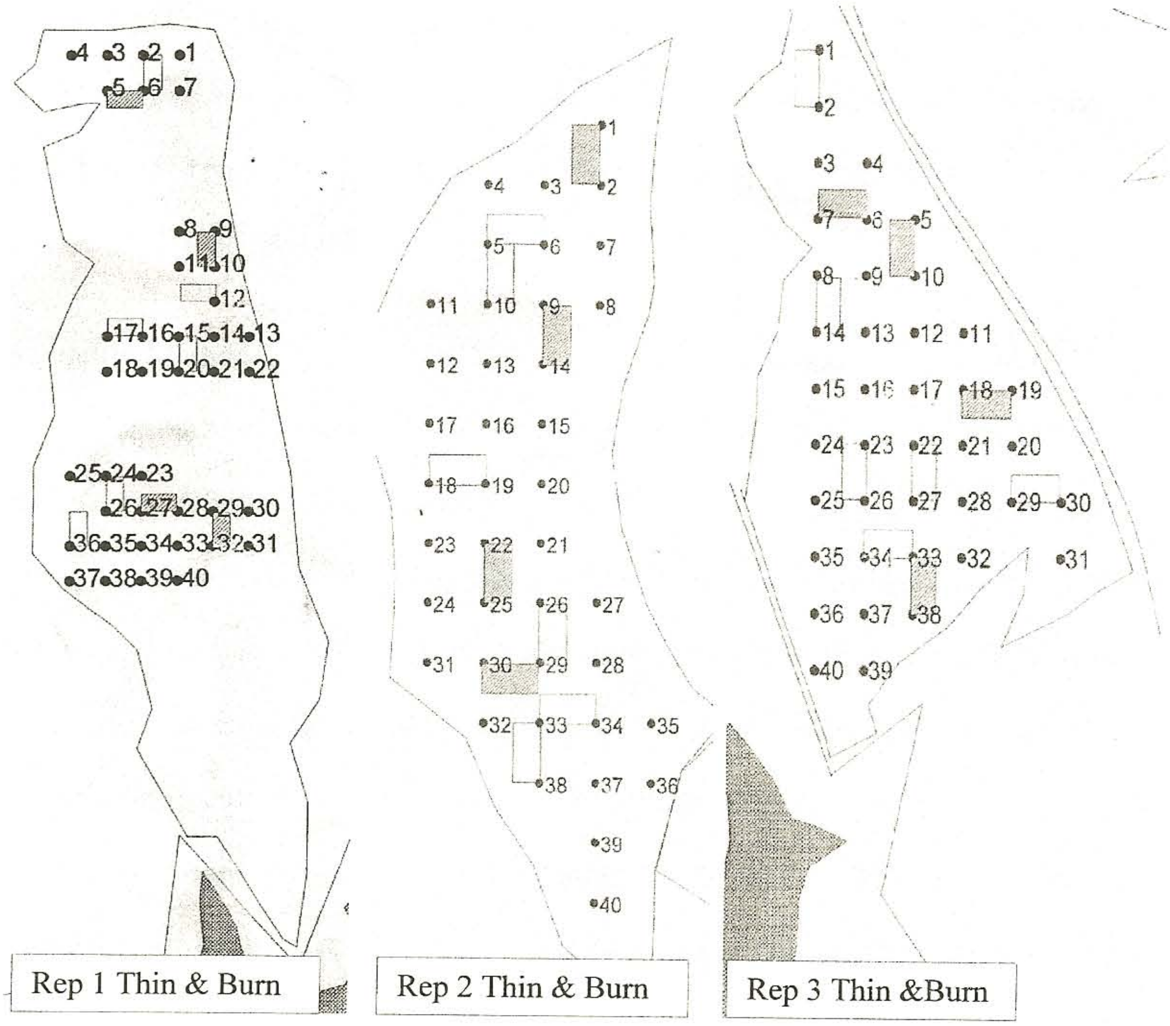

Figure 2e. Replicated thin and burn plots located in the Clemson University Experimental Forest. Darkened squares indicate 10 m x 10 m vegetation subplots.

The initial plot design and establishment, including plot locations and plot sizes, were completed by USDA Forest Service Researchers. The Clemson Experimental Forest is one of 13 sites participating in the National Fire and Fire Surrogates Study funded by the USDA/USDI Joint Fire Science Program.

Sampling Methods

The burn only plots were burned during April 2001. Thinning in both thin only and thin and burn plots also was done during 2001 (Table 1). Burning in thin and burn occurred in March 2002. Sampling was conducted every two months for one year beginning in January 2002 (Table 2). Pitfall traps were active for approximately 48 hr during each sampling period. After 48 hr, samples were placed individually into 120-ml collection vials and returned to the Cherry Farm Entomology Laboratory.

Pitfall traps were constructed using a 473-ml (16 oz) Dart© plastic drink cup placed into the ground with a 266-ml (9 oz) Solo© plastic drink cup, placed into the 473-ml cup (Fig 4). The large, 473-ml cups remained in the ground during the entire study, while the 266-ml cups were only used during the six trapping periods. To kill and preserve organisms that fell into the traps during the trapping period approximately 80 ml of 70% EtOH was placed into the 266-ml cup.

After samples were returned to the laboratory, they were sorted and all spiders were placed into separate containers labeled with date, treatment, and plot. Spiders were sorted to family and identified using published taxonomic keys (Dondale & Redner 1990; Kaston 1972; Roth 1993). Voucher specimens were deposited in the Clemson University Arthropod Collection, Clemson, SC.

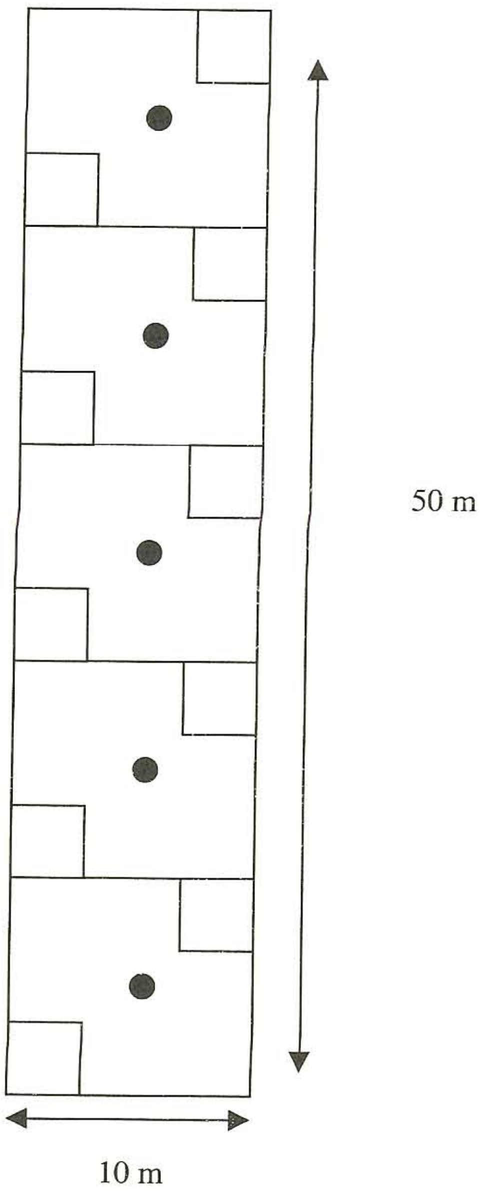

Figure 3. Example of a 10 m x 50 m vegetation subplot. Pitfall traps (black circles) were placed within the center of the five subplots.

Table 1. Thin and burn dates for replicated plots.

Rep 1 Burn, 10 April 2001
Rep 2 Burn, 12 April 2001
Rep 3 Burn, 11 April 2001
Rep 1 Thin, 8 March – 4 April 2001
Rep 2 Thin, 18 December – 18 January 2001
Rep 3 Thin, 5 February – 21 February 2001
Rep 1 Thin and Burn, Thinned 3 January – 18 January 2001; Burned early March 2002
Rep 2 Thin and Burn, Thinned 25 January – 31 January 2001; Burned 25 March 2002
Rep 3 Thin and Burn, Thinned 26 February – 7 March 2001; Burned April 2002

Table 2. Sampling dates using pitfall traps at the Clemson Experimental Forest for 2002.

Sampling Period 1: (Pre-burn Dates)
13 January – 15 January 2002
2 February – 4 February 2002

Sampling Period 2: (Pre-burn Dates)
13 March – 15 March 2002
3 April – 5 April 2002

Sampling Period 3: (Post-burn Dates)
4 June – 6 June 2002
5 June – 7 June 2002

Sampling Period 4: (Post-burn Dates)
5 August – 7 August 2002
6 August – 8 August 2002

Sampling Period 5: (Post-burn Dates)
1 October – 3 October 2002
2 October – 4 October 2002

Sampling Period 6: (Post-burn Dates)
2 December – 4 December 2002
13 December – 15 December 2002

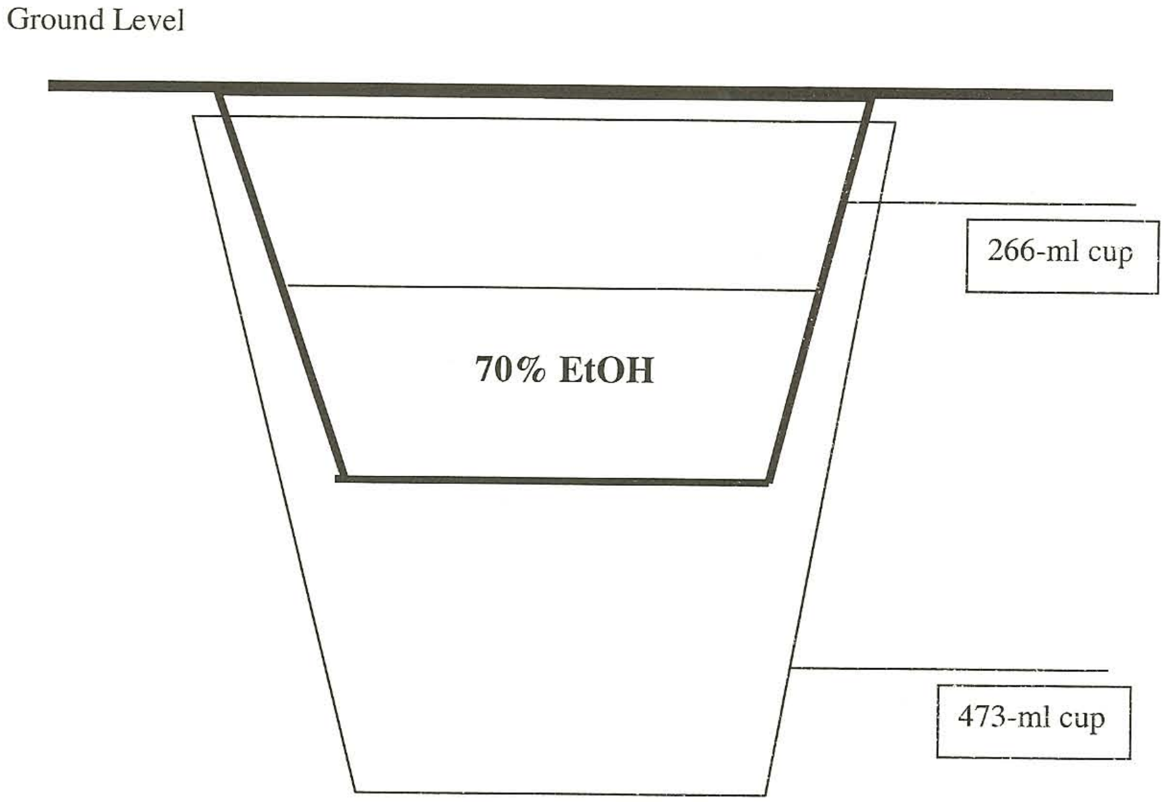

Figure 4. Pitfall trap design used in the 10 m x 50 m vegetation subplots to collect spiders for a 48-hr time period in the Clemson Experimental Forest.

Statistical Analysis

To determine if spider populations were affected by prescribed burning and mechanical thinning, the effects of time and treatment on spider families, genera, and species numbers were analyzed using a General Linear Model (• =0.05) (SAS 1999). Also, to exclude seasonality effects on spider families, time versus treatment interactions were analyzed. A comparison was made between the mean numbers of spiders recorded in the three different treatments and control plots, and comparisons were made among treatments. Also, pre-burn samples were compared to post-burn samples in the thin and burn plots to determine if burning had an effect on spider populations after the burn in March 2002. Pre-burn sampling dates were January/February, and post-burn sampling dates were March/April, June, August, October, and December. Statistical LSmeans were written as means in the thesis. Spider families were analzyed at the plot level, and due tolow numbers, spider genera totals were combined and analzyed at the replication level. All statistical analyses were performed using SAS (SAS 1999).

The spider families that were analyzed were Agelenidae, Araneidae, Atypidae, Clubionidae, Gnaphosidae, Hahniidae, Linyphiidae, Lycosidae, Oxyopidae, Pisauridae, Salticidae, Theridiidae, and Thomisidae.

Genera that were analyzed were *Agelenopsis* (Agelenidae), *Cicurina* (Agelenidae), *Coras* (Agelenidae), *Cybaeus* (Agelenidae), *Wadotes* (Agelenidae), *Gladicosa* (Lycosidae), *Hogna* (Lycosidae), *Pirata* (Lycosidae), *Schisocoza* (Lycosidae), and *Varacosa* (Lycosidae). One species was analyzed: *Gnaphosa fontinalis* Keyserling (Gnaphosidae).

RESULTS

A total of 1212 specimens of Araneae, in 13 families, were collected (Table 3).

Fuel Load Management Treatments on Spider Family Populations:

Of the 13 families identified, 11 had significant differences in the mean numbers of spiders per plot among the six sampling periods (Table 4). Families of spiders were grouped based on the temporal patterns each exhibited. The three groups that were established were 1) species where the mean numbers decreased over the six sampling periods, 2) species where numbers were lowest in winter and highest in summer months, and 3) species that exhibited no obvious patterns.

Two families, Agelenidae and Linyphiidae, exhibited a decrease in mean numbers from January/February to October sampling periods, and then an increase after October. In both families, mean numbers per plot were significantly higher (df=5, p<0.05) during January/February than during any of the remaining periods (Figure 5, 6). Theridiidae had significantly higher mean numbers per plot in January/February, then mean numbers decreased to zero during March/April and then increased (Figure 7).

Four spider families, Gnaphosidae, Oxyopidae, Pisauridae, and Salticidae, were found in greatest abundance during the summer sampling periods. In the Oxyopidae and Pisauridae, the mean numbers per plot were lowest during January/February and then increased until August. After August, mean numbers decreased (Figure 8, 9). In the

Table 3. Total numbers and total numbers collected in each treatment, in 2002, of the thirteen families of spiders (Araneae) collected during the six sampling periods in the Clemson Experimental Forest.

Family	Total	Control	Burn	Thin	Thin and Burn
Agelenidae	136	42	54	19	30
Araneidae	5	1	1	1	2
Atypidae	3	1	1	0	1
Clubionidae	44	17	9	14	4
Gnaphosidae	212	61	59	68	24
Hahniidae	34	6	3	22	3
Linyphiidae	283	66	46	108	63
Lycosidae	321	33	64	166	58
Oxyopidae	16	2	2	10	2
Pisauridae	73	22	4	34	13
Salticidae	33	6	11	8	8
Theridiidae	6	1	1	3	1
Thomisidae	46	20	10	14	2

Table 4. Families that demonstrated a significant difference between sampling dates among the six sampling periods in the Clemson Experimental Forest, during 2002.

	df	*F*	*p*-value
Agelenidae	*df*=5	*F*=4.95	*p*=0.0005
Atypidae	*df*=5	*F*=1.00	*p*=0.4235
Clubionidae	*df*=5	*F*=6.27	*p*<0.0001
Gnaphosidae	*df*=5	*F*=13.73	*p*<0.0001
Hahniidae	*df*=5	*F*=6.25	*p*<0.0001
Linyphiidae	*df*=5	*F*=34.50	*p*<0.0001
Oxyopidae	*df*=5	*F*=2.78	*p*=0.0179
Pisauridae	*df*=5	*F*=5.65	*p*<0.0001
Salticidae	*df*=5	*F*=6.80	*p*<0.0001
Theridiidae	*df*=5	*F*=2.48	*p*=0.0311
Thomisidae	*df*=5	*F*=9.72	*p*<0.0001

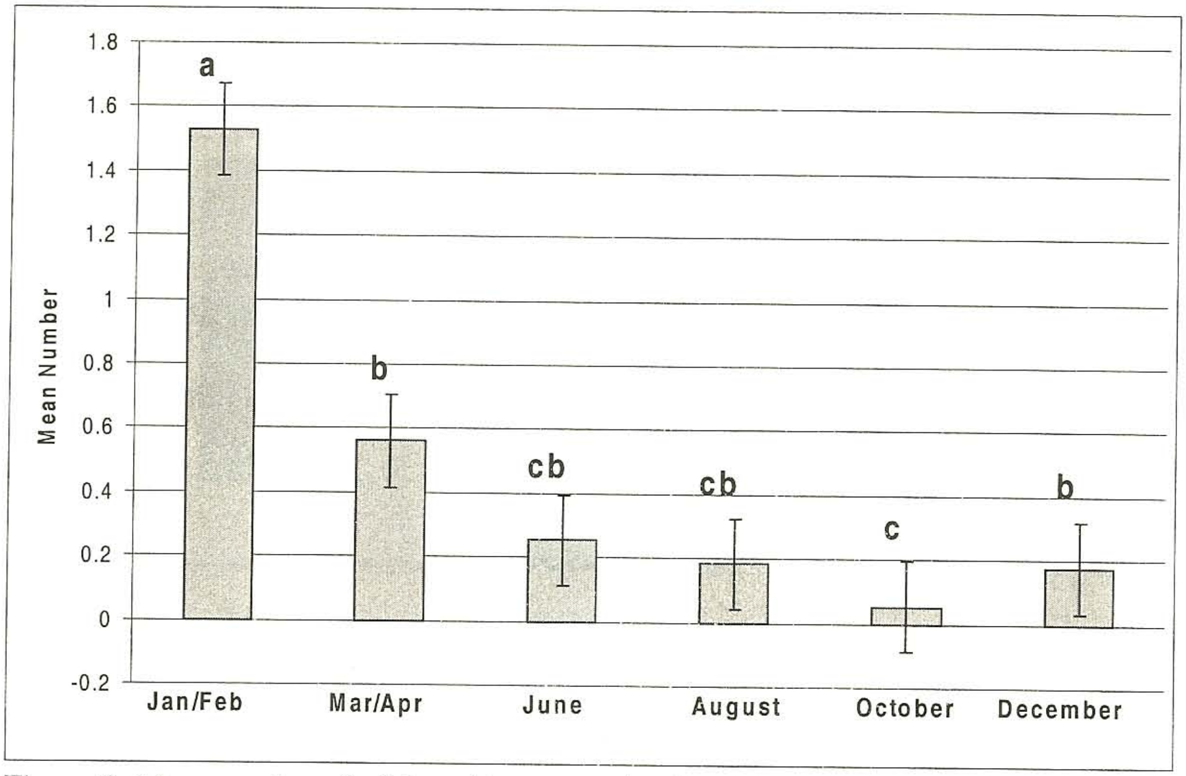

Figure 5. Mean number of adult and immature Agelenidae (O: Araneae) collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among sampling dates (p=0.05).

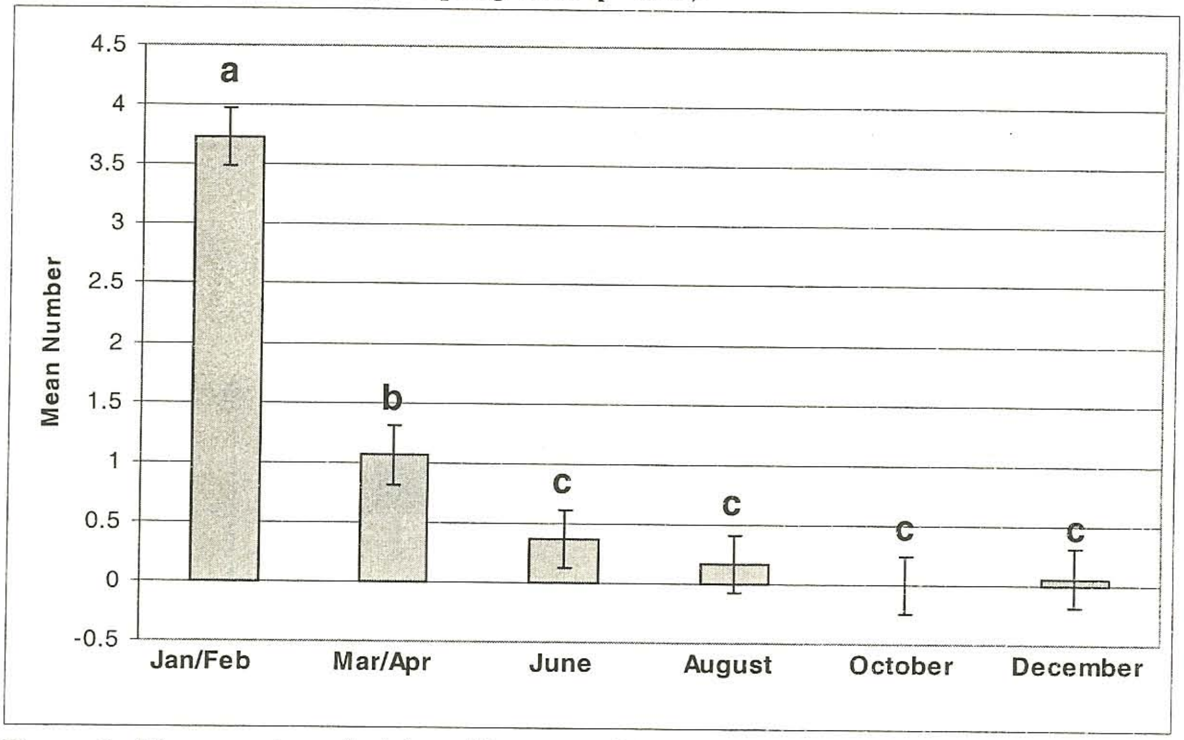

Figure 6. Mean number of adult and immature Linyphiidae (O: Araneae) collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among sampling dates (p=0.05).

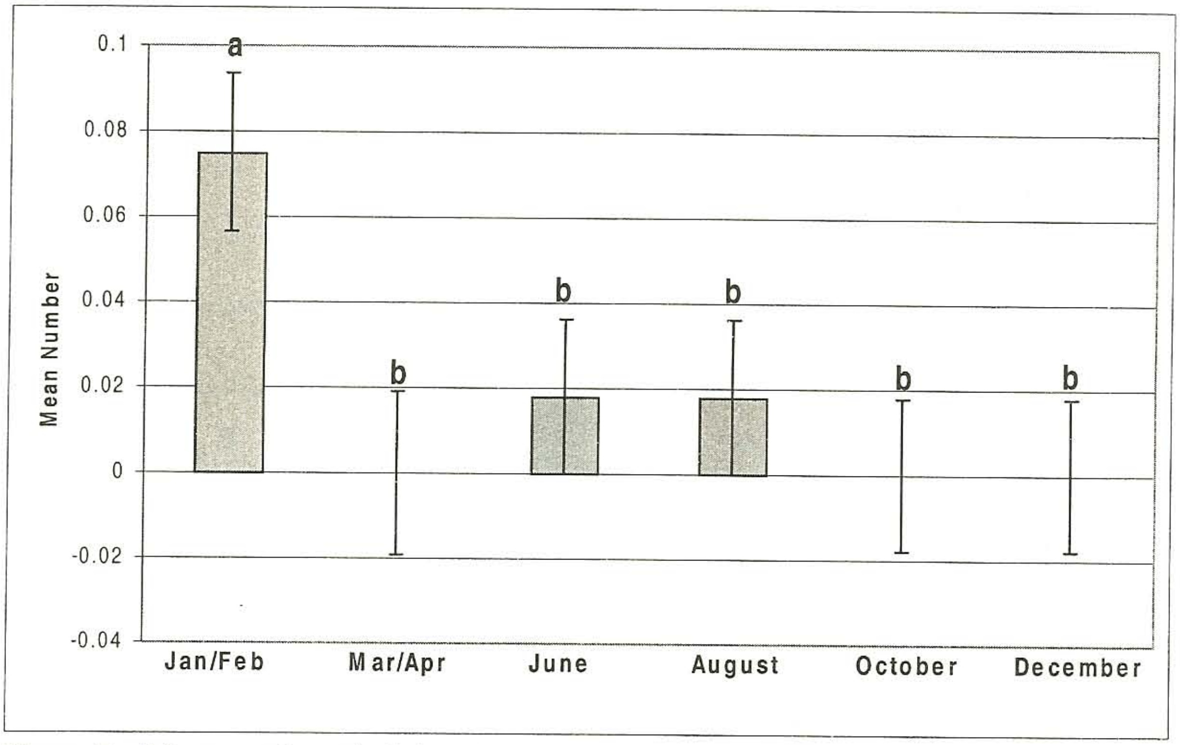

Figure 7. Mean number of adult and immature Theridiidae (O: Araneae) collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among sampling dates (p=0.05).

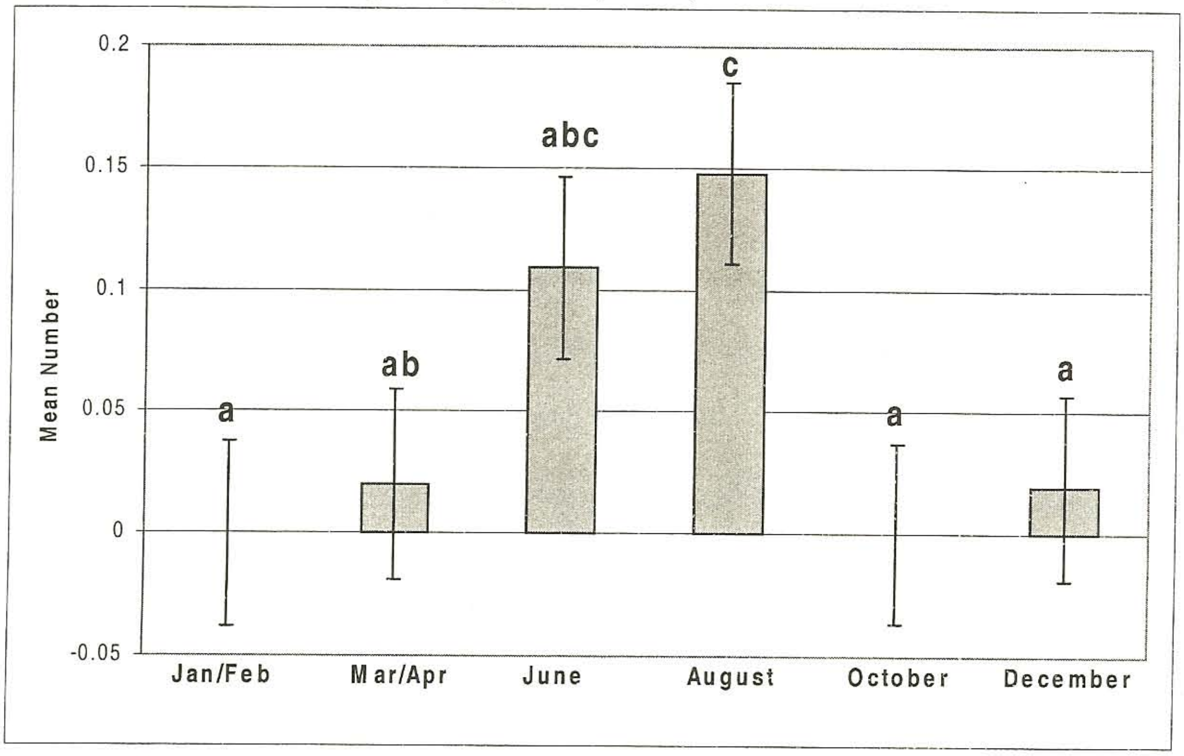

Figure 8. Mean number of adult and immature Oxyopidae (O: Araneae) collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among sampling dates (p=0.05).

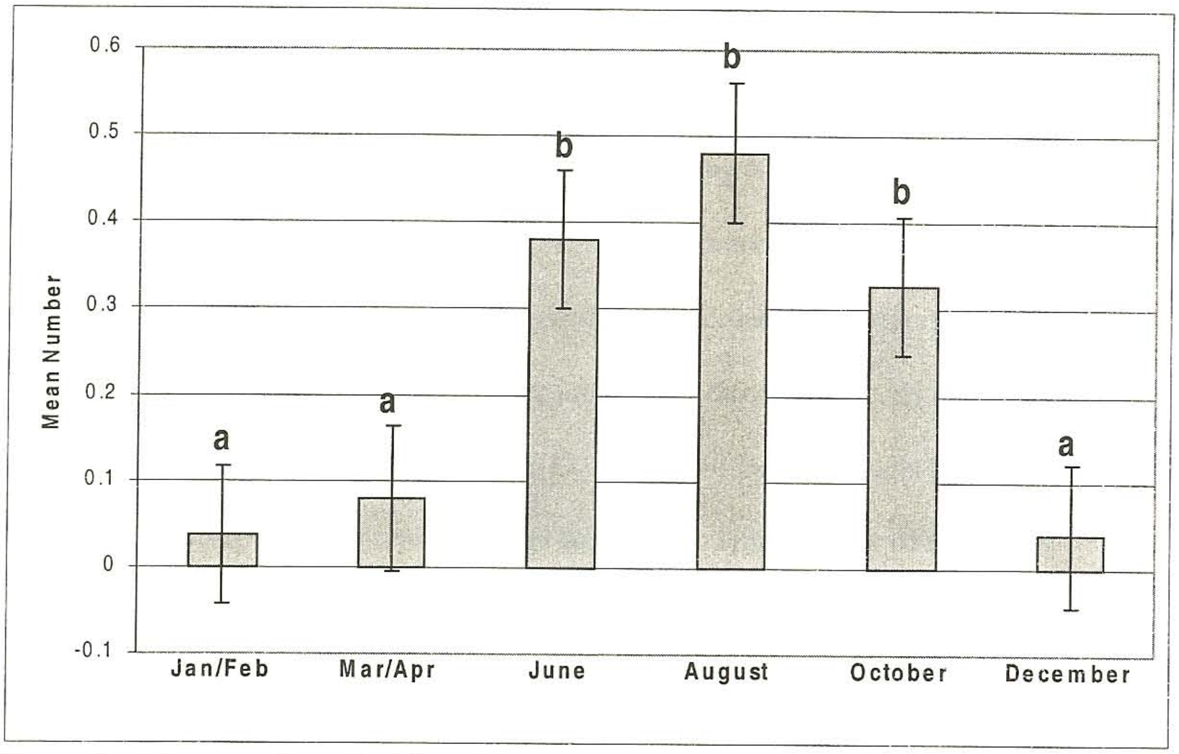

Figure 9. Mean number of adult and immature Pisauridae (O: Araneae) collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among sampling dates (p=0.05).

Gnaphosidae mean numbers were low during January/February and increased until June, and then decreased (Figure 10). Salticidae also had no spiders during January/February, then increased until March/April. They decreased during June, and then had a second increase in the number of salticids from June through October (Figure 11).

The four families, Atypidae, Clubionidae, Hahniidae, and Thomisidae, did not exhibit any distinct seasonal patterns in mean numbers during this study. Atypidae were collected only during March/April (Figure 12). Clubionidae were collected from March/April through October, but were not collected in either January/February or December (Figure 13). Hahniidae exhibited two peaks, one during March/April and another in October (Figure 14). During January/February, June, and December, the mean number of hahniids per plot was very low. In August, no hahniids were collected. Thomisidae were significantly more abundant (df=5, p<0.05) during March/April than the other sampling periods (Figure 15).

Neither the Araneidae (df=5, F=2.11, p=0.0644) (Figure 16) nor Lycosidae (df=5, F=1.56, p=0.1717) (Figure 17) exhibited any significant differences in the mean numbers of spiders per plot during the six sampling periods.

Overall, mean spider numbers per plot varied during the six sampling periods. The three web-building families, Agelenidae, Linyphiidae, and Theridiidae, were most abundant during January/February. Ground-dwelling spiders either exhibited a summer population peak (Gnaphosidae, Oxyopidae, Pisauridae, and Salticidae), or varied in numbers (Atypidae, Clubionidae, Hahniidae, and Thomisidae) during the six sampling periods.

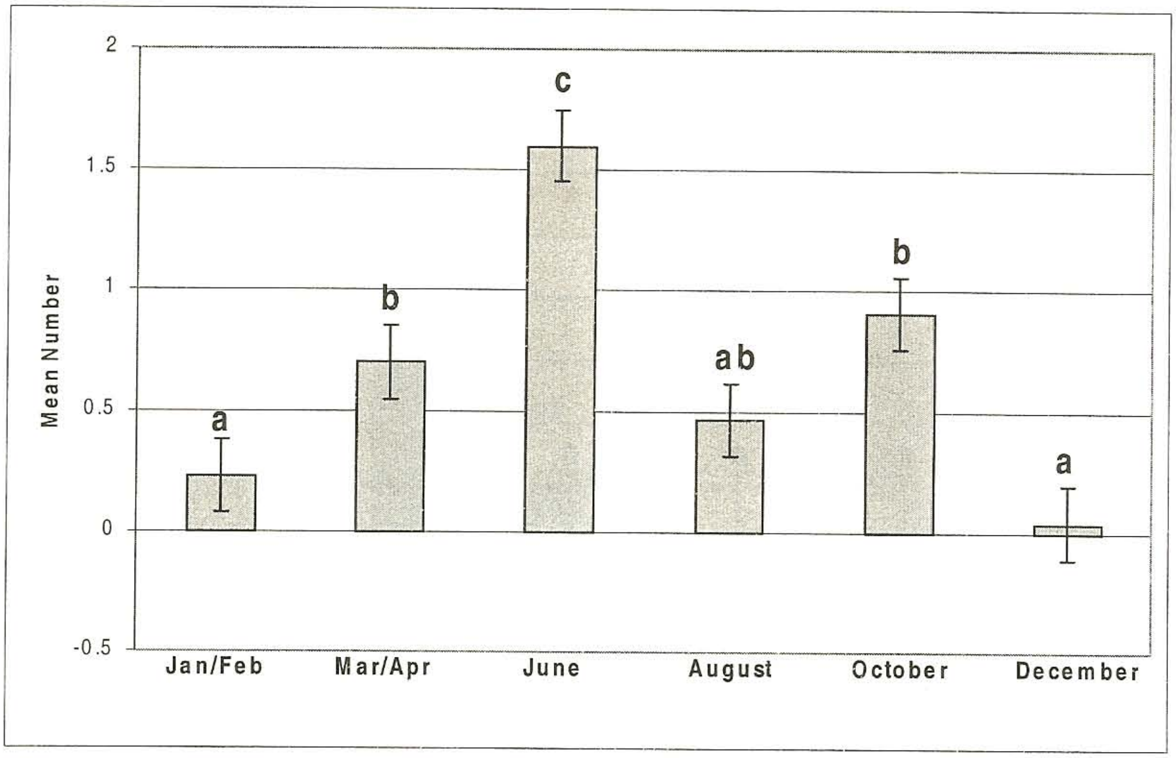

Figure 10. Mean number of adult and immature Gnaphosidae (O: Araneae) collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among sampling dates (p=0.05).

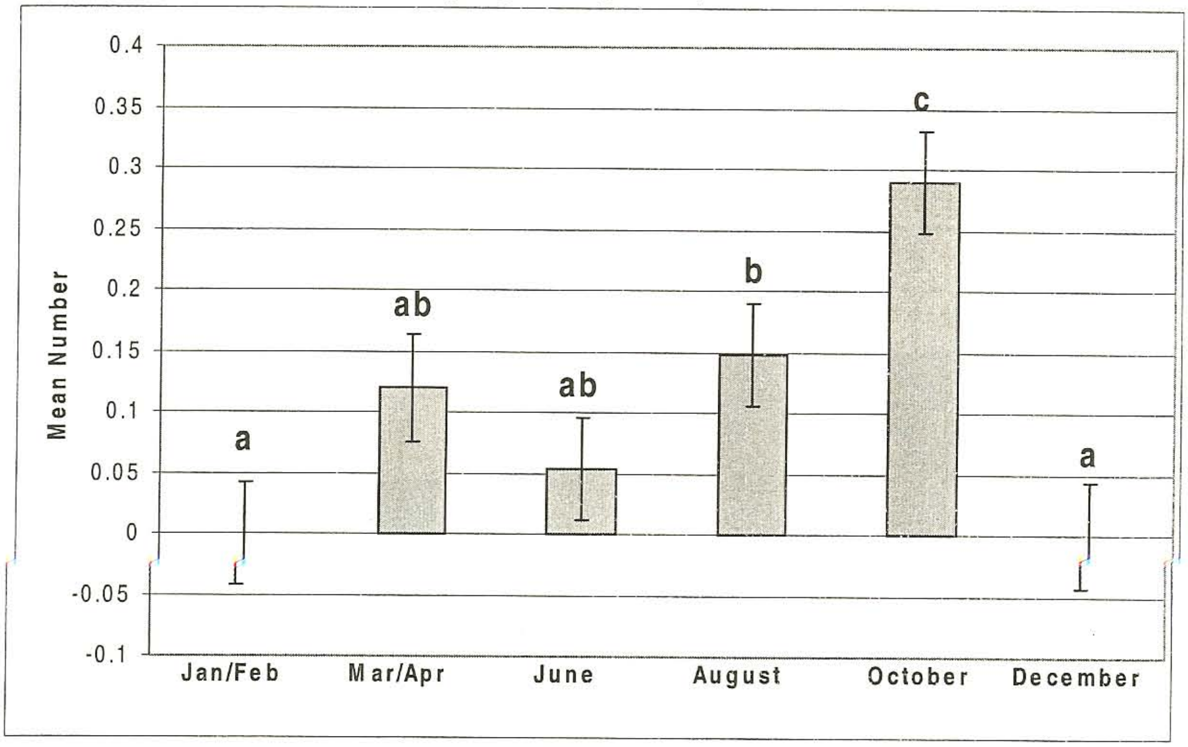

Figure 11. Mean number of adult and immature Salticidae (O: Araneae) collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among sampling dates (p=0.05).

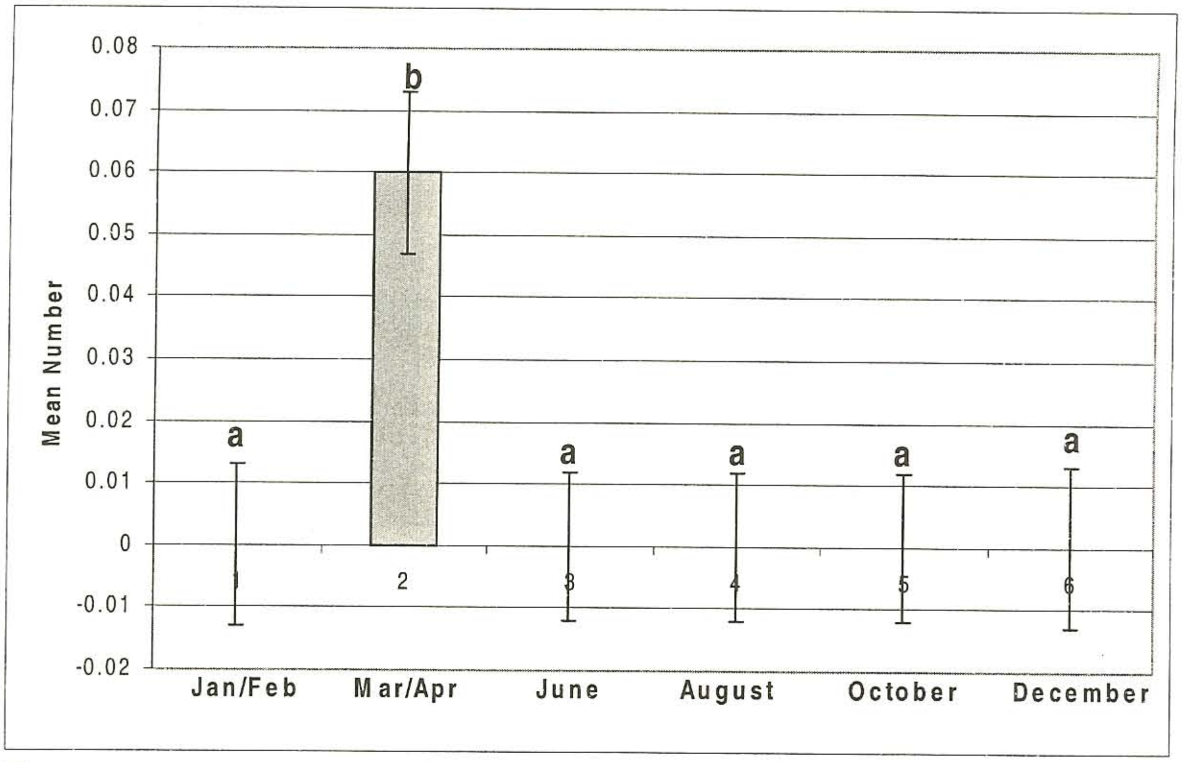

Figure 12. Mean number of adult and immature Atypidae (O: Araneae) collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among sampling dates (p=0.05).

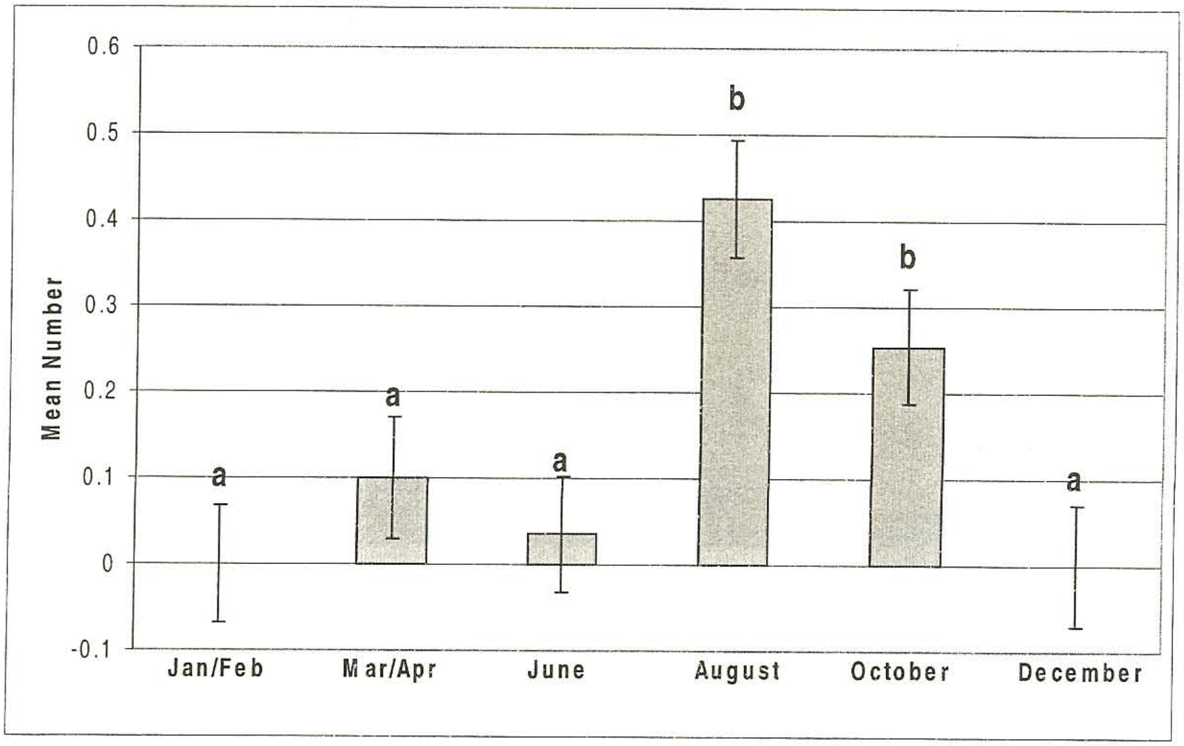

Figure 13. Mean number of adult and immature Clubionidae (O: Araneae) collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among sampling dates (p=0.05).

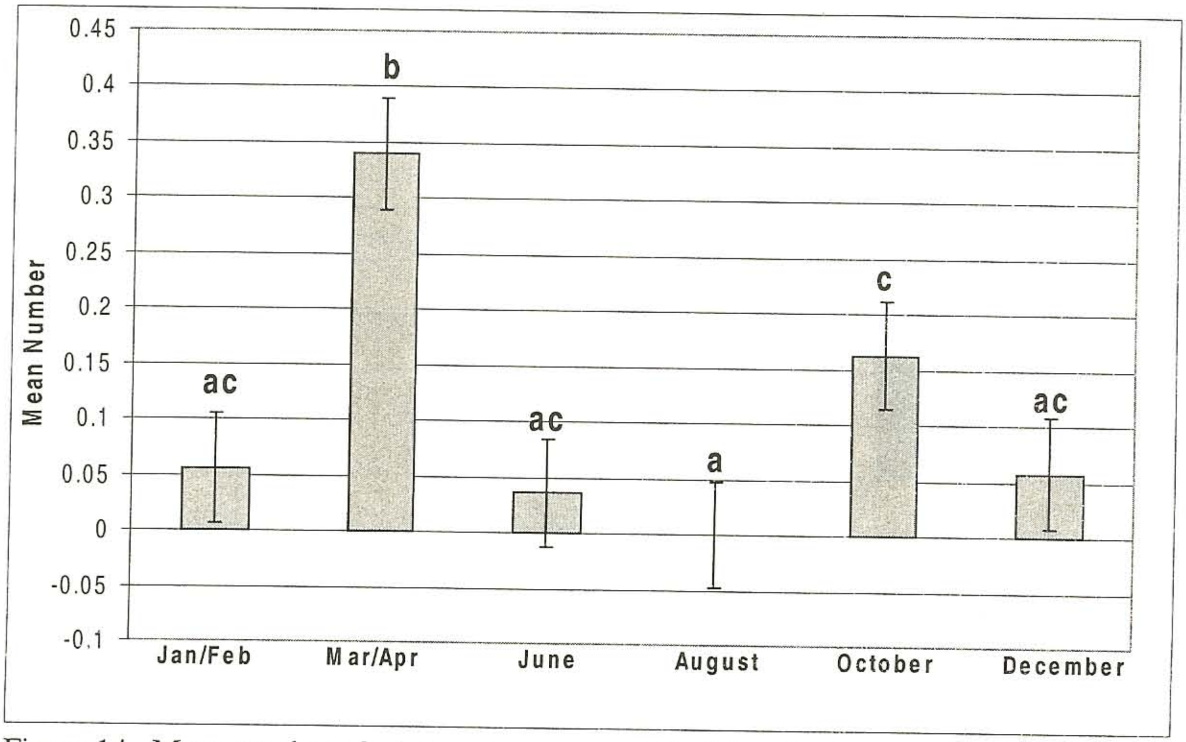

Figure 14. Mean number of adult and immature Hahniidae (O: Araneae) collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among sampling dates (p=0.05).

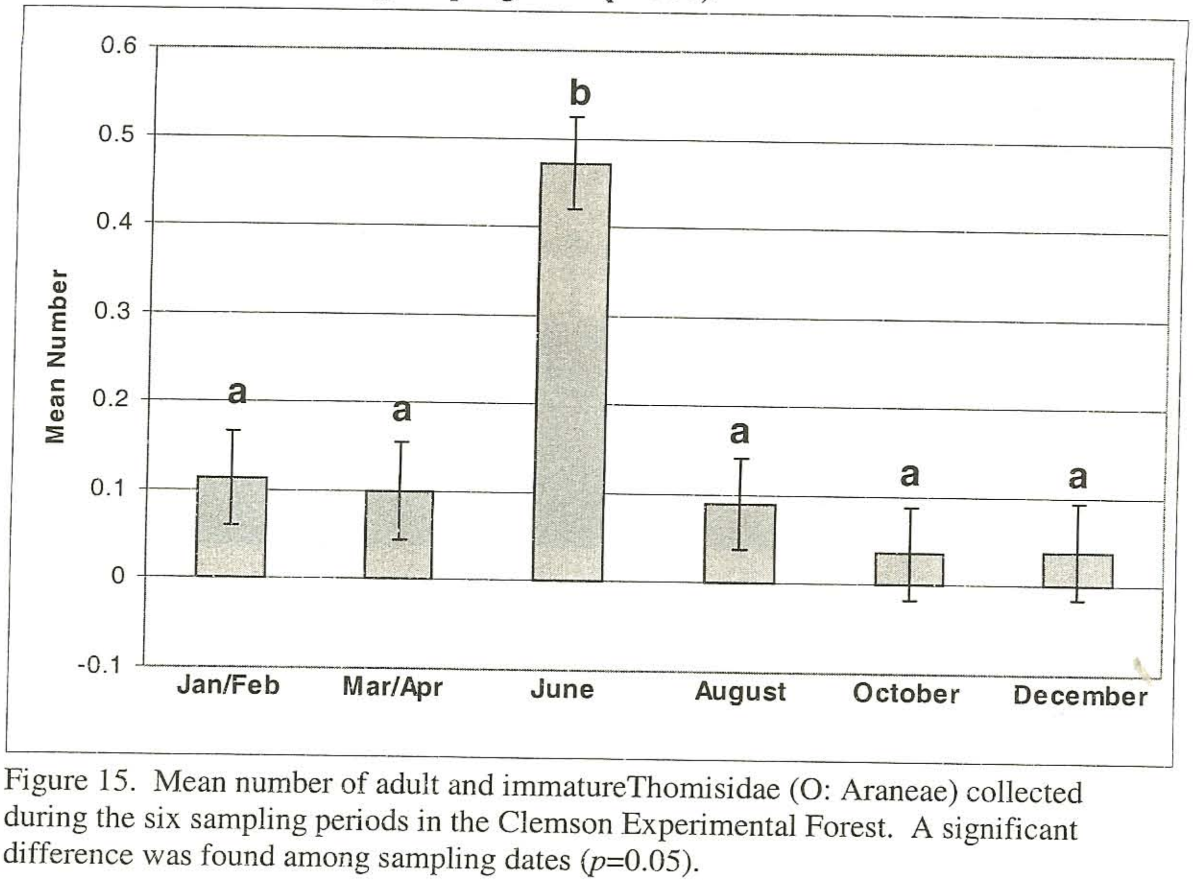

Figure 15. Mean number of adult and immatureThomisidae (O: Araneae) collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among sampling dates (p=0.05).

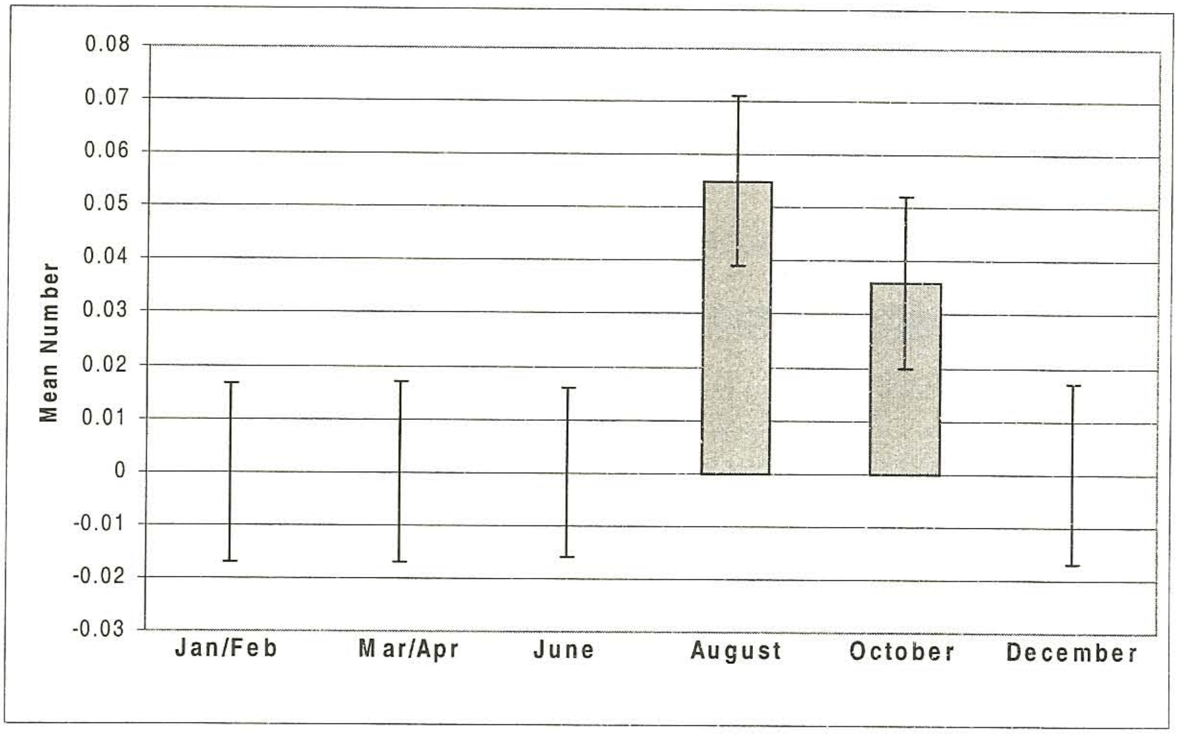

Figure 16. Mean number of adult and immature Araneidae (O: Araneae) collected during the six sampling periods in the Clemson Experimental Forest. Significant differences were not found among the sampling dates (p=0.05).

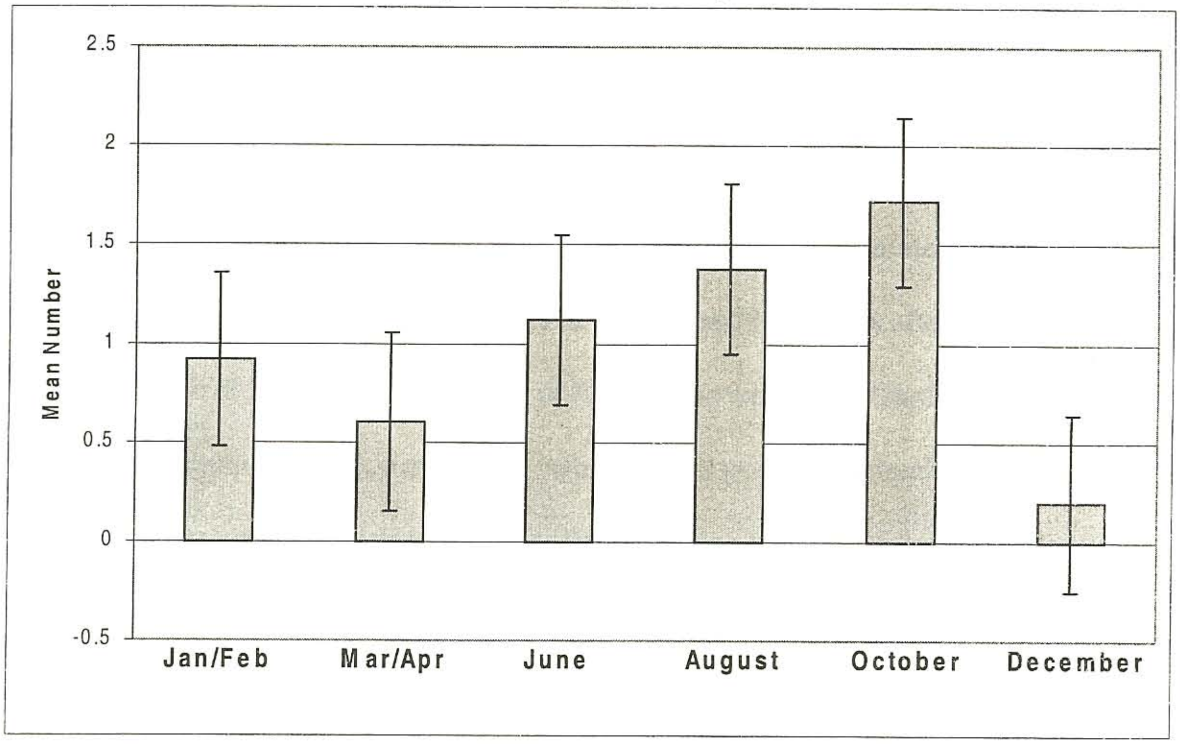

Figure 17. Mean number of adult and immature Lycosidae (O: Araneae) collected during the six sampling periods in the Clemson Experimental Forest. Significant differences were not found among the sampling dates (p=0.05).

Effects of Treatment on Spider Family Populations:

Of the 13 families collected, 5 were significantly affected by fuel load management treatments. Families that exhibited an overall significant effect were Agelenidae (*df*=3, *F*=5.96, *p*=0.0006), Gnaphosidae (*df*=3, *F*=4.15, *p*=0.0066), Hahniidae (*df*=3, *F*=3.35, *p*=0.0194), Pisauridae (*df*=3, *F*=3.17, *p*=0.0245), and Thomisidae (*df*=3, *F*=6.09, *p*=0.0005).

Agelenidae

The mean numbers of Agelenidae were not significantly different (*df*=3, *p*=0.1990) in the burn only compared to the control plots. However, mean numbers were significantly lower in the thin only plots (*df*=3, *p*=<0.0001), and thin and burn plots (*df*=3, *p*=0.0199), compared to the control plots. Agelenidae numbers were significantly lower in the thin only compared to the burn only plots (*df*=3, *p*=0.0084). No significant difference was found between the burn only and thin and burn plots (*df*=3, *p*=0.2897), or the thin only and thin and burn plots (*df*=3, *p*=0.1336) (Figure 18).

To determine the immediate effects of burning, pre-burn mean numbers per plot were compared to post-burn mean numbers in the thin and burn plots after they were burned in March of 2002. Mean numbers of Agelenidae were significantly lower in the first post-burn sample (*df*=23, *p*<0.0001). After the first post-burn sample, mean numbers remained constant during the other five sampling periods (Figure 19). However, control mean numbers significantly decreased (*df*=23, *p*=<0.0001) after first post-burn samples were compared to pre-burn samples.

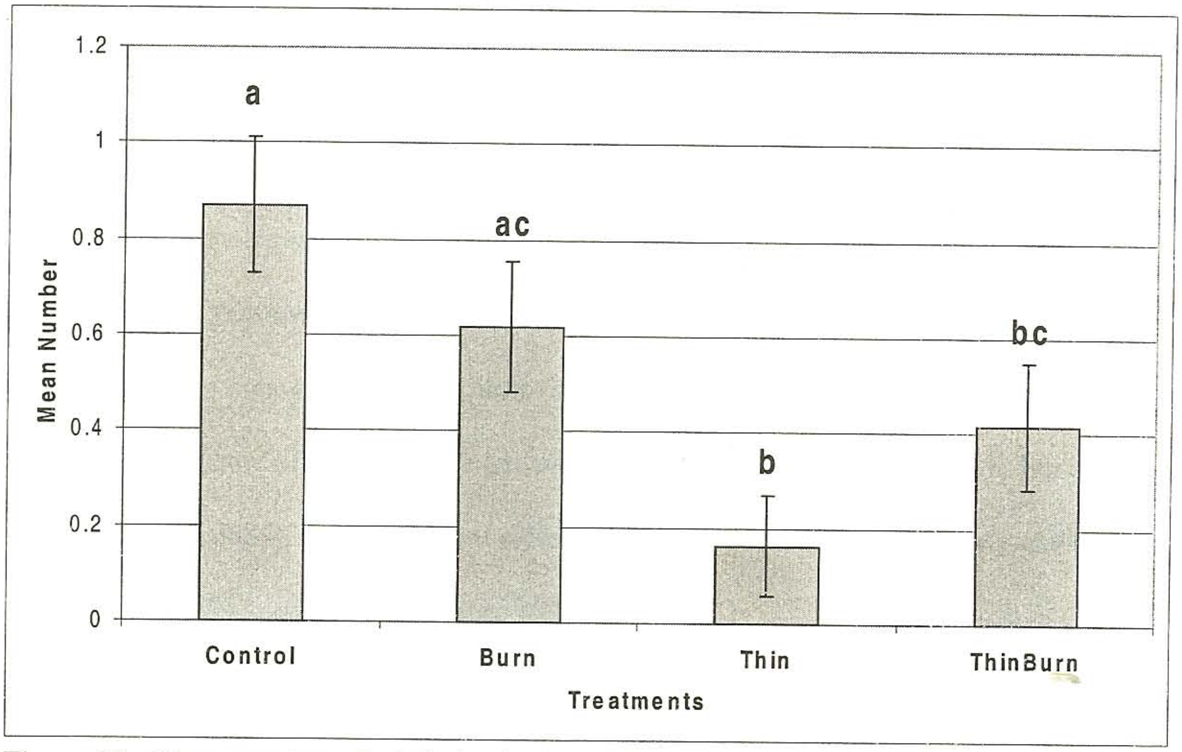

Figure 18. Mean number of adult Agelenidae (O: Araneae) collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among treatments (p=0.05).

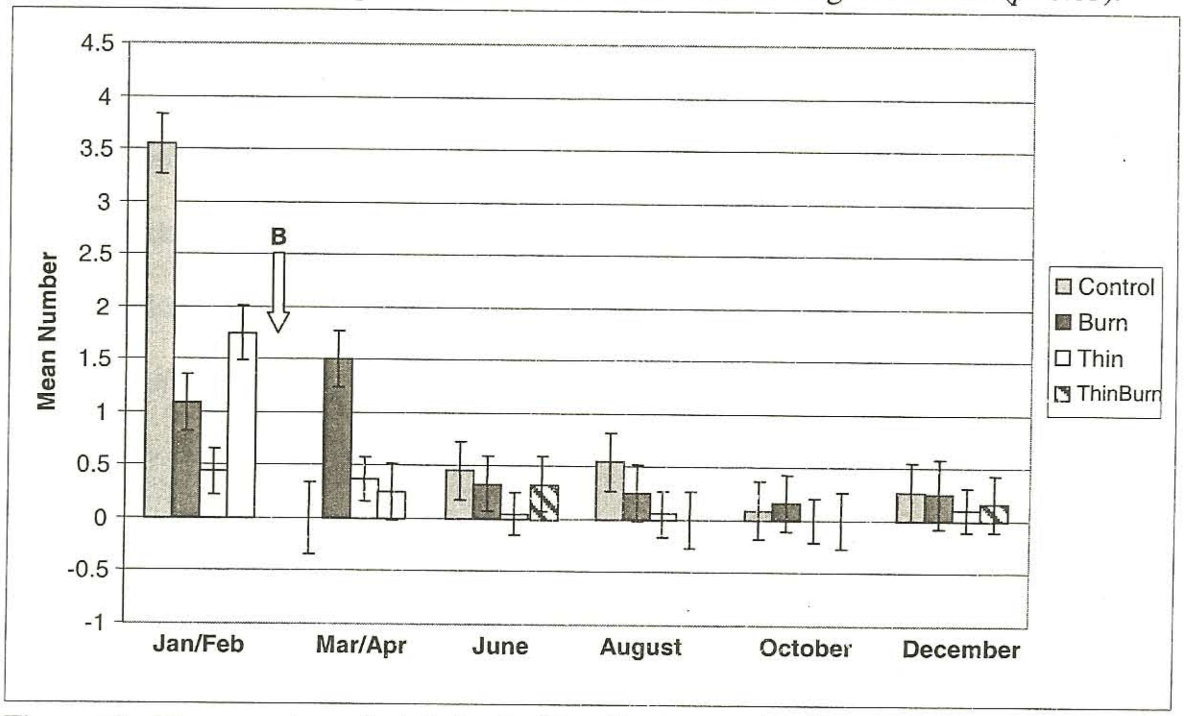

Figure 19. Mean number of adult Agelenidae (O: Araneae) collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. The B indicates when the burn occurred in the thin and burn plots in 2002.

Gnaphosidae

The mean number of Gnaphosidae were not significantly different (df=3, p=0.5794) in the burn compared to the control plots. However, mean numbers of Gnaphosidae were significantly lower in the thin only (*df*=3, *p*=0.0349) and thin and burn (*df*=3, *p*=0.5794) compared to control plots. No significant difference was found between the burn only and thin only plots (*df*=3, *p*=0.1235). There were significantly lower mean numbers of Gnaphosidae per plot in the thin and burn compared to burn only plots (*df*=3, *p*=0.0085). No significant difference was found between thin only and thin and burn plots (*df*=3, *p*=0.1587) (Figure 20).

No significant difference was found in the mean numbers of Gnaphosidae collected before and after the burning of the thin and burn plots in March of 2002 (*df*=23, *p*>0.05) (Figure 21).

Hahniidae

Hahniidae numbers were not significantly different in the burn only (*df*=3, *p*=0.4183), thin only (*df*=3, *p*=0.1116), or thin and burn plots (*df*=3, *p*=0.3907) compared to control plots. No significant difference was found between the thin only and thin and burn plots (*df*=3, *p*=0.9688). The mean number of Hahniidae were significantly higher in the thin only compared to burn only plots (*df*=3, *p*=0.0105). Hahniidae numbers were significantly lower in the thin and burn compared to thin only plots (*df*=3, *p*=0.0081) (Figure 22).

No significant difference was found in the mean numbers of Hahniidae (*df*=23, *p*>0.05) following the burn in the thin and burn plots in March 2002 (Figure 23).

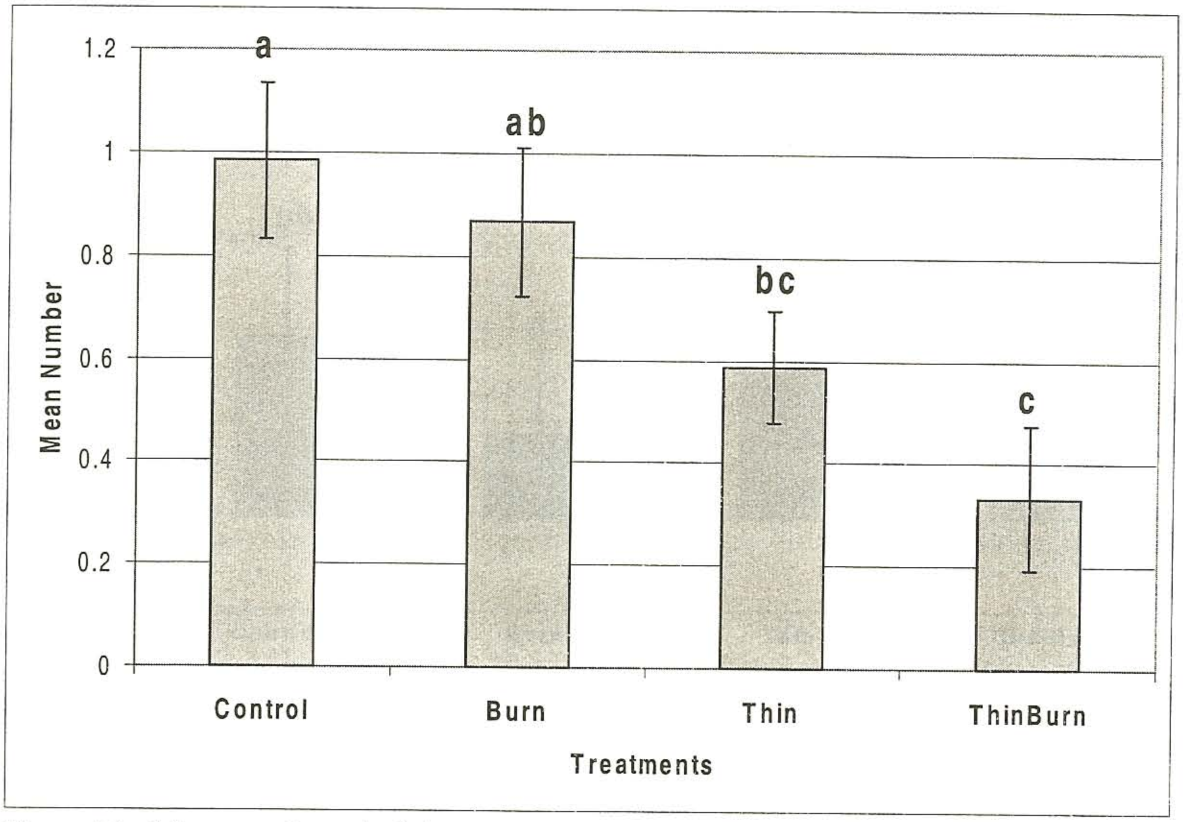

Figure 20. Mean number of adult and immature Gnaphosidae (O: Araneae) collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among treatments (p=0.05).

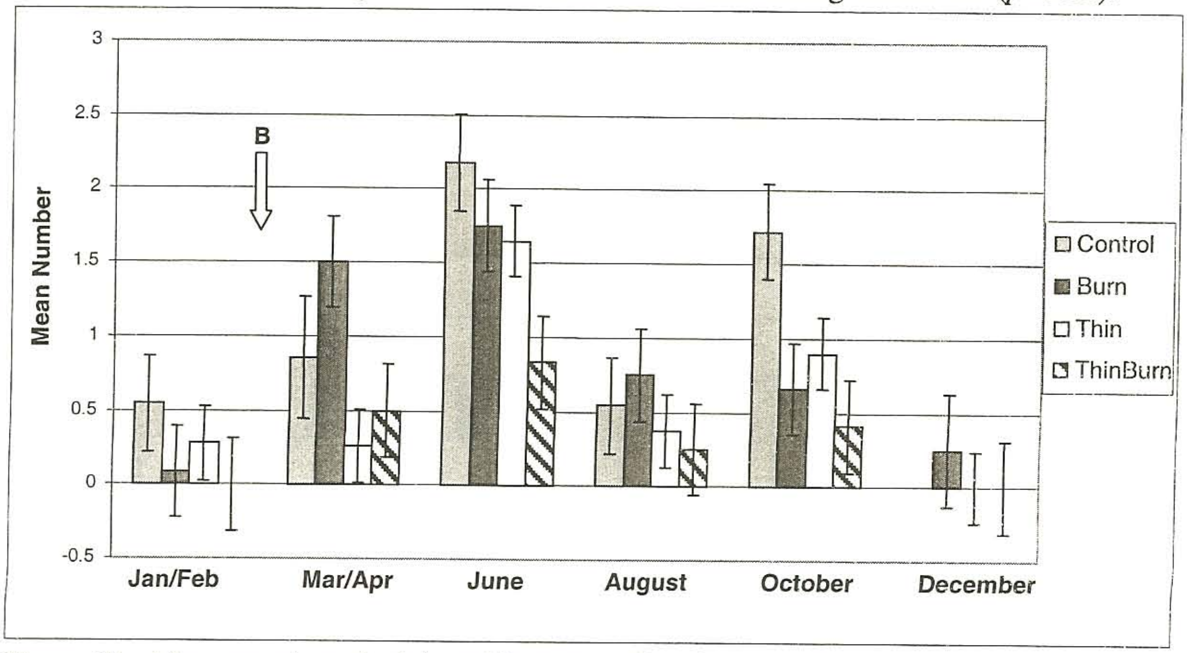

Figure 21. Mean number of adult and immature Gnaphosidae (O: Araneae) collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. The B indicates when the burn occurred in the thin and burn plots in 2002.

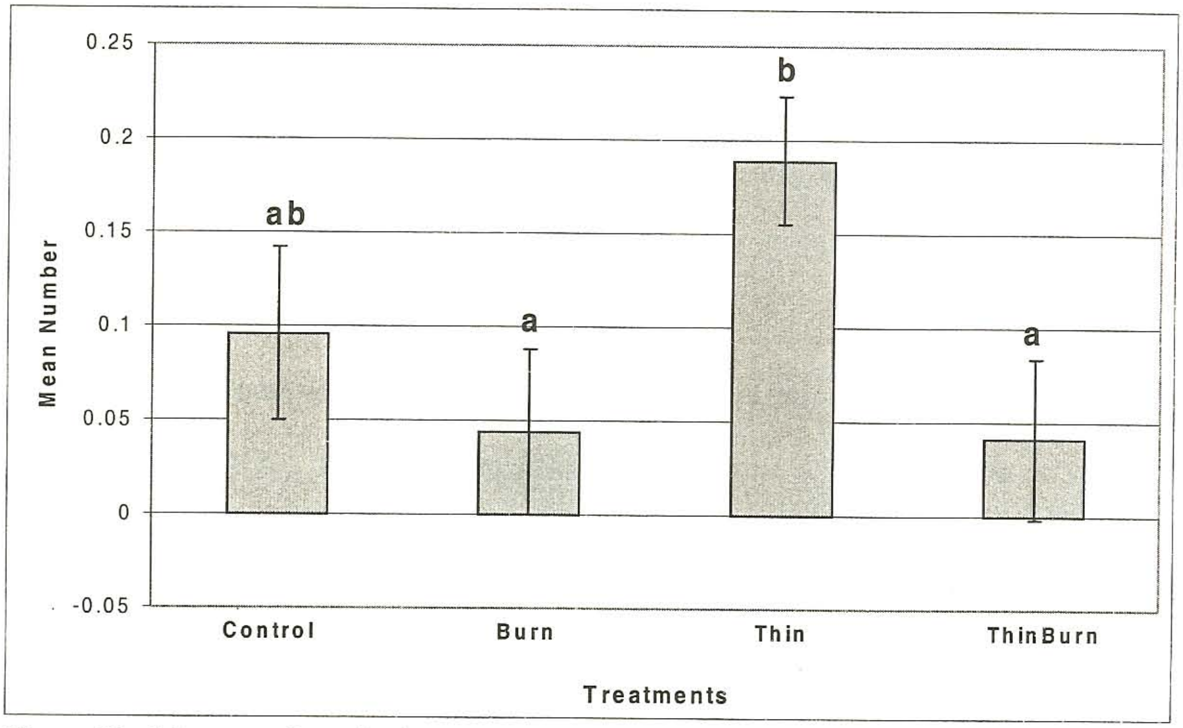

Figure 22. Mean number of adult and immature Hahniidae (O: Araneae) collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among treatments (p=0.05).

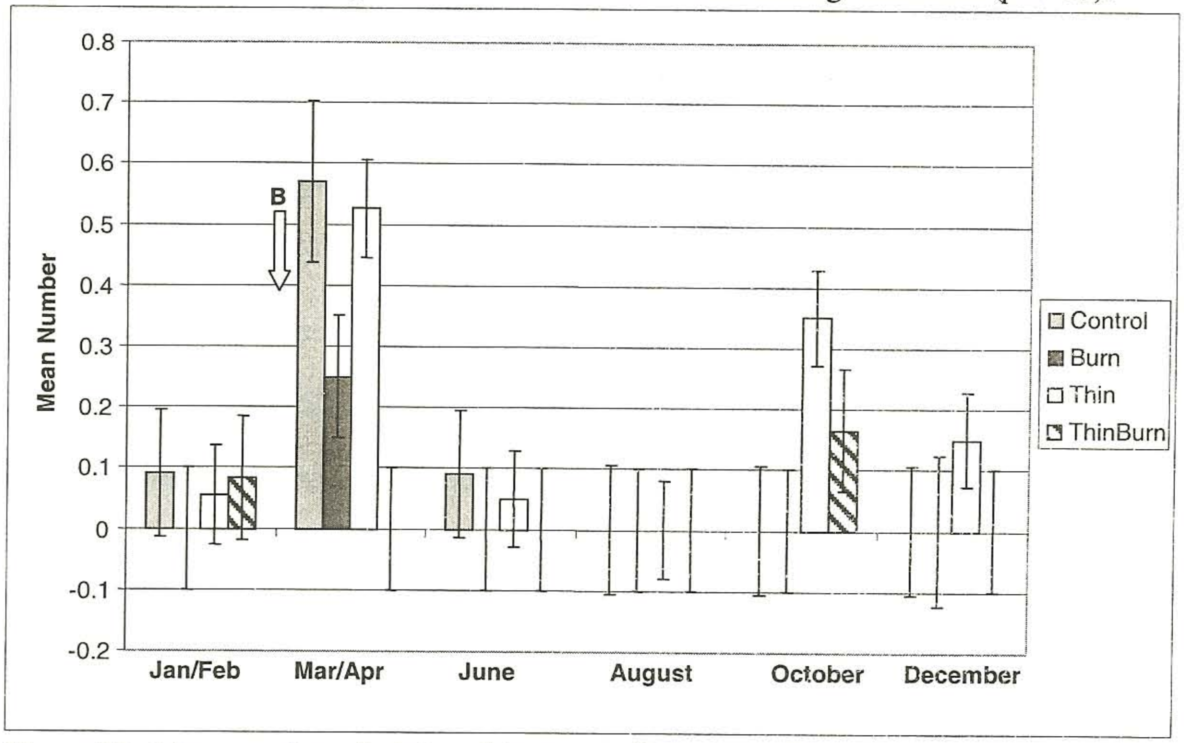

Figure 23. Mean number of adult and immature Hahniidae (O: Araneae) collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. The B indicates when the burn occurred in the thin and burn plots in 2002.

Pisauridae

The numbers of Pisauridae were significantly lower in the burn only (df=*3*, *p*=0.0064) than in the control plots, but were not significantly different either in the Thin only *(df*=3, *p*=0.5237) and thin and burn plots (*df*=3, *p*=0.1027) compared to the control plots.

Their numbers were significantly lower in the burn only compared to thin only plots (*df*=3, *p*=0.0131). No significant difference was found between the burn only and thin and burn plots (*df*=3, *p*=0.2424), or the thin only and thin and burn plots (*df*=3, *p*=0.2232) (Figure 24).

No significant difference was found in the mean number of Pisauridae (*df*=23, *p*>0.05) following the burn in the thin and burn plots in March 2002 (Figure 25).

Thomisidae

Numbers of Thomisidae were significantly lower in the burn only (*df*=3, *p*=0.0147), thin only (*df*=3, *p*=0.0018), and thin and burn plots (*df*=3, *p*=<0.0001) compared to control plots. No significant differences were found in comparisons among any of the three treatments (*df*=3, *p*>0.05) (Figure 26).

No significant difference was found in the mean numbers of Thomisidae following the burn in the thin and burn plots in March 2002 (Figure 27).

Overall Treatment Effects on Spider Family Populations:

Overall, plots that were burned in April 2001 had significantly lower mean numbers of Pisauridae (*df*=3, *p*=0.0064) (Figure 24) and Thomisidae (*df*=3, *p*=0.0147) (Figure 26) per plot during the study compared to control plots. Agelenidae (*df*=3, *p*=0.0018) (Figure 18) were collected in significantly lower numbers in thin only plots

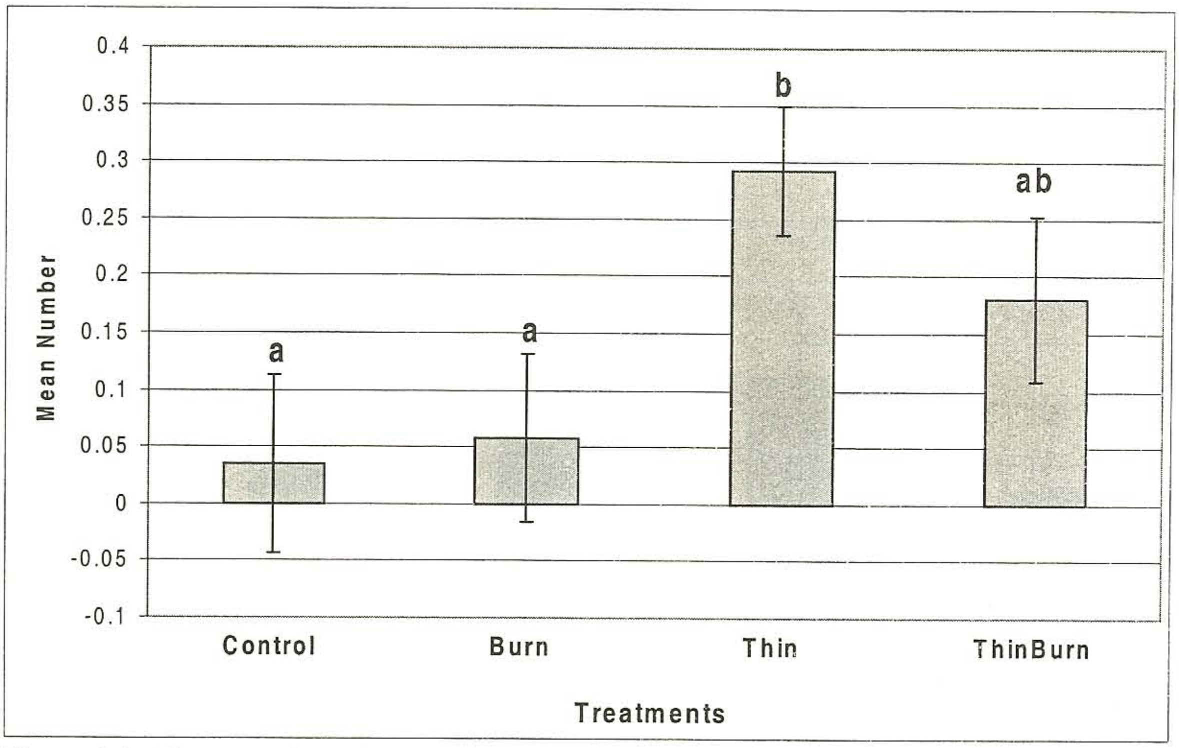

Figure 24. Mean number of adult and immature Pisauridae (O: Araneae) collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among treatments (p=0.05).

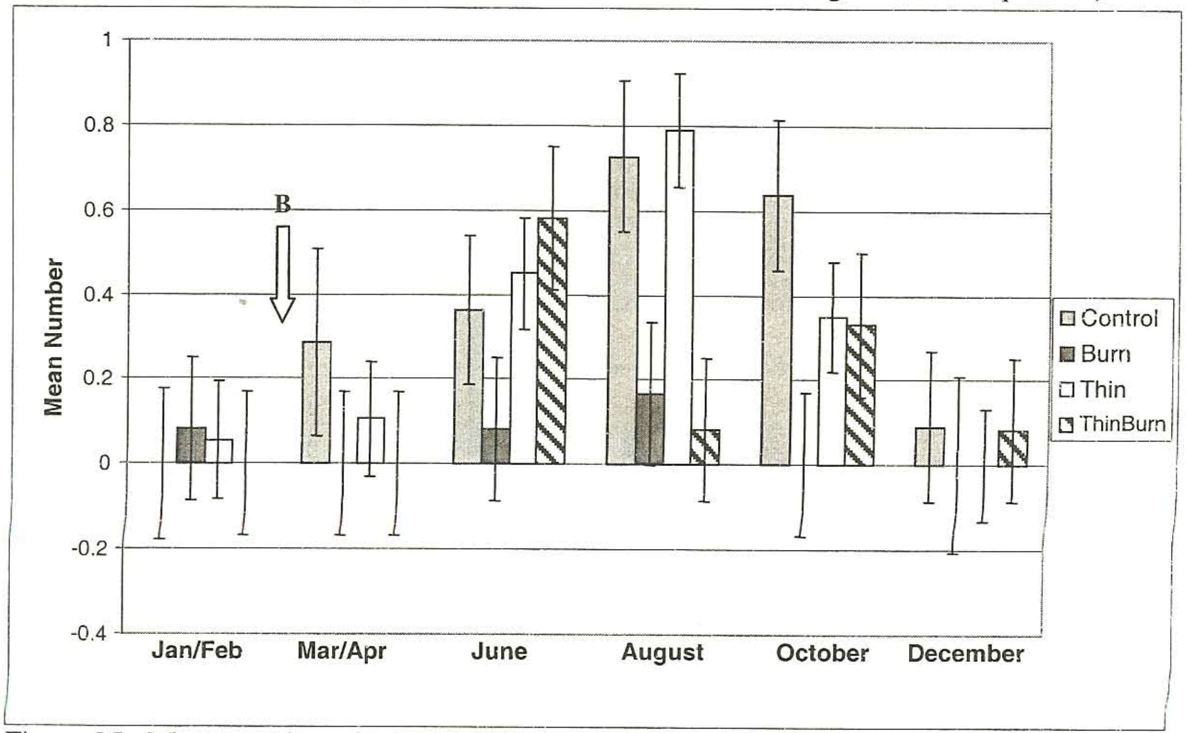

Figure 25. Mean number of adult and immature Pisauridae (O: Araneae) collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. The B indicates when the burn occurred in the thin and burn plots in 2002.

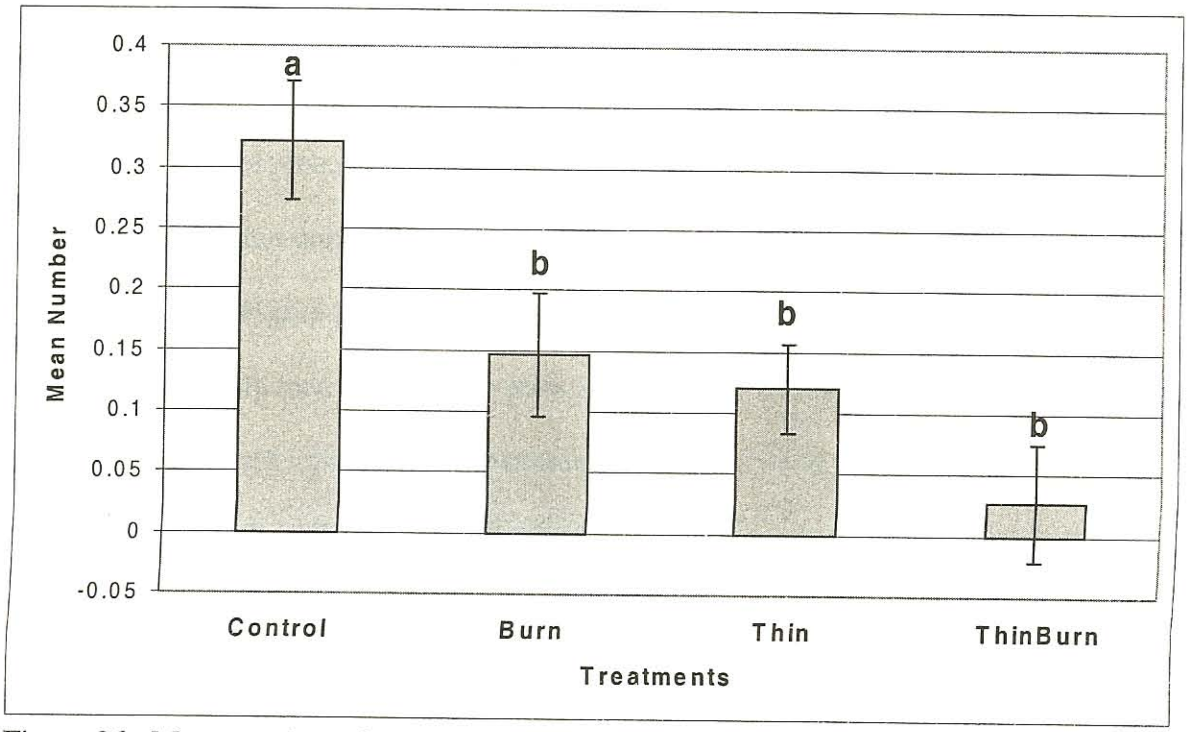

Figure 26. Mean number of adult and immature Thomisidae (O: Araneae) collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among treatments (p=0.05).

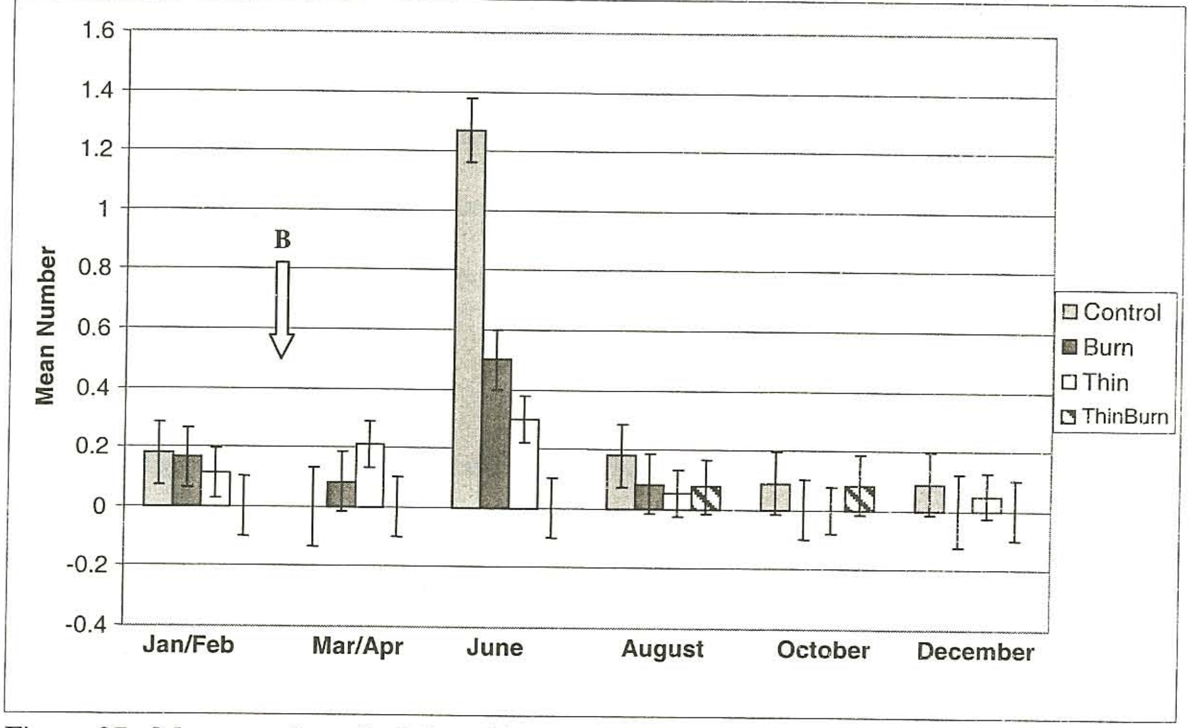

Figure 27. Mean number of adult and immature Thomisidae (O: Araneae) collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. The B indicates when the burn occurred in the thin and burn plots in 2002.

compared to controls. Also, both Agelenidae (*df*=3, *p*=0.0199) and Thomisidae (*df*=3, *p*=<0.0001) were found in significantly lower numbers in the thin and burn plots compared to control plots. The Agelenidae had significantly fewer (*df*=3, *p*=0.0084) individuals in the thin only compared to burn only plots. In contrast, both the Hahniidae (*df*=3, *p*=0.0105) (Figure 22) and Pisauridae (*df*=3, *p*=0.0131) had significantly higher numbers in thin only than in burn only plots. Numbers of Thomisidae were not significantly different (*df*=3, *p*>0.05) between the burn only and thin only plots.

The Hahniidae (Figure 22) was collected in significantly lower numbers in the thin only plots compared to the thin and burn plots (*df*=3, *p*=0.0081). The Agelenidae, Gnaphosidae (Figure 20), Pisauridae, and Thomisidae, did not have significantly different numbers in the thin only plots compared to the thin and burn plots (*df*=3, *p*>0.05).

When pre-burn numbers were compared to post-burn numbers, Agelenidae (Figure 19) and Linyphiidae (Figure 29), were found to have decreased significantly after the burn in thin and burn plots in March of 2002 (*df*=23, *p*<0.05). However, Agelenidae means in the control plots also decreased after pre-burn samples were collected, and Linyphiidae mean numbers decreased in the thin only plots after pre-burn samples were compared to post-burn samples.

Effects of Time versus Treatment on Spider Family Populations:

Agelenidae

During January/February, Agelenidae mean numbers per plot were significantly higher in controls compared to the burn only plots (*df*=23, *p*=<0.0001), thin only (*df*=23, *p*=<0.0001), and thin and burn plots (*df*=23, *p*<0.0001). No significant differences were found between burn only and thin only plots (*df*=23, *p*=0.0633) or thin and burn plots (*df*=23, *p*=0.0768). Thin only plots, during January/February, had significantly lower agelenid numbers than thin and burn plots (*df*=23, *p*=0.0002) (Figure 19).

During, March/April, numbers of Agelenidae in control plots were significantly lower than in burn only plots (*df*=23, *p*=0.0002), but were not significantly different than either thin only (*df*=23, *p*=0.3657) or thin and burn plots (*df*=23, *p*=0.5681). The burn only plots had significantly higher numbers than either thin only (*df*=23, *p*=0.0010) or thin and burn plots (*df*=23, *p*=0.0010). During June, August, October, and December, no significant differences were found between the three treatments and control plots (*df*=23, *p*>0.05) (Figure 19).

Clubionidae

During August, the mean numbers of Clubionidae per plot were significantly higher in control plots compared to burn only (*df*=23, *p*=0.0015), thin only (*df*=23, *p*=0.0207), or thin and burn plots (*df*=23, *p*=<0.0001). Clubionid numbers in burn only plots were not significantly different than in either thin only (*df*=23, *p*=0.2205) or thin and burn plots (*df*=23, *p*=0.4093). Numbers in thin only plots were significantly higher than in the thin and burn plots (*df*=23, *p*=0.0330) (Figure 28).

In October, mean numbers in control plots were not significantly different than in the burn only (*df*=23, *p*=0.5090), thin only (*df*=23, *p*=0.2503), or thin and burn plots (*df*=23, *p*=0.1752). Burn only plots had significantly higher numbers than the thin and burn plots (*df*=23, *p*=0.0397), but the numbers were not significantly different than in the thin only plots (*df*=23, *p*=0.0533). During January/February, March/April, June, and October, no significant differences were found between the three treatments and control plots (*df*=23, *p*>0.05) (Figure 28).

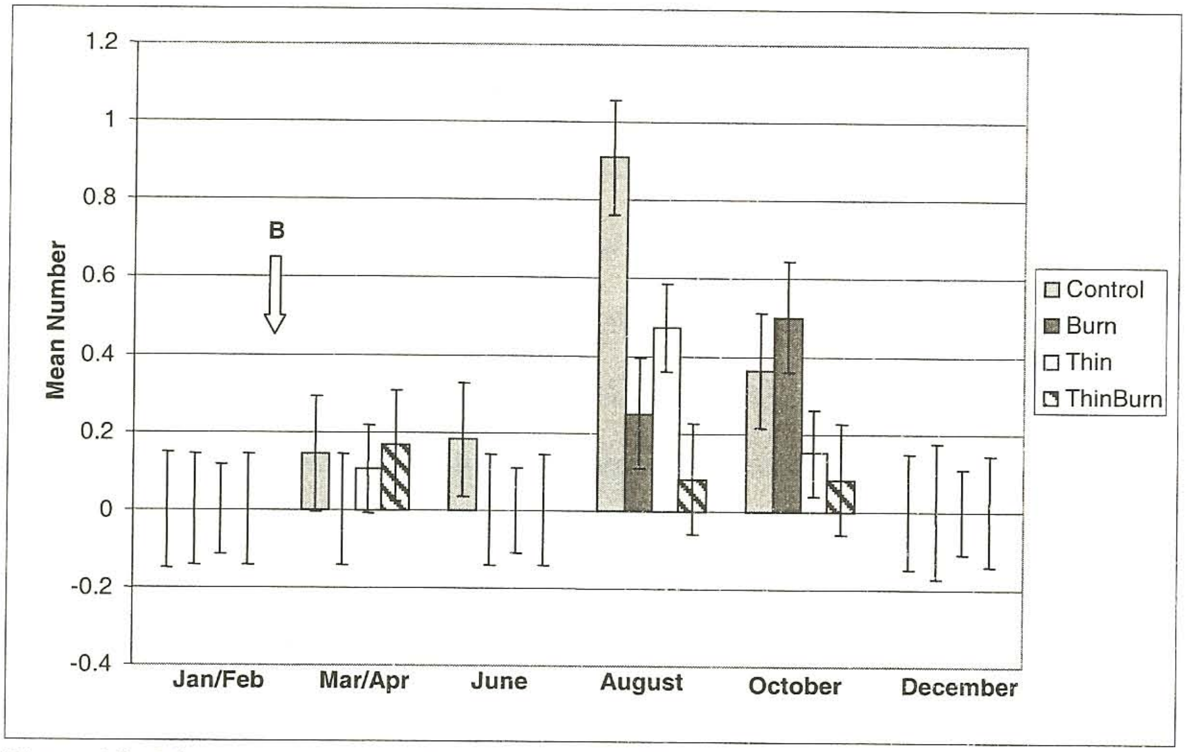

Figure 28. Mean number of adult and immature Clubionidae (O: Araneae) collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. The B indicates when the burn occurred in the thin and burn plots in 2002.

Gnaphosidae

During March/April, the mean numbers of Gnaphosidae per plot were not significantly different in burn only (*df*=23, *p*=0.5710), thin only (*df*=23, *p*=0.2143), or thin and burn plots (*df*=23, *p*=0.4872) compared to the control plots. In the burn only plots, the mean numbers of Gnaphosidae were significantly higher than in both thin only (*df*=23, *p*=0.0021) and thin and burn plots (*df*=23, *p*=0.0240). The mean number of Gnaphosidae per plot was not significantly different in the thin only and thin and burn plots (*df*=23, *p*=0.5523) (Figure 21).

In June, numbers of gnaphosids were not significantly different in burn only (*df*=23, *p*=0.3387) or thin only (*df*=23, *p*=0.1904)compared to control plots, but burn only and thin only were significantly greater than in the thin and burn plots (*df*=23, *p*=0.0030). Numbers in burn only plots were not significantly different than in thin only plots (*df*=23, *p*=0.7999), but were significantly higher than in the thin and burn plots (*df*=23, *p*=0.0384) (Figure 21).

In October, numbers in control plots were significantly higher than in burn only (*df*=23, *p*=0.0192), thin only (*df*=23, *p*=0.0421), or thin and burn plots (*df*=23, *p*=0.0039). No significant differences were found among burn only, thin only, or thin and burn plots (*df*=23, *p*>0.05). During January/February, August, and December, no significant differences were found in the number of gnaphosids among the three treatments and control plots (*df*=23, *p*>0.05) (Figure 21).

Hahniidae

During March/April, mean numbers of Hahniidae per plot were significantly lower in the thin and burn plots compared to controls (*df*=23, *p*=0.0007). However, their numbers were not significantly different in burn only (*df*=23, *p*=0.0547) or thin only plots (*df*=23, *p*=0.7711) compared to control plots. Numbers of hahniids in burn only were significantly lower than in thin only plots (*df*=23, *p*=0.0333), but were not significantly different than in the thin and burn plots (*df*=23, *p*=0.0816) (Figure 23).

In October, mean numbers of Hahniidae per plot were significantly lower in control plots compared to thin only plots (*df*=23, *p*=0.0082), but were not significantly different in the burn only (*df*=23, *p*=1.000) or thin and burn (*df*=23, *p*=0.2554) compared to control plots. Burn only plots had significantly lower numbers than the thin only plots (*df*=23, *p*=0.0066), but were not significantly different than the thin and burn plots (*df*=23, *p*=0.2449). Numbers in thin only plots were not significantly different than in thin and burn plots (*df*=23, *p*=0.1530). During January/February, June, August, and December, no significant differences were found between the three treatments and control plots (*df*=23, *p*>0.05) (Figure 23).

Linyphiidae

During January/February, mean numbers of Linyphiidae per plot was significantly higher in the control plots compared to thin only plots (*df*=23, *p*=0.0148), but were not significantly different than burn only (*df*=23, *p*=0.0778) or thin and burn plots (*df*=23, *p*=0.2148). Burn only plots had significantly lower numbers than thin only (*df*=23, *p*=0.0058) or thin and burn plots (*df*=23, *p*=0.0023). Numbers in the thin only plots were not significantly different than in thin and burn plots (*df*=23, *p*=0.2615) (Figure 29).

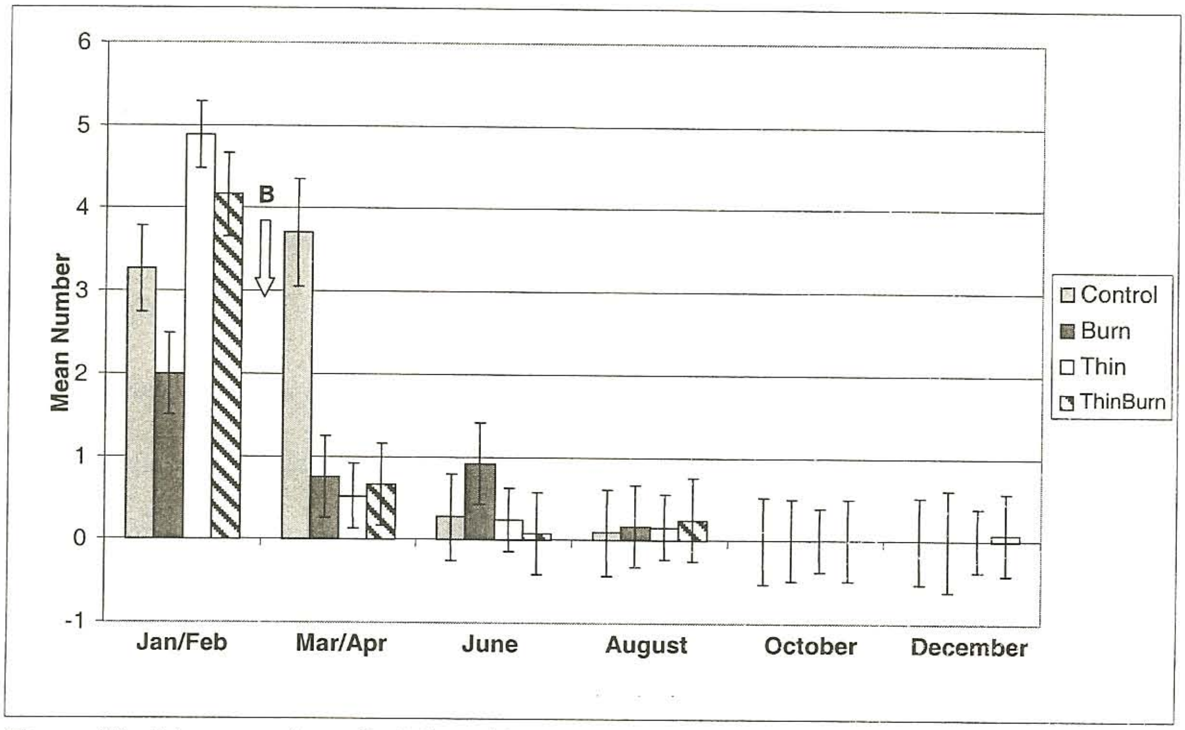

Figure 29. Mean number of adult and immature Linyphiidae (O: Araneae) collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. The B indicates when the burn occurred in the thin and burn plots in 2002.

In March/April, mean numbers of Linyphiidae per plot were significantly higher in control plots compared to burn only (df=23, p=0.0003), thin only (df=23, p=<0.0001), or thin and burn plots (df=23, p<0.0001). No significant differences in mean numbers were found in the mean numbers between the three treatments and control plots (*df*=23, *p*>0.05) (Figure 29).

Mean numbers of Linyphiidae per plot were significantly lower in the first post-burn samples compared to pre-burn samples (df=23, p=<0.0001) in the thin and burn plots in 2002. After the first pre-burn sample, mean number of Linyphiidae decreased (Figure 29).

Oxyopidae

During June, mean numbers of Oxyopidae per plot were significantly higher in thin only plots (*df*=23, *p*=0.0005), but were not significantly different than burn only (*df*=23, *p*=0.4684) or thin and burn plots (*df*=23, *p*=1.000). Numbers in the burn only plots were significantly lower than in thin only plots (*df*=23, *p*=0.0053), but were not significantly different than thin and burn plots (*df*=23, *p*=0.4585). Mean numbers in the thin only plots were significantly higher than in thin and burn plots (*df*=23, *p*=0.0003). During January/February, March/April, June, August, and December, no significant differences in mean numbers were found between the three treatments and control plots (*df*=23, *p*>0.05) (Figure 30).

Pisauridae

During June, mean numbers of Pisauridae per plot were not significantly different in burn only, thin only, or thin and burn plots compared to control plots (*df*=23, p>0.05).

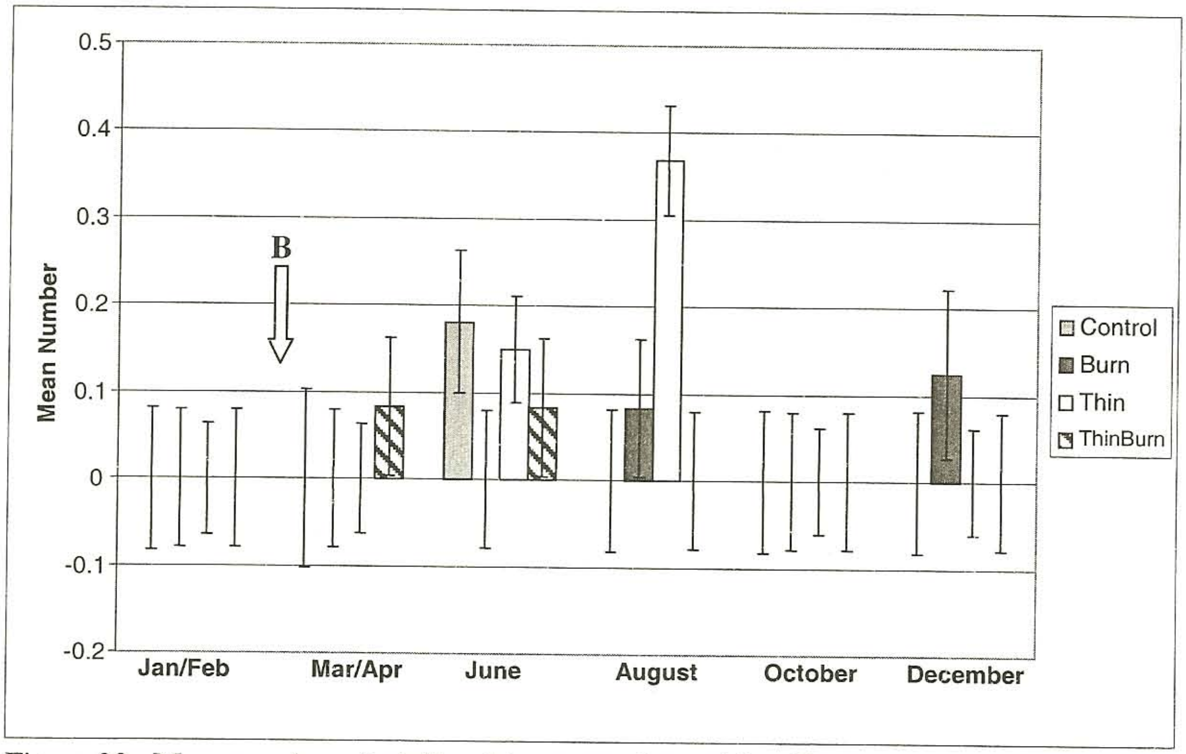

Figure 30. Mean number of adult and immature Oxyopidae (O: Araneae) collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. The B indicates when the burn occurred in the thin and burn plots in 2002.

Numbers in the burn only plots were significantly lower than thin and burn plots (*df*=23, *p*=0.0384), but were not significantly different than thin only plots (*df*=23, *p*=0.0892). Mean numbers in thin only plots were not significantly different than thin and burn plots (*df*=23, *p*=0.5356) (Figure 25).

In August, mean numbers of Pisauridae per plot were significantly higher in control plots compared to burn only (*df*=23, *p*=0.0233) and thin and burn plots (*df*=23, *p*=0.0092). No significant difference was found between mean numbers in thin only plots compared to control plots (*df*=23, *p*=0.0786). Numbers in burn only plots were significantly lower than in thin only plots (*df*=23, *p*=0.0044), but were not significantly different than thin and burn plots (*df*=23, *p*=0.7291). Numbers in thin only plots were significantly higher than thin and burn plots (*df*=23, *p*=0.0013) (Figure 25).

In October, mean numbers of Pisauridae per plot were significantly higher in control plots compared to burn only plots (*df*=23, *p*=0.0101). No significant differences were found in mean numbers between control and thin only (*df*=23, *p*=0.1961) or thin and burn plots (*df*=23, *p*=02186). Numbers in burn only, thin only, and thin and burn plots were not significantly different (*df*=23, *p*>0.05). During January/February, March/April, and December, no significant differences were found between the three treatments and control plots (*df*=23, *p*>0.05) (Figure 25).

Salticidae

In October, mean numbers of Salticidae per plot were significantly lower in control plots compared to burn only plots (*df*=23, *p*=0.0019), but were not significantly different than the thin only (*df*=23, *p*=0.1766) or thin and burn plots (*df*=23, *p*=0.0645). Numbers in burn only plots were significantly higher than thin only plots (*df*=23, *p*=0.0295), but were not significantly different than the thin and burn plots (*df*=23, *p*=0.1930). Mean numbers of salticids in thin only plots were not significantly different than thin and burn plots (*df*=23, *p*=0.4664). During January/February, March/April, June, August, and December, no significant differences were found among the three treatments and control plots (*df*=23, *p*>0.05) (Figure 31).

Theridiidae

During January/February, mean numbers of Theridiidae were significantly lower in control plots compared to thin only plots (df=23, p=0.0012), but were not significantly different than burn only (df=23, p=0.1360) or thin and burn plots (df=23, p=1.000). Numbers in burn only plots were not significantly different than in thin only (df=23, p=0.0951) or thin and burn plots (df=23, p=0.1274). Mean numbers in thin only plots were significantly higher than in thin and burn plots (df=23, p=0.0009). No significant differences were found among mean numbers in the three treatments and control plots during March/April, June, August, October, or December (Figure 32).

Thomisidae

During June, mean numbers of Thomisidae per plot were significantly higher in control plots compared to burn only, thin only, and thin and burn plots (df=23, *p*>0.05). Numbers in burn only plots were significantly higher than in thin and burn plots (*df*=23, *p*=0.0006), but were not significantly different than in thin only plots (*df*=23, *p*=0.1212). Mean numbers in thin only plots were significantly higher than thin and burn plots (*df*=23, *p*=0.0204). No significant differences were found in the mean numbers among

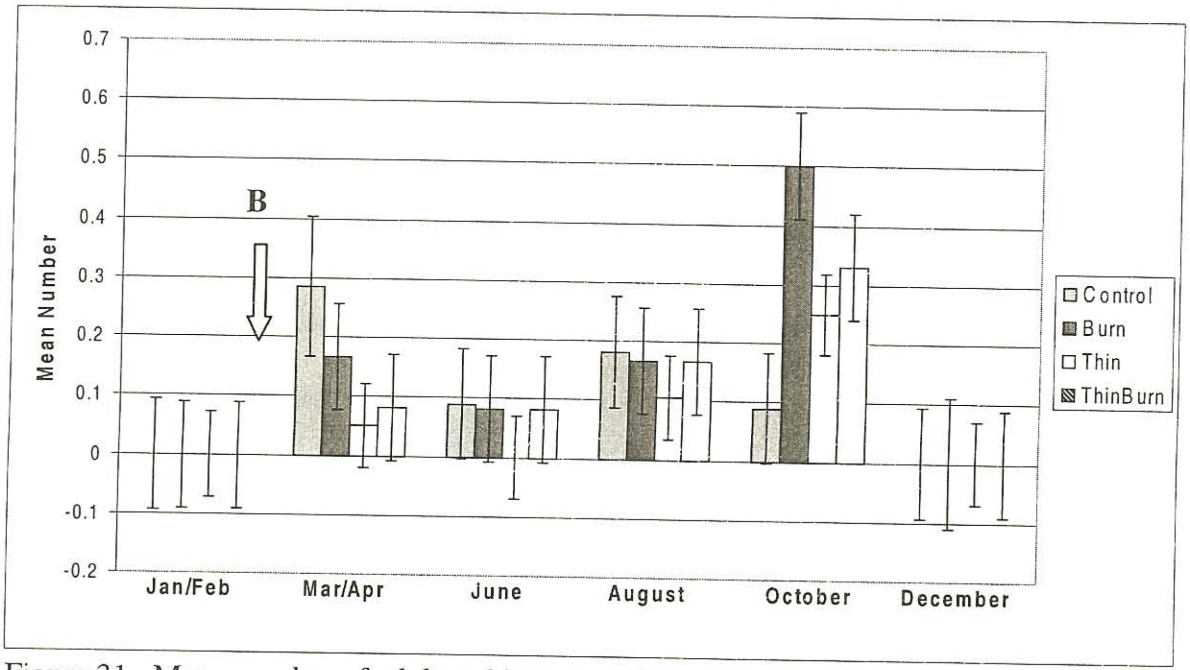

Figure 31. Mean number of adult and immature Salticidae (O: Araneae) collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. The B indicates when the burn occurred in the thin and burn plots.

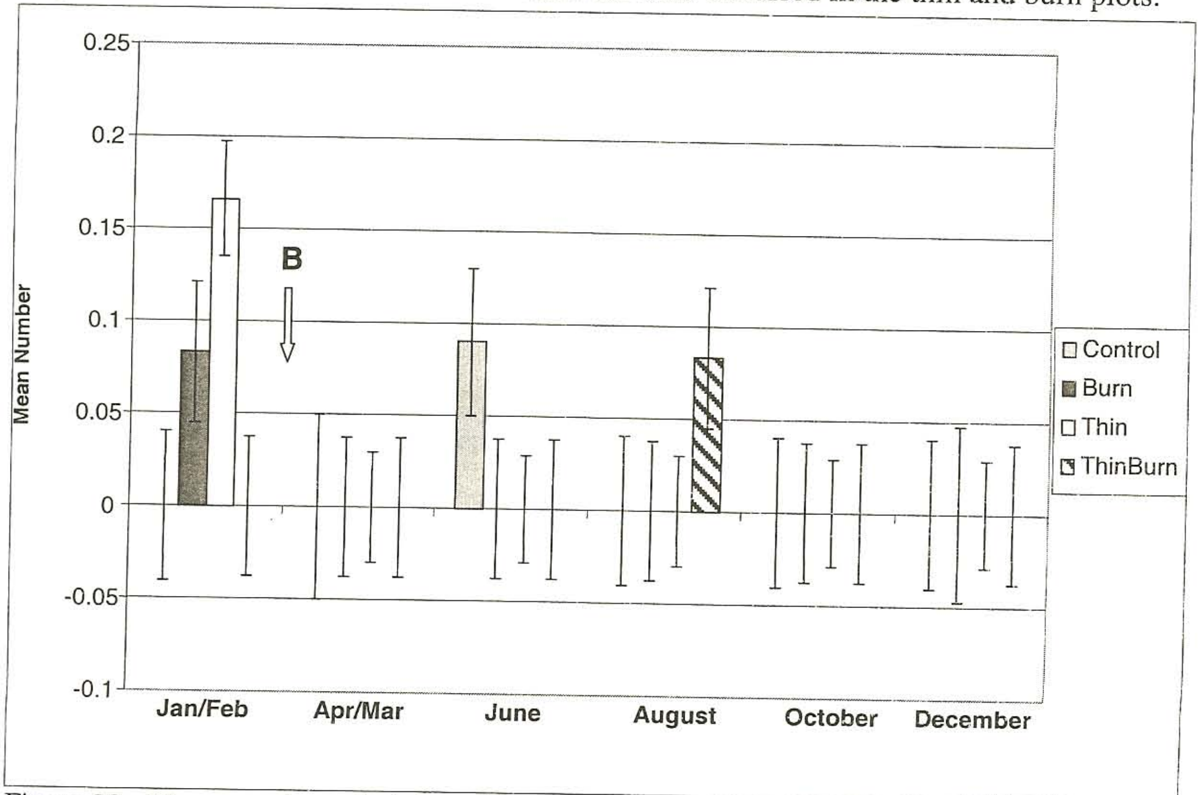

Figure 32. Mean number of adult and immature Theridiidae (O: Araneae) collected in the three replicated treatments and control plots during the six sampling periods in the Clemson Experimental Forest. The B indicates when the burn occurred in the thin and burn plots in 2002.

the three treatments and control plots during January/February, March/April, August, or December (Figure 27).

Three families of spiders, Araneidae (*df*=23, *F*=0.87, *p*=0.6342) (Figure 33), Atypidae (*df*=23, *F*=1.34, *p*=0.1422) (Figure 34), and Lycosidae (*df*=23, *F*=0.80, *p*=0.7322) (Figure 35), exhibited no significant difference in the mean numbers of spiders per plot in the three treatments compared to the numbers in the control plots during the six sampling periods in the Clemson Experimental Forest. Overall, spider families exhibited varied responses in mean population numbers per plot during the six sampling periods.

Genera and Species Level Identifications

Due to the large numbers of specimens collected, two families of spiders, Agelenidae and Lycosidae, were able to be identified to genera. *Gnaphosa fontinalis* Keyserling was the most abundant species collected.

Fuel Load Management Treatments on Selected Spider Genera:

Agelenidae

In the Agelenidae, 136 spiders were identified to the generic level (Table 5). These were, *Agelenopsis*, *Cicurina*, *Coras*, *Cybaeus*, and *Wadotes*, (Table 6). Due to its being collected in large numbers throughout the study, the genus *Wadotes* was analyzed to determine if fuel-load management practices had an effect on its numbers. *Cicurina* spp. were also collected in large numbers, but were not analyzed due to only being collected during January/February.

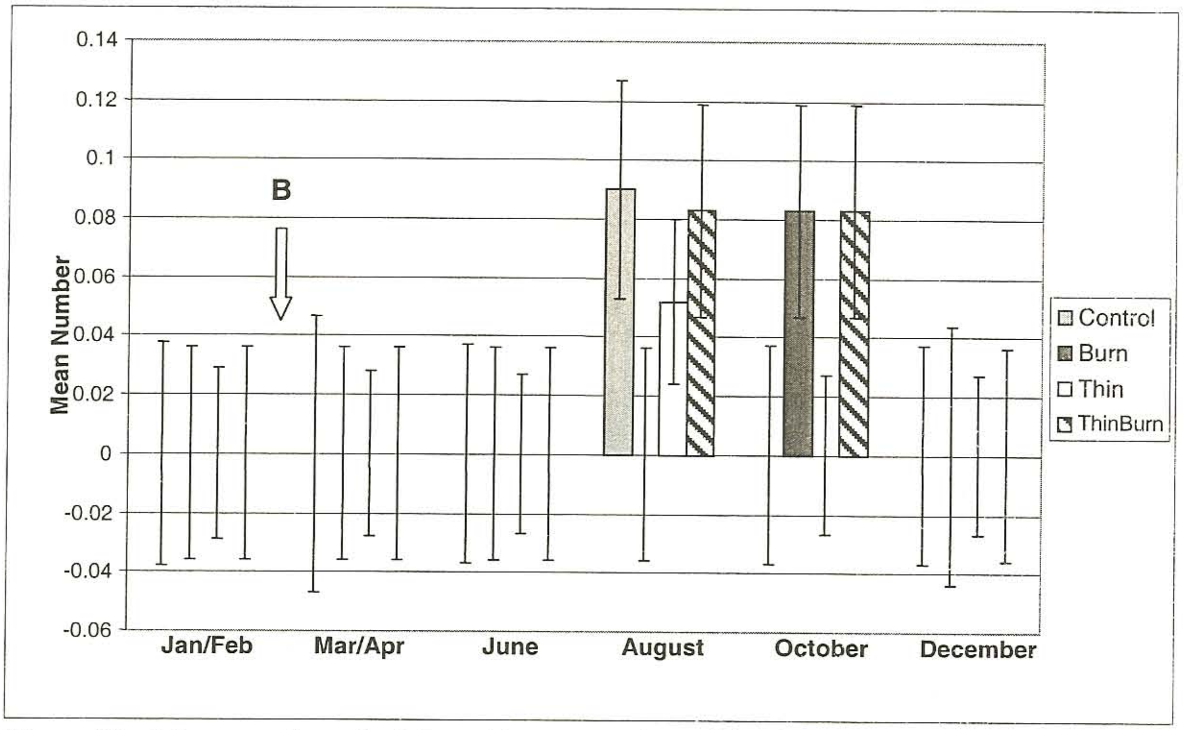

Figure 33. Mean number of adult and immature Araneidae (O: Araneae) collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. The B indicates when the burn occurred in the thin and burn plots in 2002.

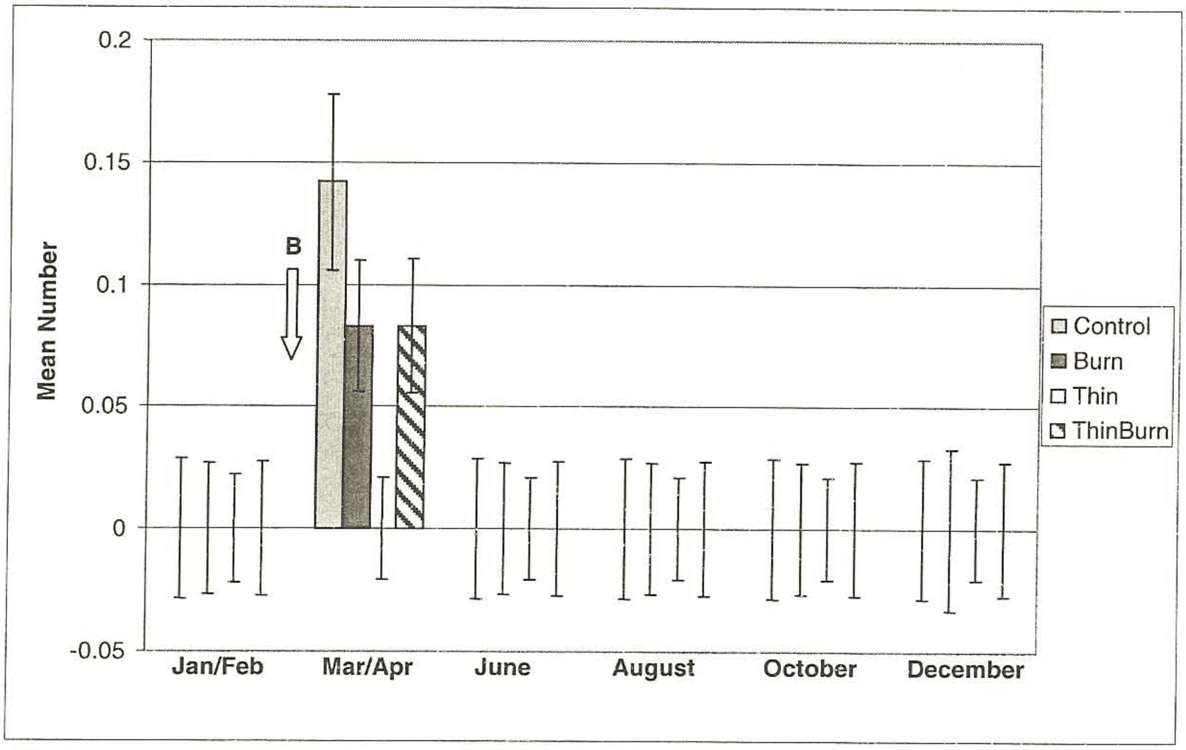

Figure 34. Mean number of adult and immature Atypidae (O: Araneae) collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. The B indicates when the burn occurred in the thin and burn plots.

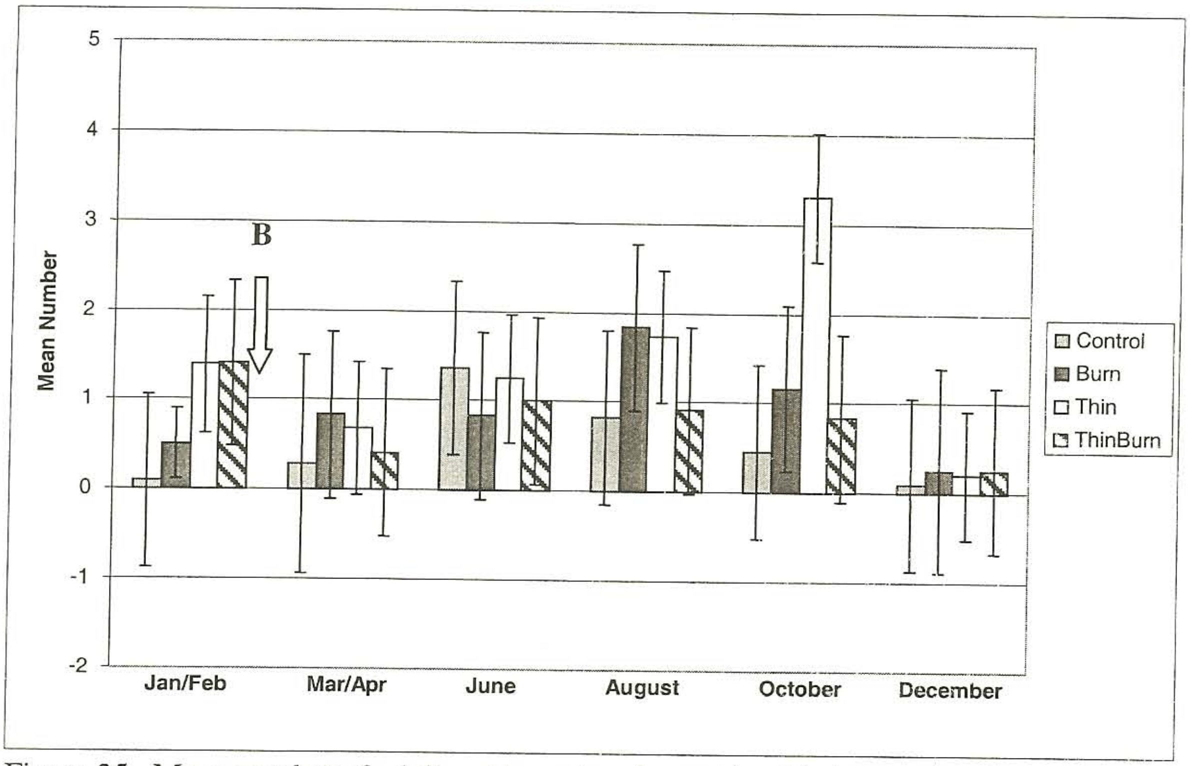

Figure 35. Mean number of adult and immature Lycosidae (O: Araneae) collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. The B indicates when the burn occurred in the thin and burn plots in 2002.

Table 5. Total numbers and total numbers collected, during 2002, in each treatment, of Agelenidae genera collected during the six sampling periods in the Clemson Experimental Forest.

Genera	Total	Control	Burn	Thin	Thin and Burn
Agelenopsis spp.	23	1	10	8	4
Cicurina spp.	48	22	7	6	13
Coras spp.	1	1	0	0	0
Cybaeus spp.	2	2	0	0	0
Wadotes spp.	62	28	17	11	6
Immatures	0	0	0	0	0

Table 6. Total numbers and total numbers collected in each treatment, in 2002, of Lycosidae genera collected during the six sampling periods in the Clemson Experimental Forest.

Genera	Total	Control	Burn	Thin	Thin and Burn
Gladicosa spp.	1	0	0	0	1
Hogna spp.	13	2	1	5	5
Pirata spp.	5	2	0	2	1
Schizocosa spp.	40	5	10	15	10
Varacosa spp.	35	4	0	15	16
Immatures	227	21	52	123	31

Effect of Sampling Date on *Wadotes* spp. Populations:

There was a significant overall effect on numbers of *Wadotes* spp. per plot (*df*=5, *F*=5.58, *p*=0.0002) with mean numbers being highest during January/February and then significantly decreasing during March/April (*df*=5, *p*=<0.0001). After January/February, there were no significant differences (*df*=5, *p*>0.05) in the mean number of *Wadotes* spp. per plot during March/April, June, August, October, or December (Figure 36).

Effect of Treatment on *Wadotes* spp. Populations:

Wadotes spp. were collected in significantly lower numbers in thin only (*df*=3, *p*=0.0004) and thin and burn plots (*df*=3, *p*=0.0192) compared to control plots. No significant difference was found between numbers of *Wadotes* spp. in burn only and control plots (*df*=3, *p*=0.1480). Numbers of *Wadotes* spp. were significantly lower in thin only compared to burn only plots (*df*=3, *p*=0.0408), but were not significantly different in burn only compared to thin and burn plots (*df*=3, *p*=0.3554). No significant difference was found between numbers in thin only and thin and burn plots (*df*=3, *p*=0.3018) (Figure 37). Numbers in burn only were significantly higher than in thin only plots (*df*=23, *p*=0.0015), but were not significantly different than those in thin and burn plots (*df*=23, *p*=0.6884). Thin only plots had significantly higher numbers than did thin and burn plots (*df*=23, *p*=0.0055).

A significant difference was found in mean numbers of *Wadotes* spp. between pre-burn and post-burn numbers per plot after the thin and burn plots were burned in March of 2002 (*df*=23, *p*=<0.0001) (Figure 38). However, mean numbers in all treatments decreased significantly to zero (*df*=23, *p*<0.05) after pre-burn samples were collected.

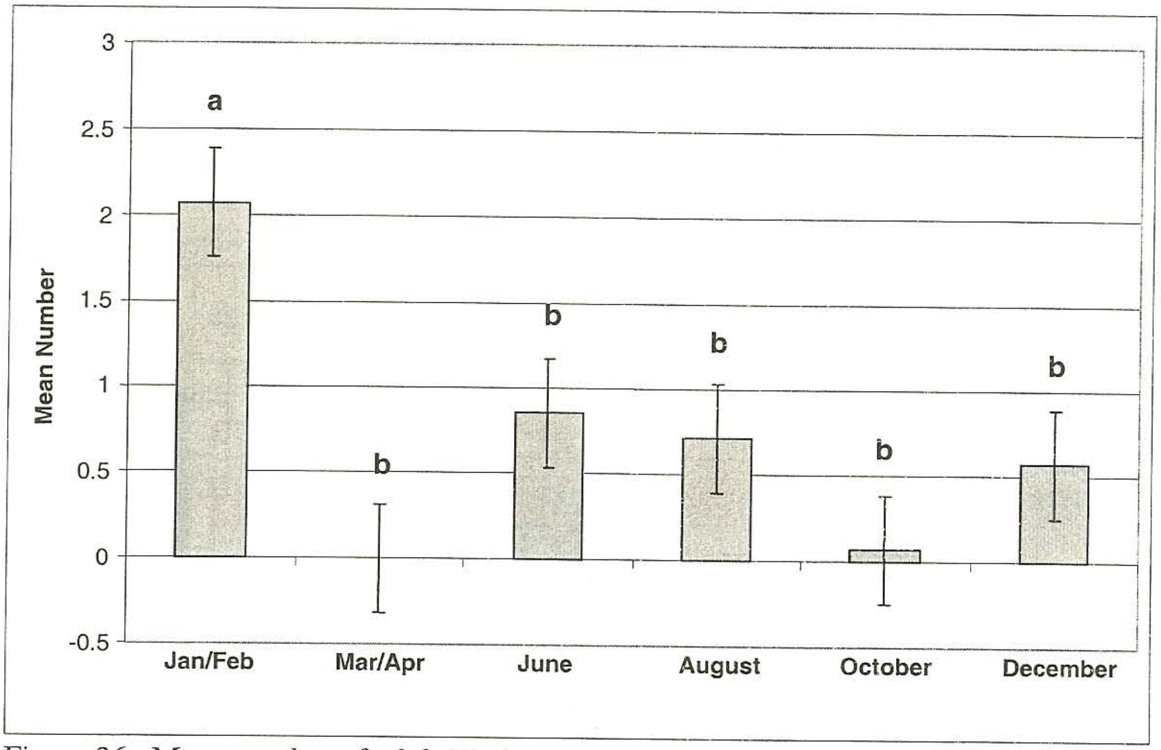

Figure 36. Mean number of adult *Wadotes* spp. (Agelenidae) collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among the sampling dates (p=0.05).

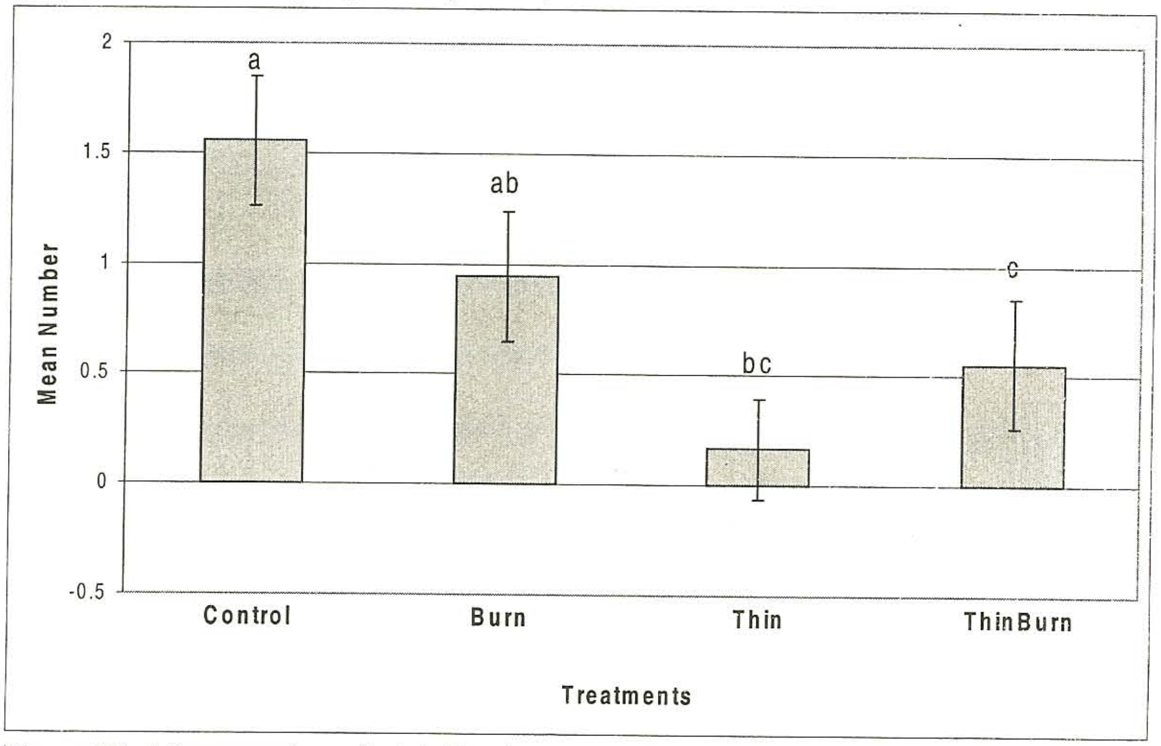

Figure 37. Mean number of adult *Wadotes* spp. (Agelenidae) collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among the treatments (p=0.05).

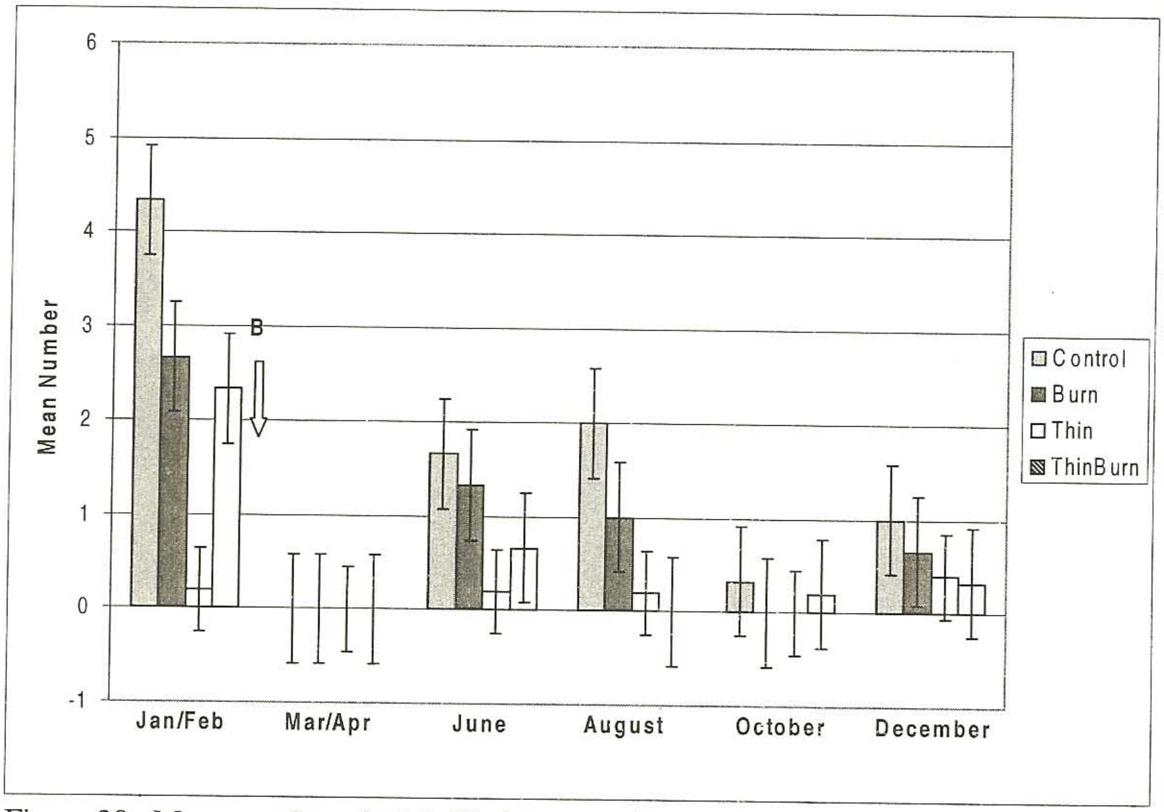

Figure 38. Mean number of adult *Wadotes* spp. (Agelenidae) collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. The B indicates when the burn occurred in the thin and burn plots in 2002.

In August, mean numbers of *Wadotes* spp. per plot were significantly lower in both thin only (*df*=23, *p*=0.0187) and thin and burn plots (*df*=23, *p*=0.0187) compared to control plots. No significant differences were found between control s and burn only plots (*df*=23, *p*=0.2315). No significant differences were found among the three treatments in August (*df*=23, *p*>0.05). In March/April, June, October, and December, no significant differences were found among the three treatments and control plots (*df*=23, *p*>0.05) (Figure 38).

Lycosidae

A total of 321 specimens of Lycosidae (O: Araneae) were collected during the study. Five genera were identified, *Gladicosa*, *Hogna*, *Pirata*, *Schizocosa*, and *Varacosa*, (Table 6). Four of these five genera were analyzed to determine effects of fuel-load management practices. Immature spiders also were analyzed separately due to the large numbers collected. The genus *Gladicosa* was not analyzed because only one spider was collected over the course of 12 months sampling.

Effect of Sampling Date on Lycosidae Genera Populations:

The mean number of *Hogna* spp. per plot was not significantly different during the six sampling periods (*df*=5, *F*=2.03, *p*=0.0837) (Figure 39). However, when males and females were analyzed separately, there were significant differences in the mean numbers of males (*df*=5, *p*=0.0156) (Figure 40), but not females during the six sampling periods (*df*=5, *p*=0.7105) (Figure 41). The highest numbers of male *Hogna* spp. were collected during October.

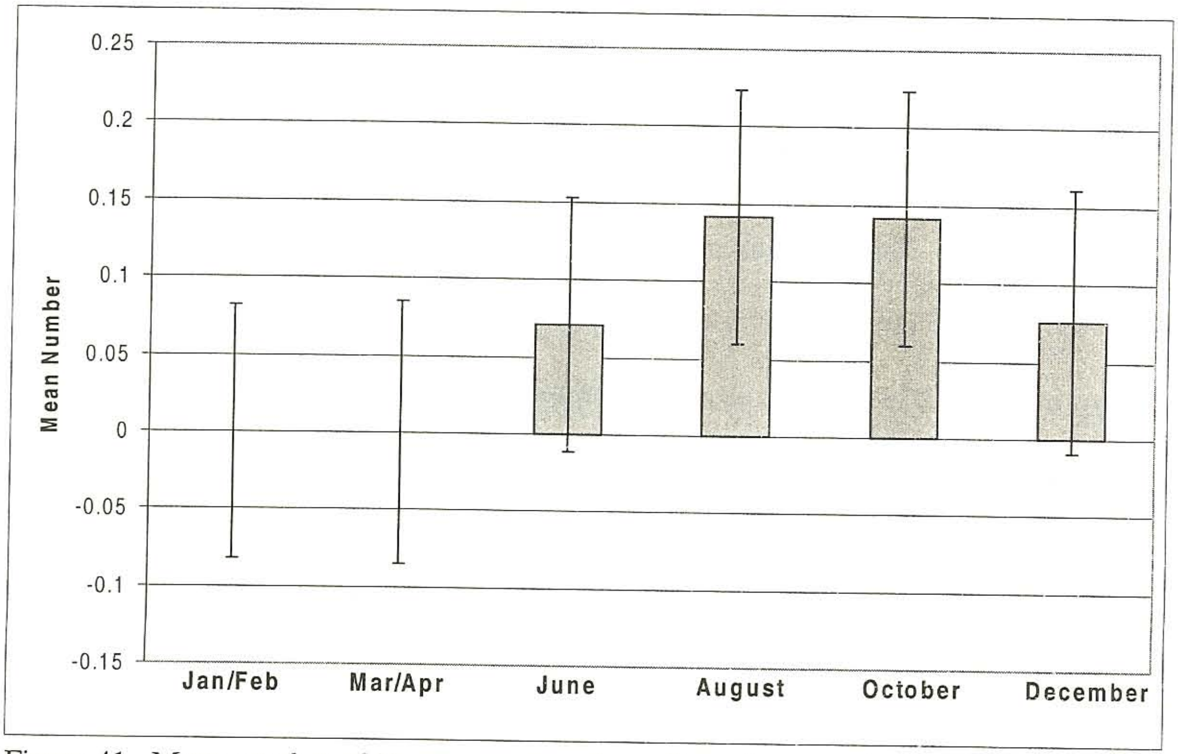

Figure 41. Mean number of *Hogna* spp. females collected during the six sampling periods in the Clemson Experimental Forest. Significant differences were not found among the sampling dates (p=0.05).

Mean number of *Pirata* spp. per plot were not significantly different among the six sampling periods (*df*=5, *F*=0.63, *p*=0.6811) (Figure 42). Mean numbers of males (*df*=5, *F*=0.83, *p*=0.5331) (Figure 43) and females (*df*=5, *F*=0.97, p=0.4419) (Figure 44) were not significantly different during any of the six sampling periods.

The mean number of *Schizocosa* spp. per plot was significantly different during the six sampling periods (*df*=5, *F*=4.30, *p*=0.0017). Mean numbers of *Schizocosa* spp. per plot increased from January/February until June. After June, mean numbers significantly decreased (*df*=5, *p*=0.0046) (Figure 45). Mean numbers males (*df*=5, *F*=5.63, *p*=0.0002) per plot varied significantly during the six sampling periods, female mean numbers were not significantly different (*df*=5, *F*=2.28, *p*=0.0552). An increase in male numbers per plot occurred from January/February until June, and then decreased significantly (*df*=5, *p*=<0.0001) (Figure 46). Mean numbers of females were significantly highest during summer months (*df*=5, *p*>0.05) (Figure 47).

Mean numbers of *Varacosa* spp. per plot were significantly different during the six sampling periods (*df*=5, *F*=5.57, *p*=0.0002). In January/February, mean numbers of *Varacosa* spp. per plot were significantly higher than in the other five sampling periods (*df*=5, *p*>0.05). After January/February, mean numbers of *Varacosa* spp. per plot decreased then remained relatively constant (Figure 48). Mean numbers of males were significantly different during the six sampling periods(*p*=0.0002) (Figure 49), but mean female numbers were not significantly different during the six sampling periods (*df*=5, *F*=0.46, *p*=0.8075) (Figure 50). Mean numbers of males were highest during January/February and then significantly decreased (*df*=5, *p*<0.05).

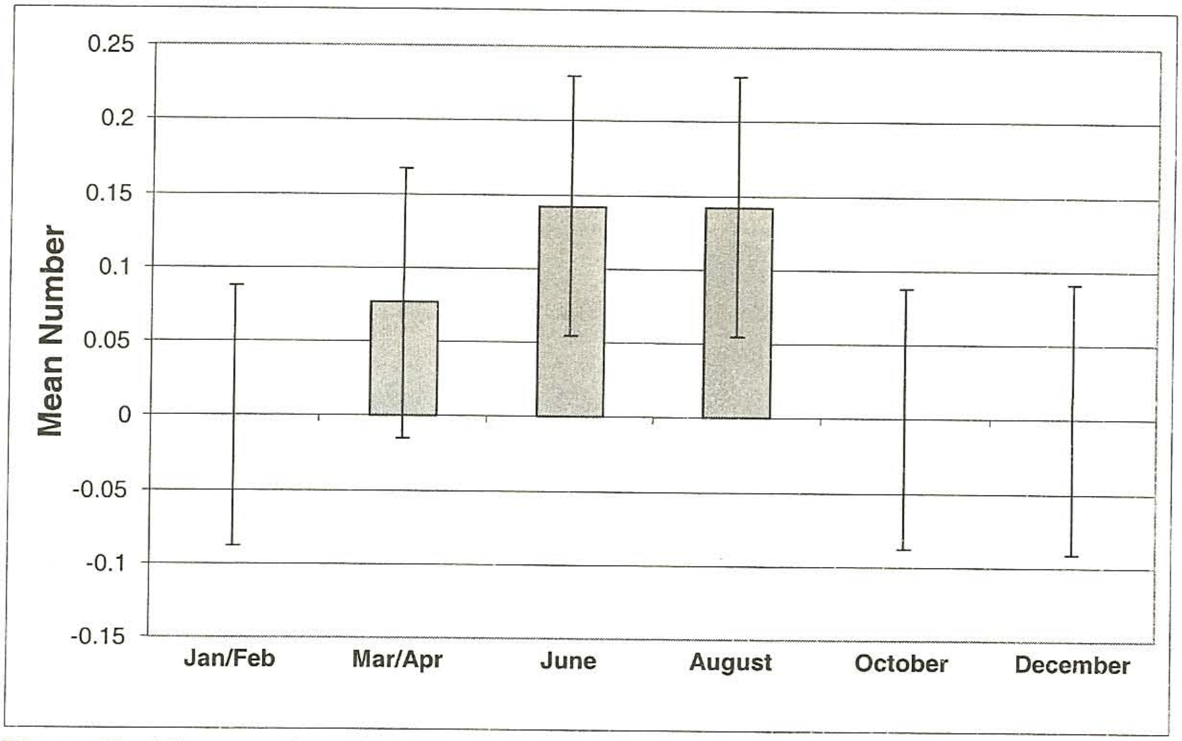

Figure 42. Mean number of adult *Pirata* spp. collected during the six sampling periods in the Clemson Experimental Forest. Significant differences were not found among the sampling dates (*p*=0.05).

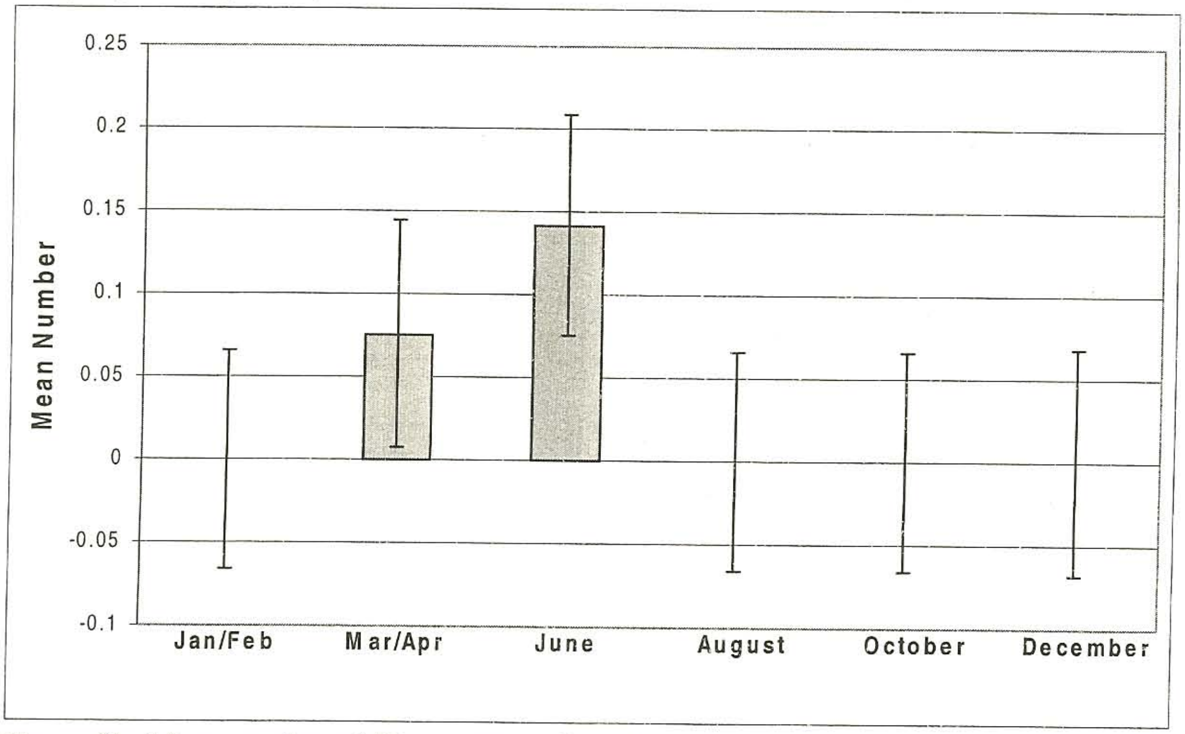

Figure 43. Mean number of *Pirata* spp. males collected during the six sampling periods in the Clemson Experimental Forest. Significant differences were not found among the sampling dates (*p*=0.05).

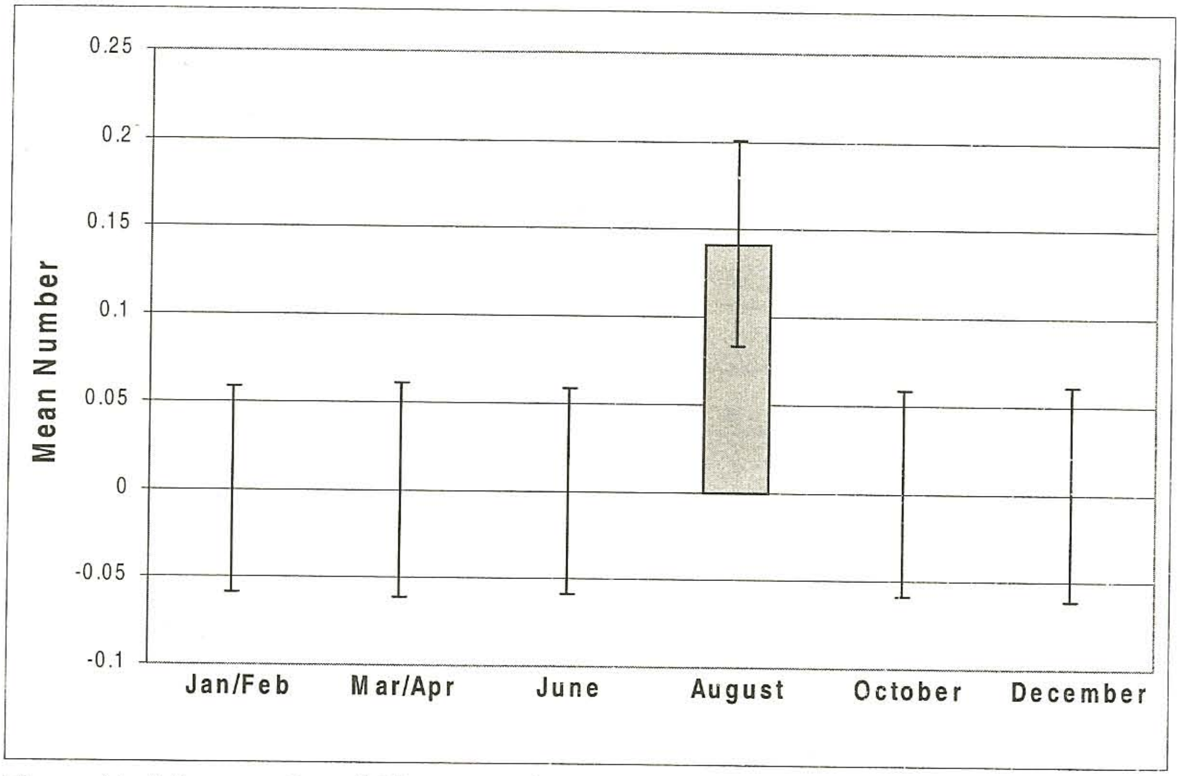

Figure 44. Mean number of *Pirata* spp. females collected during the six sampling periods in the Clemson Experimental Forest. Significant differences were not found among the sampling dates (p=0.05).

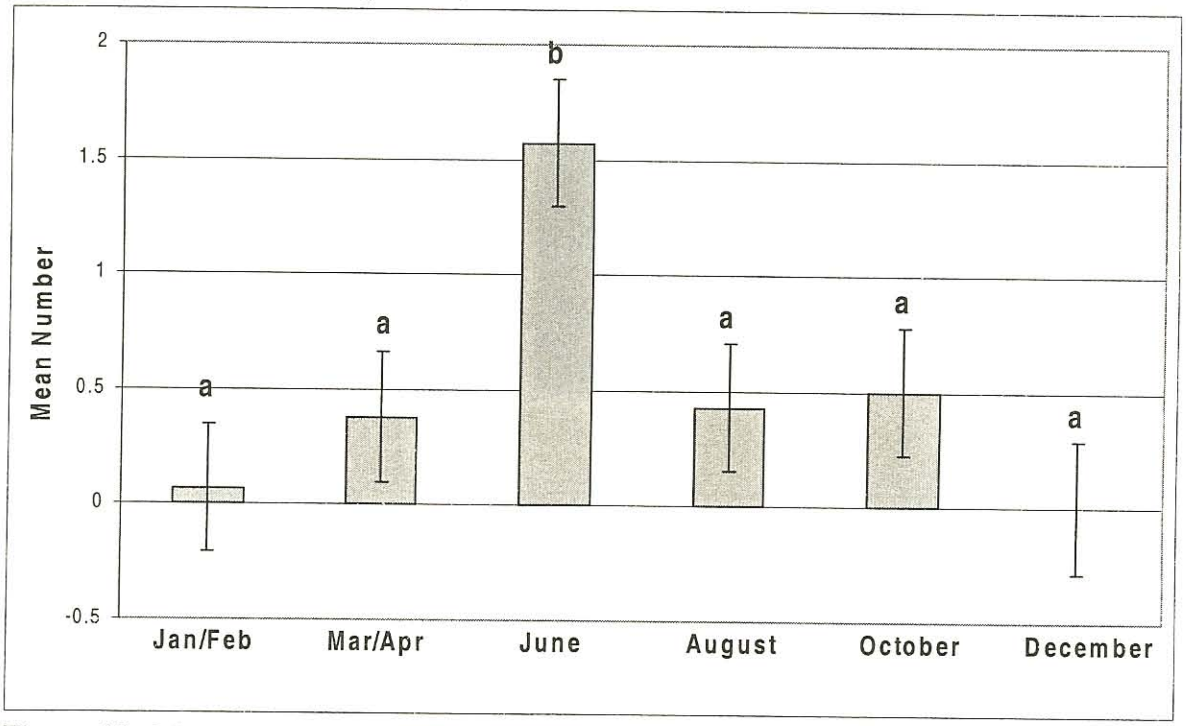

Figure 45. Mean number of adult *Schizocosa* spp. collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among the six sampling dates (p=0.05).

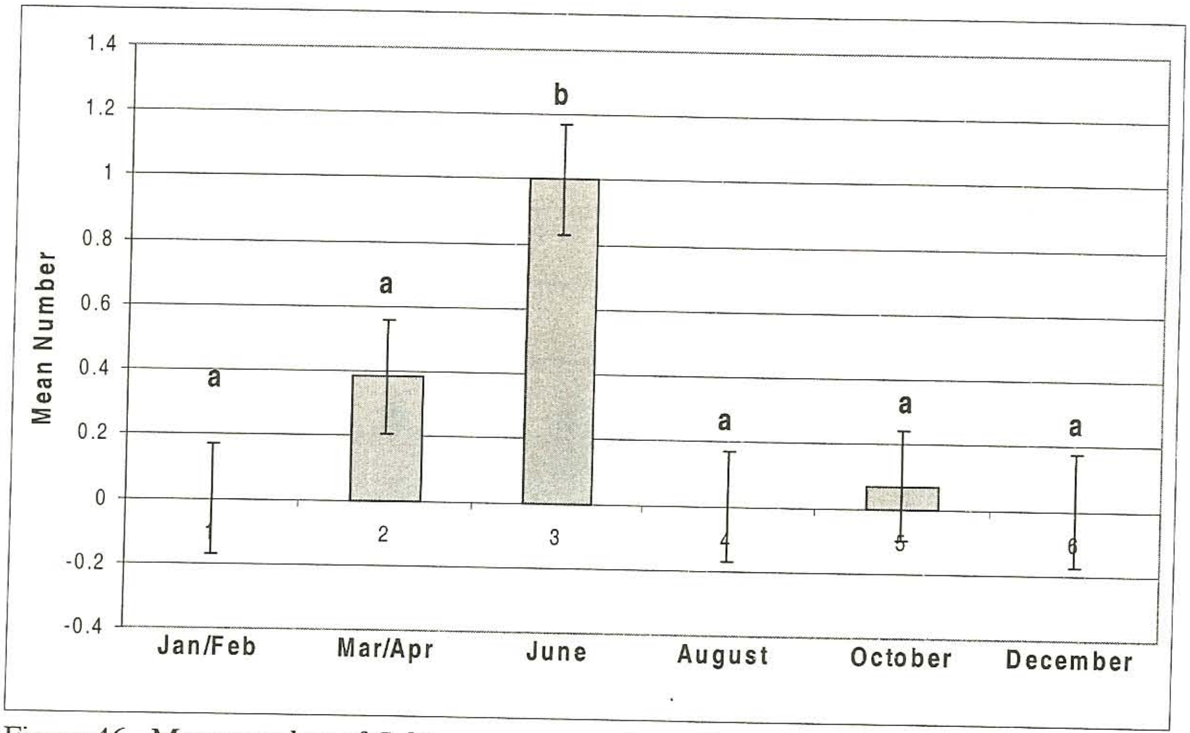

Figure 46. Mean number of *Schizocosa* spp. males collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among the six sampling dates (p=0.05).

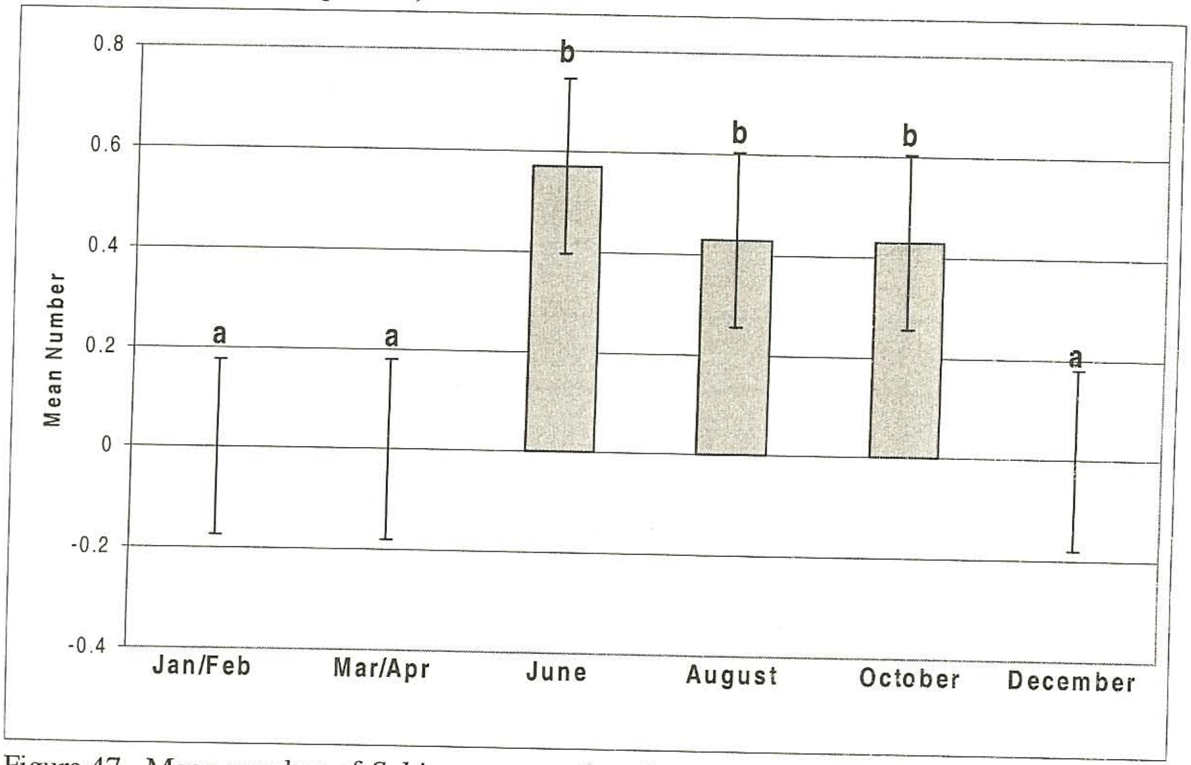

Figure 47. Mean number of *Schizocosa* spp. females collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among the six sampling dates (p=0.05).

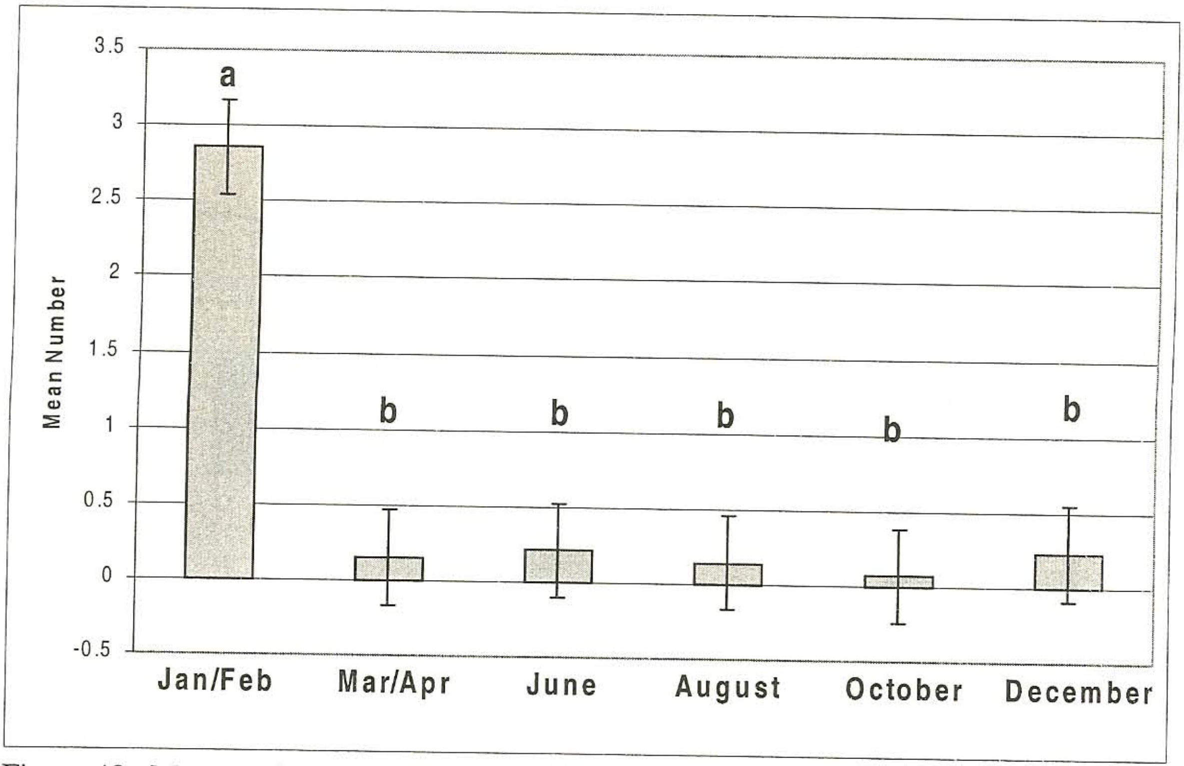

Figure 48. Mean number of adult *Varacosa* spp. collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among the six sampling dates (p=0.05).

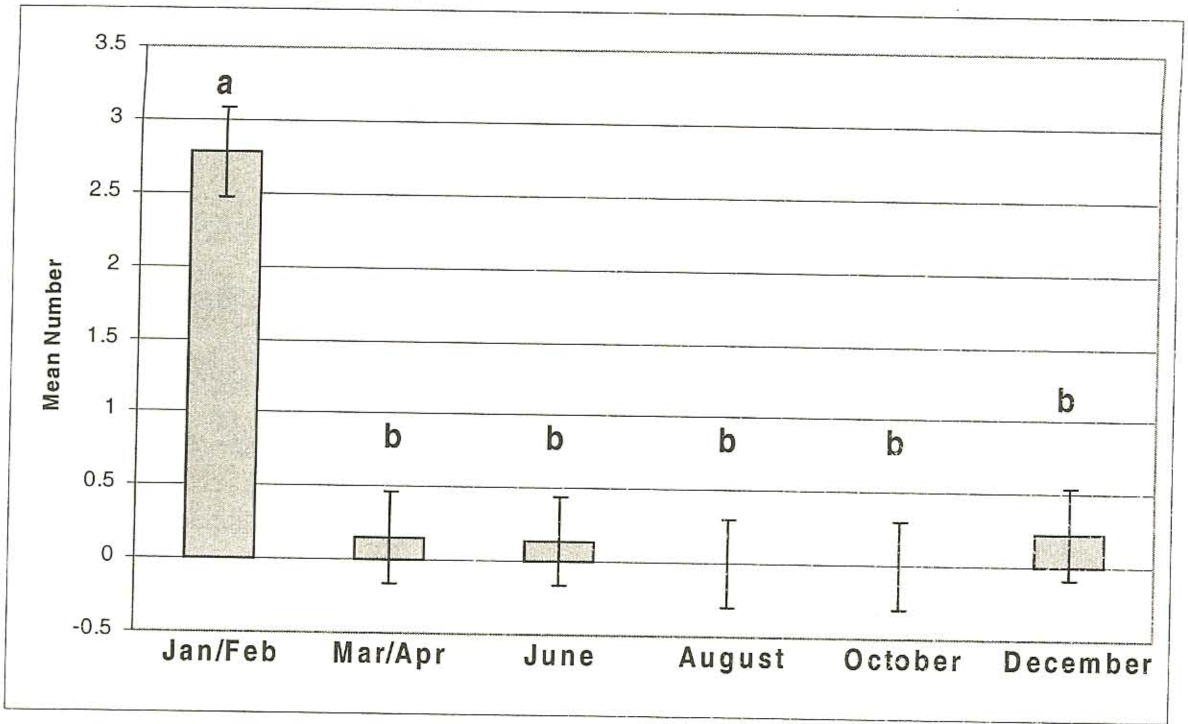

Figure 49. Mean number of *Varacosa* spp. males collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among the six sampling dates (p=0.05).

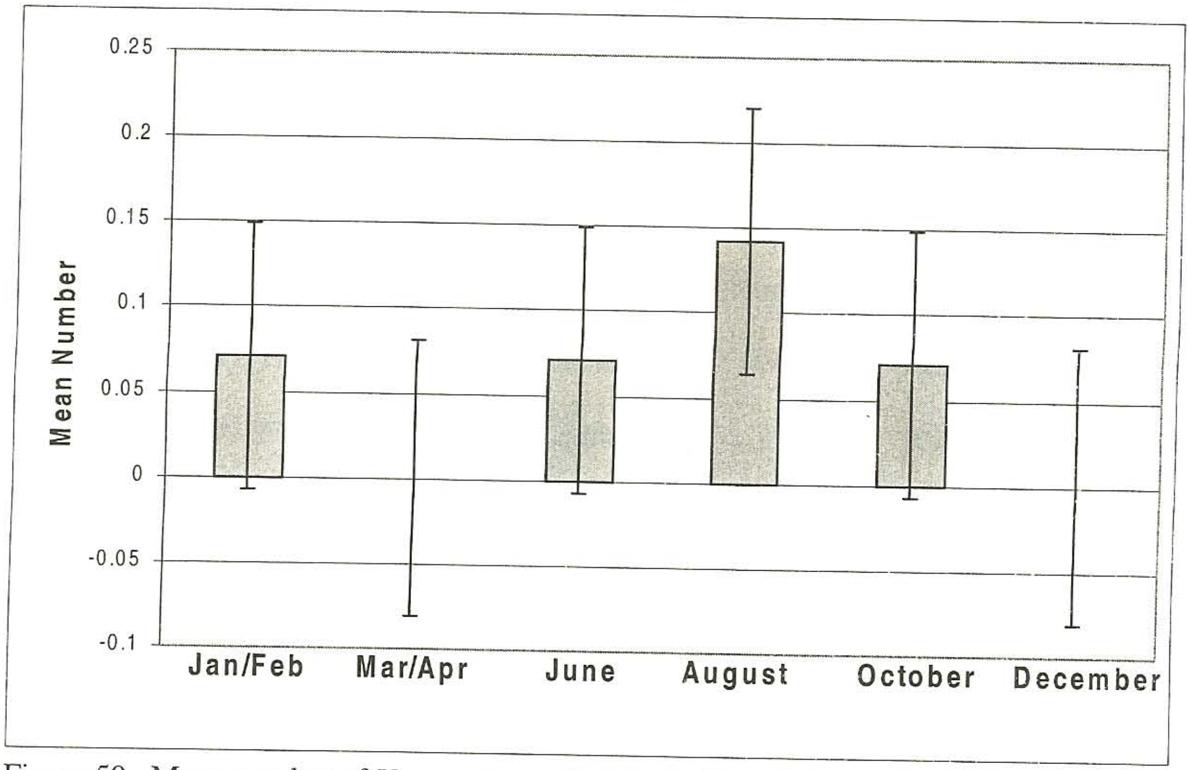

Figure 50. Mean number of *Varacosa* spp. females collected during the six sampling periods in the Clemson Experimental Forest. Significant differences were not found among the sampling dates (p=0.05).

Mean numbers of lycosid immatures per plot were not significantly different during the six sampling periods (Figure 51).

Effect of Treatment on Selected Genera of Lycosidae:

There were no significant differences in the total numbers of *Hogna* spp. (df=3, F=0.45, p=0.7201) (Figure 52) or in the mean number of *Hogna* spp. males (df=3, F=0.96, p=0.4152) (Figure 53) and females (df=3, F=0.74, p=0.5325) (Figure 54) among the three treatments and control plots. The mean numbers of *Hogna* spp. were not significantly different (df=23, p>0.05) in the first 2002 post-burn sample compared to the pre-burn sample in the thin and burn plots (Figure 55).

There were no significant differences in the total numbers of *Pirata* spp. (df=3, F=0.36, p=0.7808) (Figure 56) or in the mean numbers of *Pirata* spp. males (df=3, F=1.00, p=0.3975) (Figure 57) and females (df=3, F=0.57, p=0.6374) (Figure 58) among the three treatments and control plots. In 2002, the mean numbers of *Pirata* spp. were not significantly different (df=23, p>0.05) in the first post-burn sample compared to the pre-burn numbers in the thin and burn plots (Figure 59).

There were no significant differences in the total numbers of *Schizocosa* spp. (df=3, F=0.29, p=0.8302) (Figure 60) or in the mean numbers of *Schizocosa* spp. males (df=3, F=0.65, p=0.5837) (Figure 61) nor females (df=3, F=0.22, p=0.8809) (Figure 62) among the three treatments and control plots.

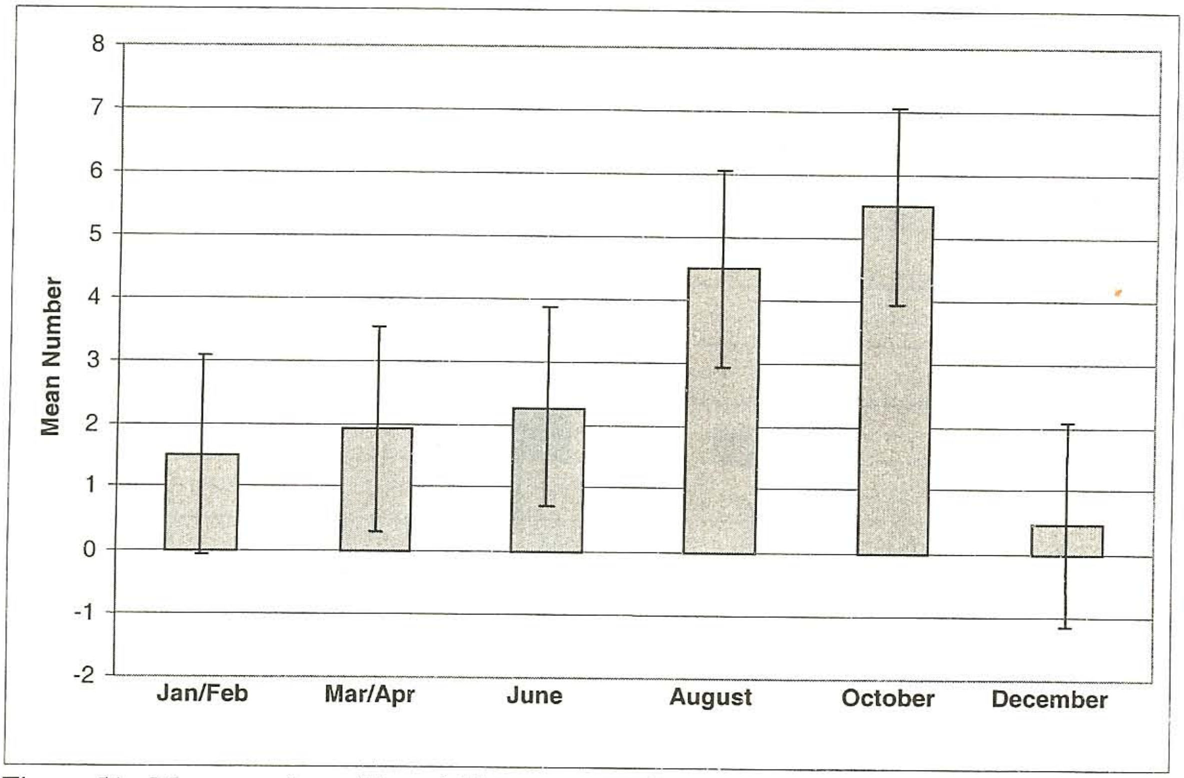

Figure 51. Mean number of lycosid immatures collected during the six sampling periods in the Clemson Experimental Forest. Significant differences were not found among the sampling dates (p=0.05).

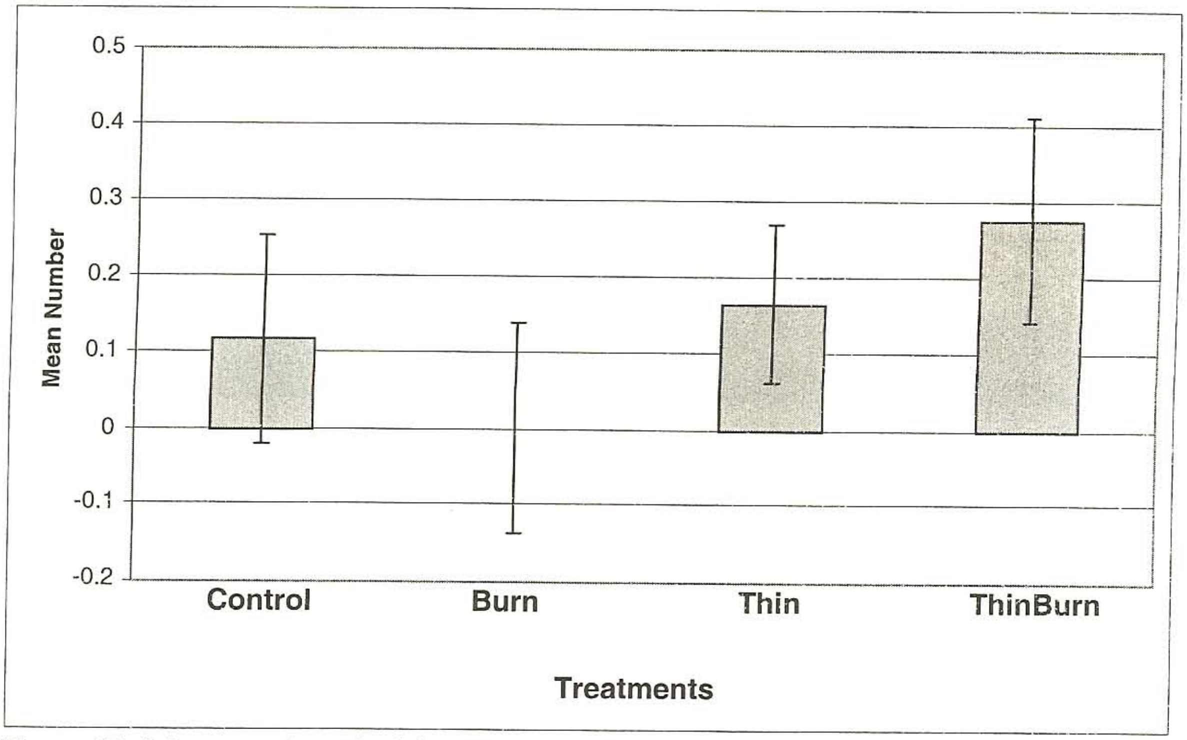

Figure 52. Mean number of adult *Hogna* spp. collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Significant differences were not found among the sampling dates (p=0.05).

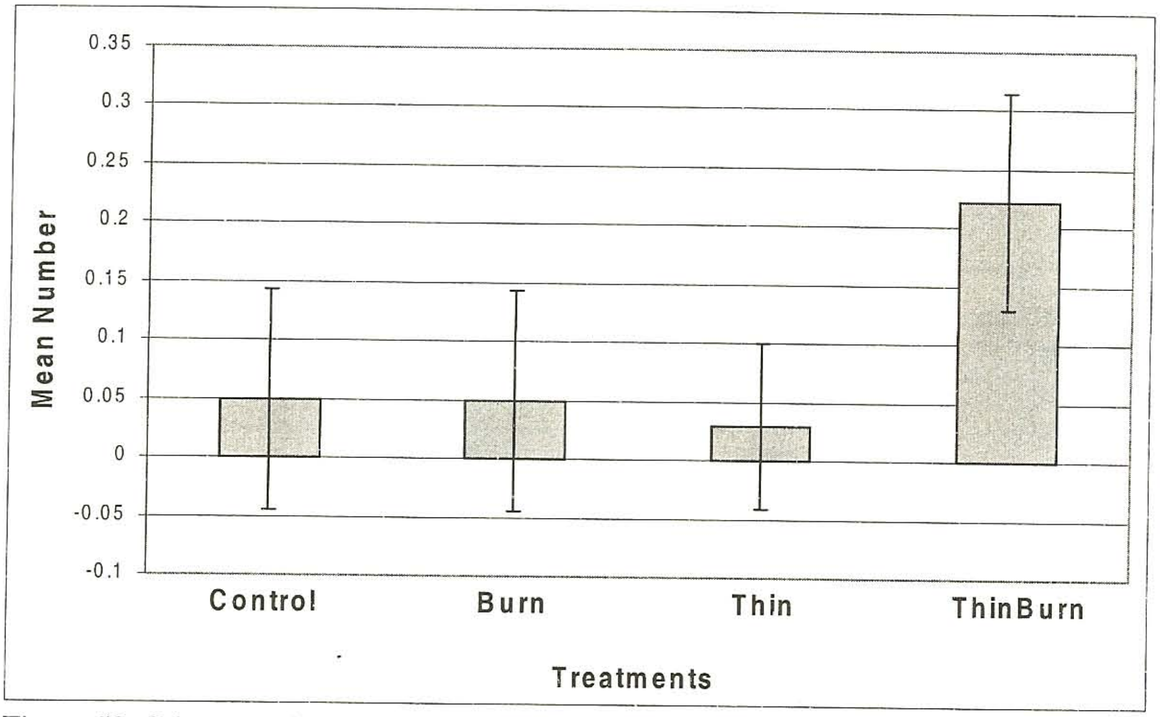

Figure 53. Mean number of *Hogna* spp. males collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Significant differences were not found among the sampling dates (p=0.05).

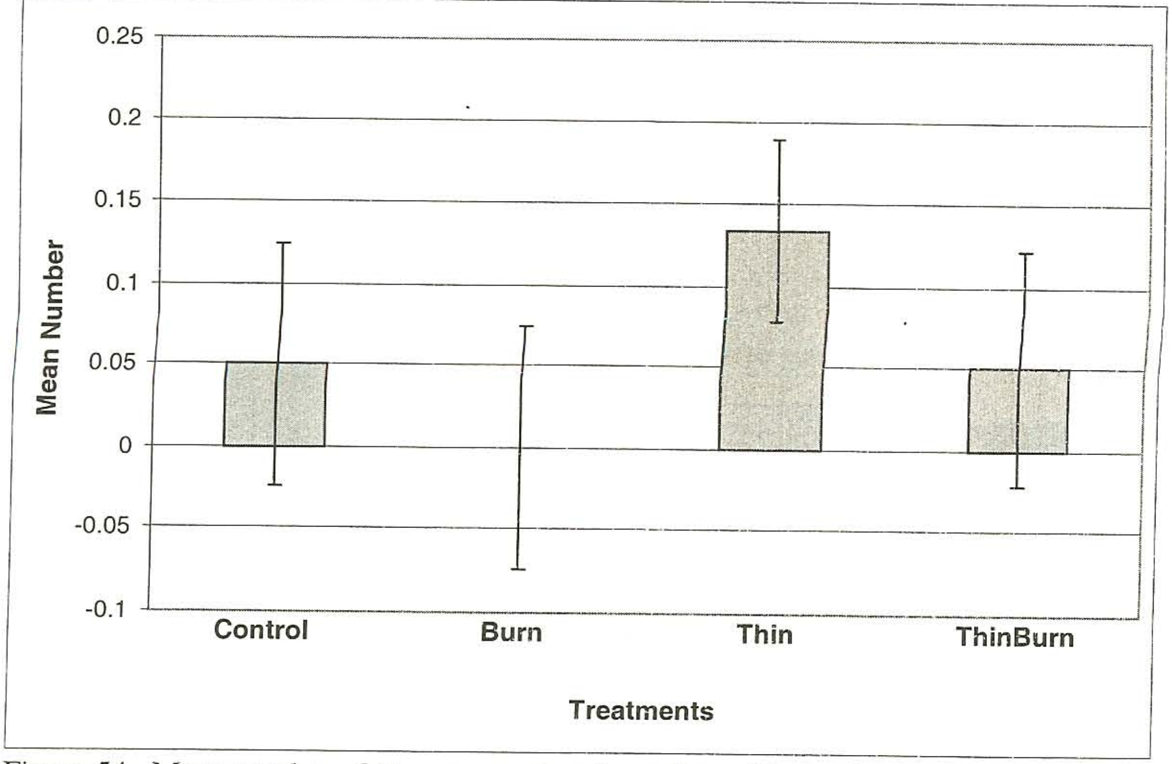

Figure 54. Mean number of *Hogna* spp. females collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Significant differences were not found among the sampling dates (p=0.05).

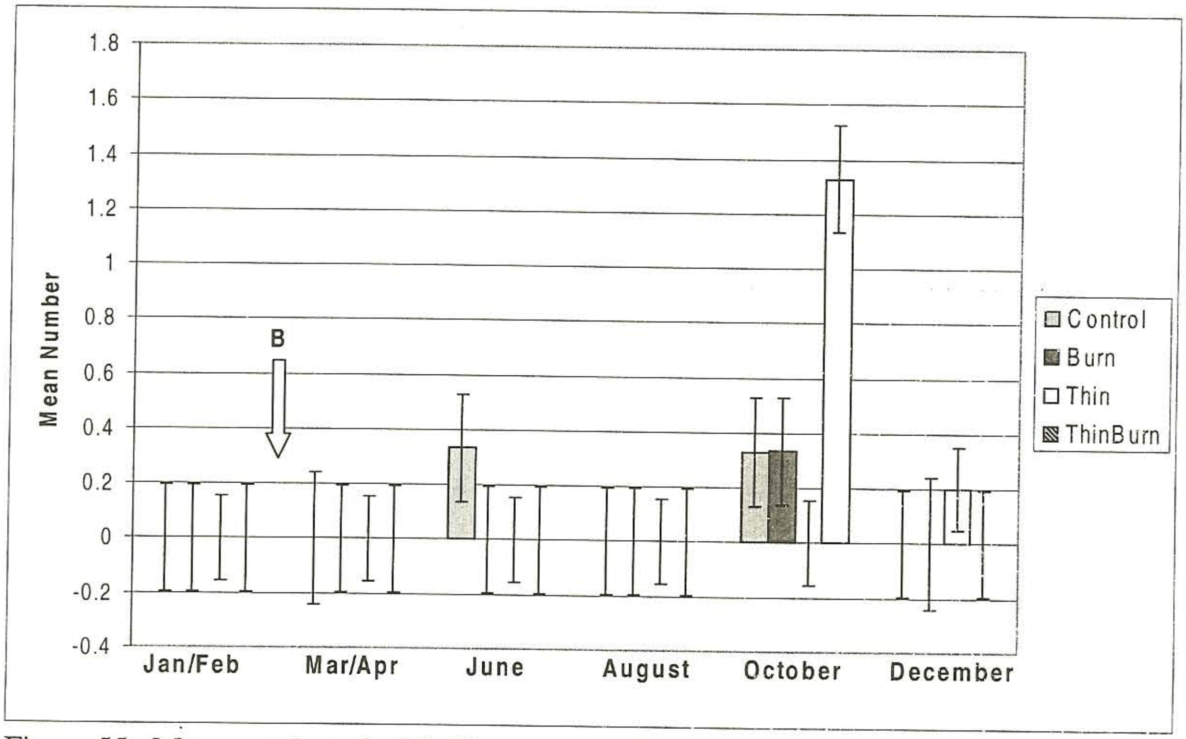

Figure 55. Mean number of adult *Hogna* spp. collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Pre-burn months include January/February. Post-burn months are March/April, June, August, October, and December. The B indicates when the burn occurred in the thin and burn plots in 2002.

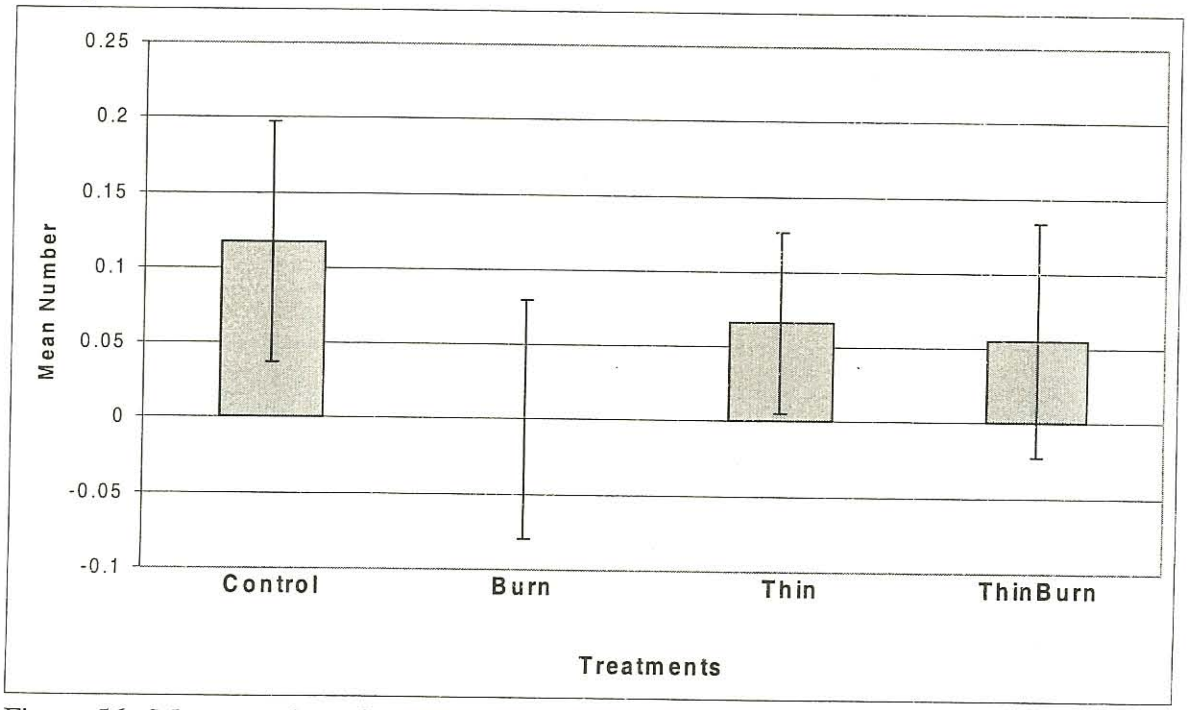

Figure 56. Mean number of adult *Pirata* spp. collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Significant differences were not found among the sampling dates (p=0.05).

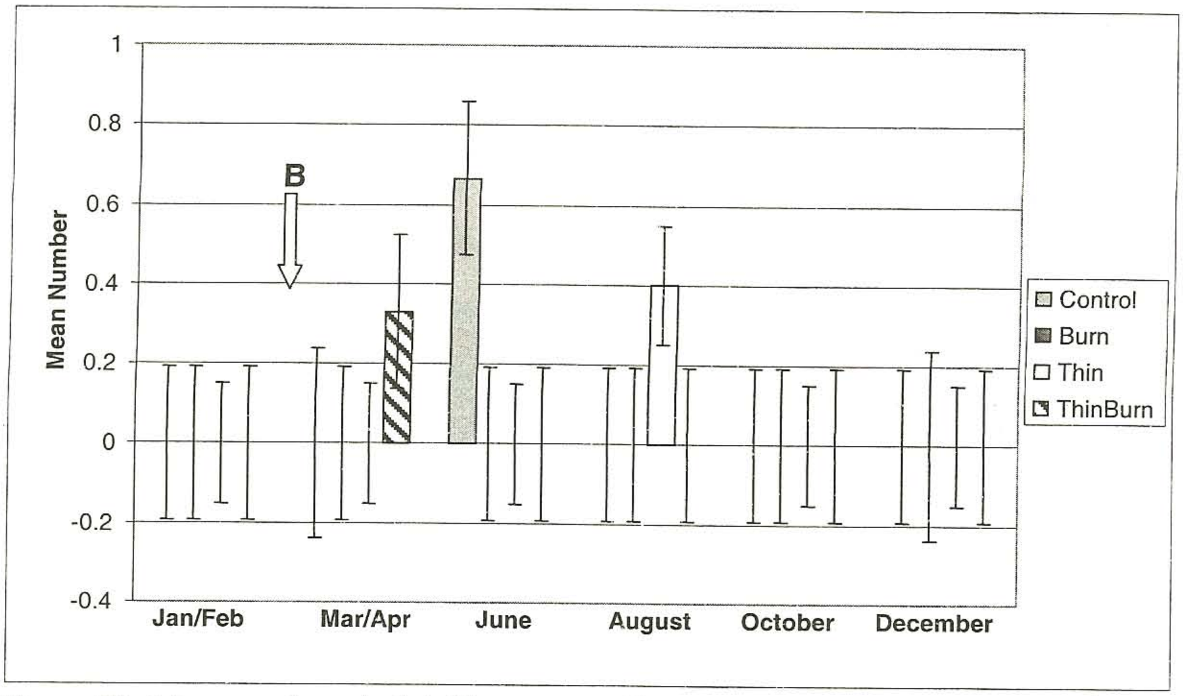

Figure 59. Mean number of adult *Pirata* spp. collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Pre-burn months include January/February. Post-burn months are March/April, June, August, October, and December. The B indicates when the burn occurred in the thin and burn plots in 2002.

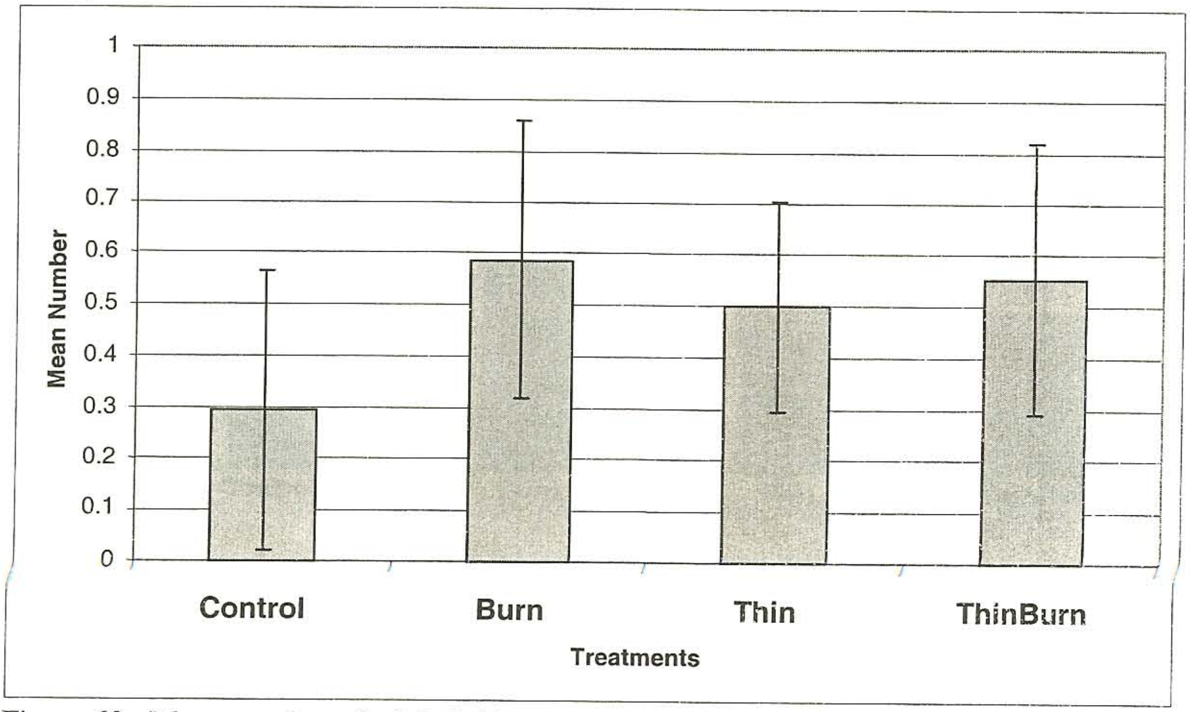

Figure 60. Mean number of adult *Schizocosa* spp. collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Significant differences were not found among the sampling dates (p=0.05).

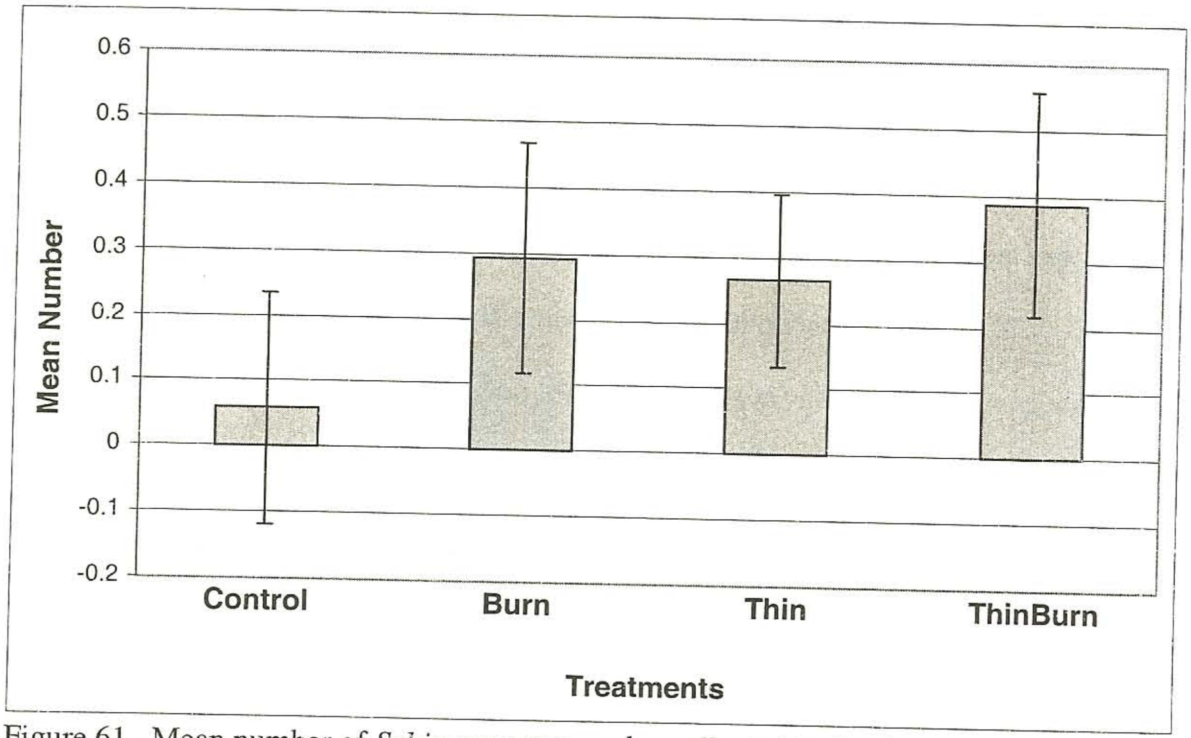

Figure 61. Mean number of *Schizocosa* spp. males collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Significant differences were not found among the sampling dates (p=0.05).

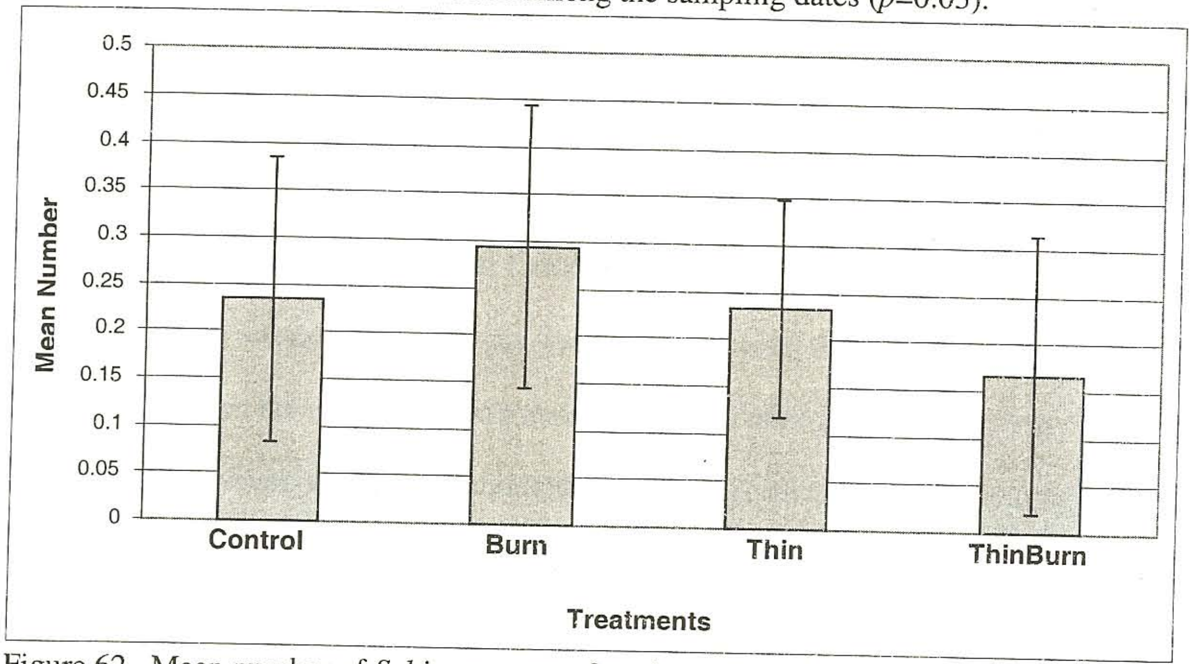

Figure 62. Mean number of *Schizocosa* spp. females collected during the six sampling periods in the Clemson Experimental Forest. Significant differences were not found among the sampling dates (p=0.05).

treatments and control plots. The mean number of *Shizocosa* spp. was not significantly different in the first post-burn sample compared to the pre-burn numbers in the thin and burn plots (*df*=23, *p*>0.05) (Figure 63).

There were no significant differences in the total numbers of *Varacosa* spp. (*df*=3, *F*=1.56, *p*=0.2066) (Figure 64) or in the mean numbers of males (*df*=3, *F*=1.59, *p*=0.1994) (Figure 65) nor females (*df*=3, *F*=1.86, *p*=0.1435) (Figure 66) among the three treatments and control plots. The mean numbers of *Varacosa* spp. were significantly lower in the first 2002 post-burn sample compared to the pre-burn numbers in the thin and burn plots (*df*=23, *p*=<0.0001) (Figure 67). Thin only plots were significantly lower in the first post-burn sample compared to the pre-burn numbers (*df*=23, *p*<0.05).

There were no significant differences in the total numbers of lycosid immatures (*df*=3, *F*=1.16, *p*=0.3310) (Figure 68) or in the mean numbers of immatures were not significantly different in the first post-burn sample compared to the pre-burn numbers in the thin and burn plots (*df*=23, *p*>0.05) (Figure 69).

Effect of Time versus Treatment on Lycosidae Genera Populations:

The mean number of *Hogna* spp. was not significantly different (*df*=23, *F*=1.28, *p*=0.2215) between the three treatments and control plots during the six sampling periods (Figure 55). However, when males and females were analyzed, the mean numbers of males per plot were significantly different (*df*=23, *F*=2.08, *p*=0.0130) between the three treatments and control plots during the six sampling periods (Figure 70). There were significantly higher numbers of males collected during October in the thin and burn plots

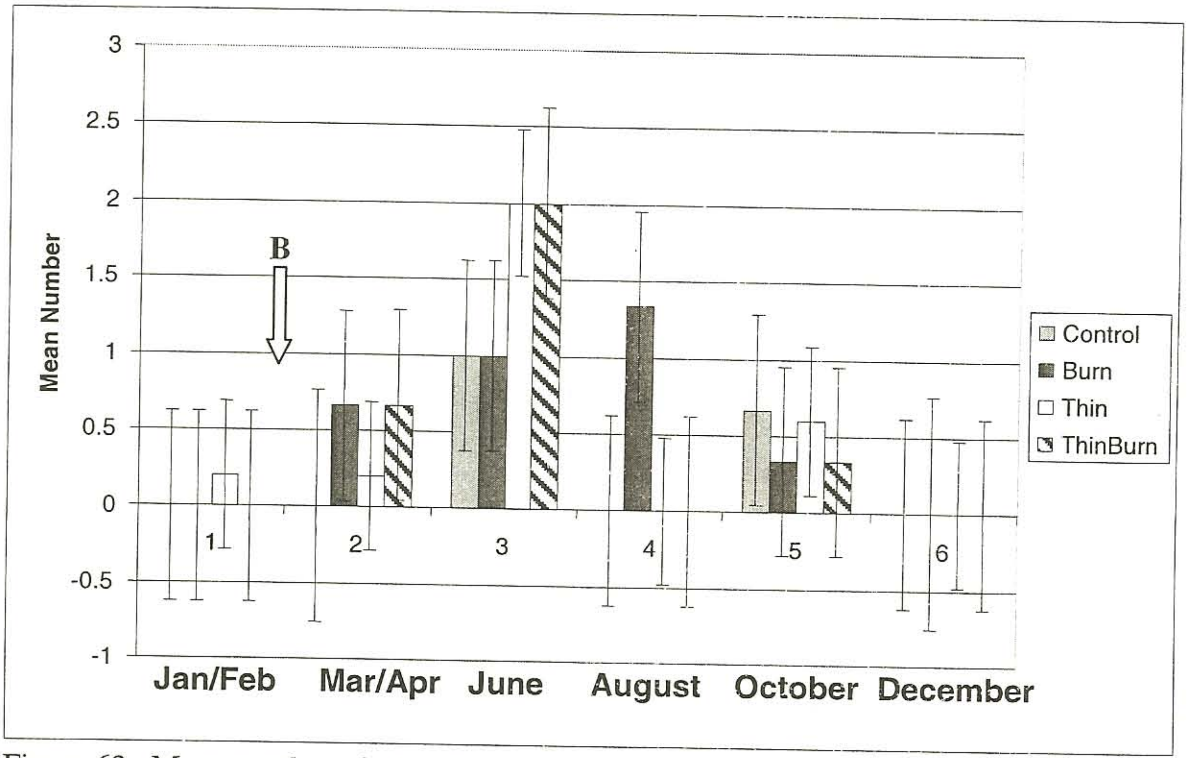

Figure 63. Mean number of adult *Schizocosa* spp. collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Pre-burn months include January/February. Post-burn months are March/April, June, August, October, and December. The B indicates when the burn occurred in the thin and burn plots in 2002.

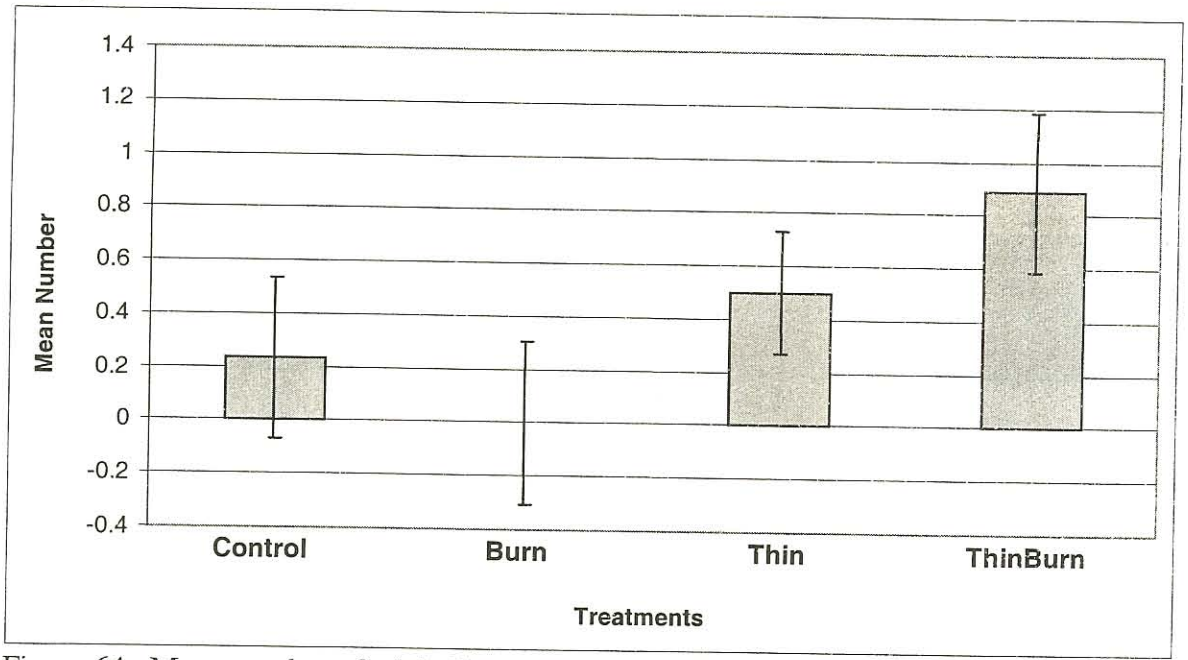

Figure 64. Mean number of adult *Varacosa* spp. collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Significant differences were not found among the sampling dates (p=0.05).

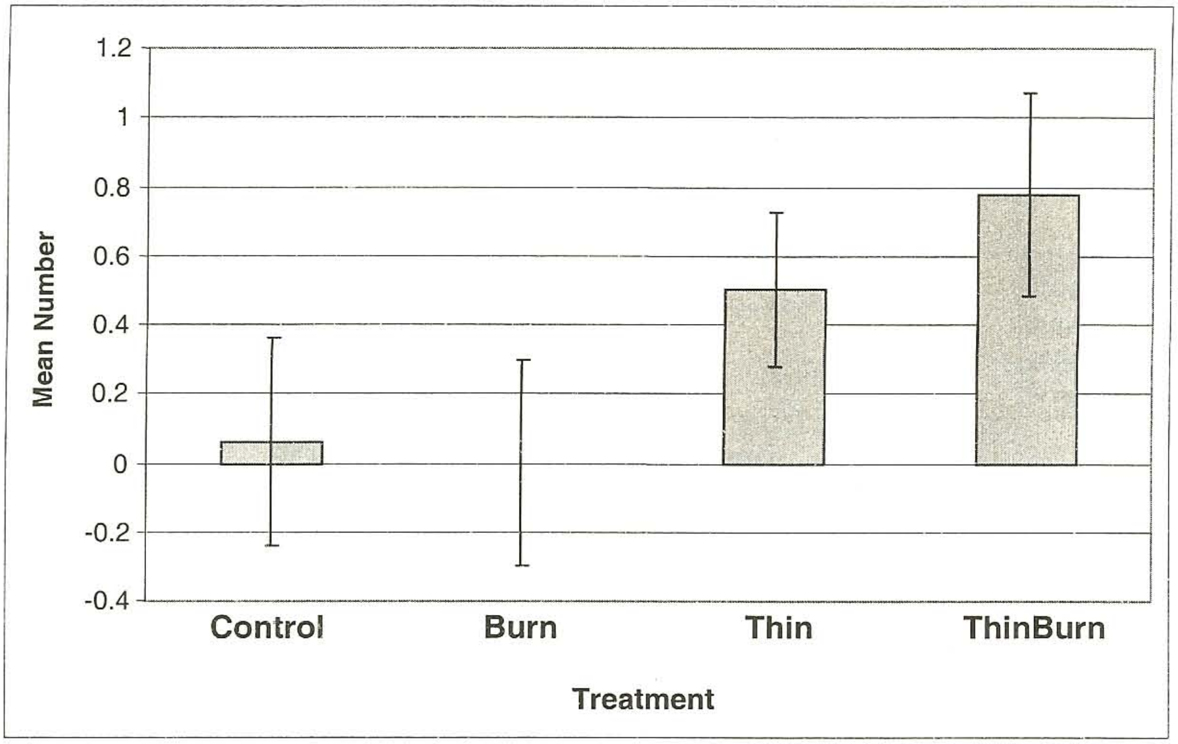

Figure 65. Mean number of *Varacosa* spp. males collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Significant differences were not found among the sampling dates (p=0.05).

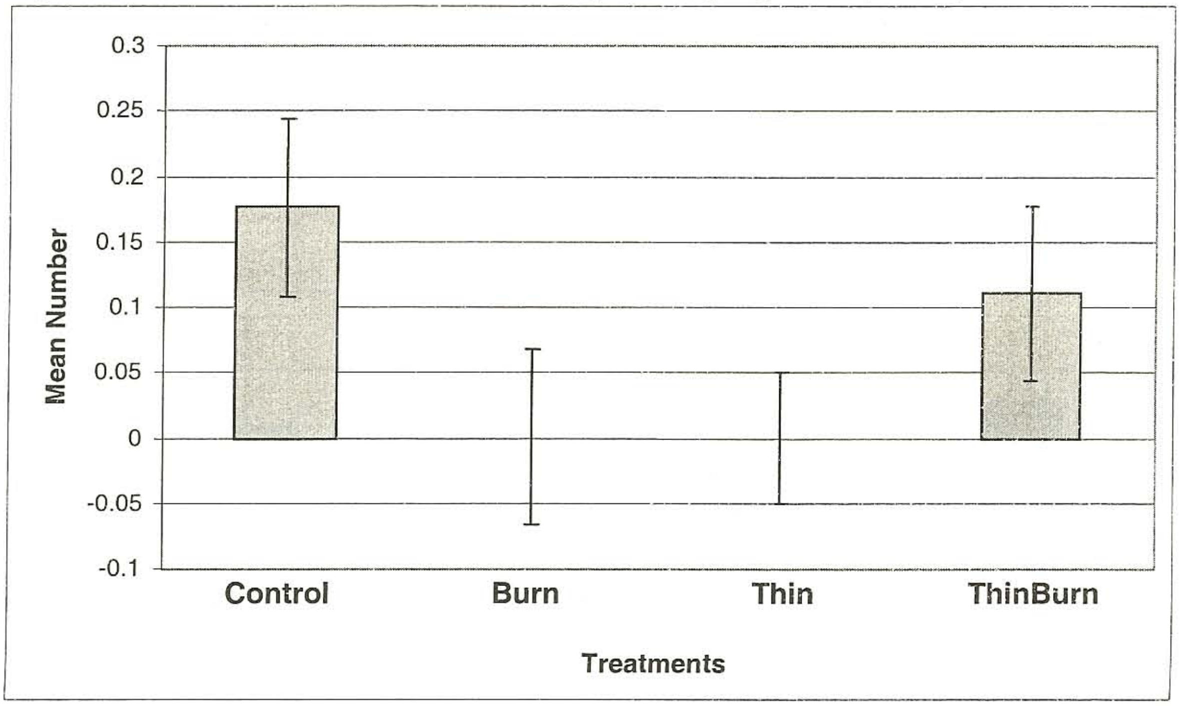

Figure 66. Mean number of *Varacosa* spp. females collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Significant difference were not found among the sampling dates (p=0.05).

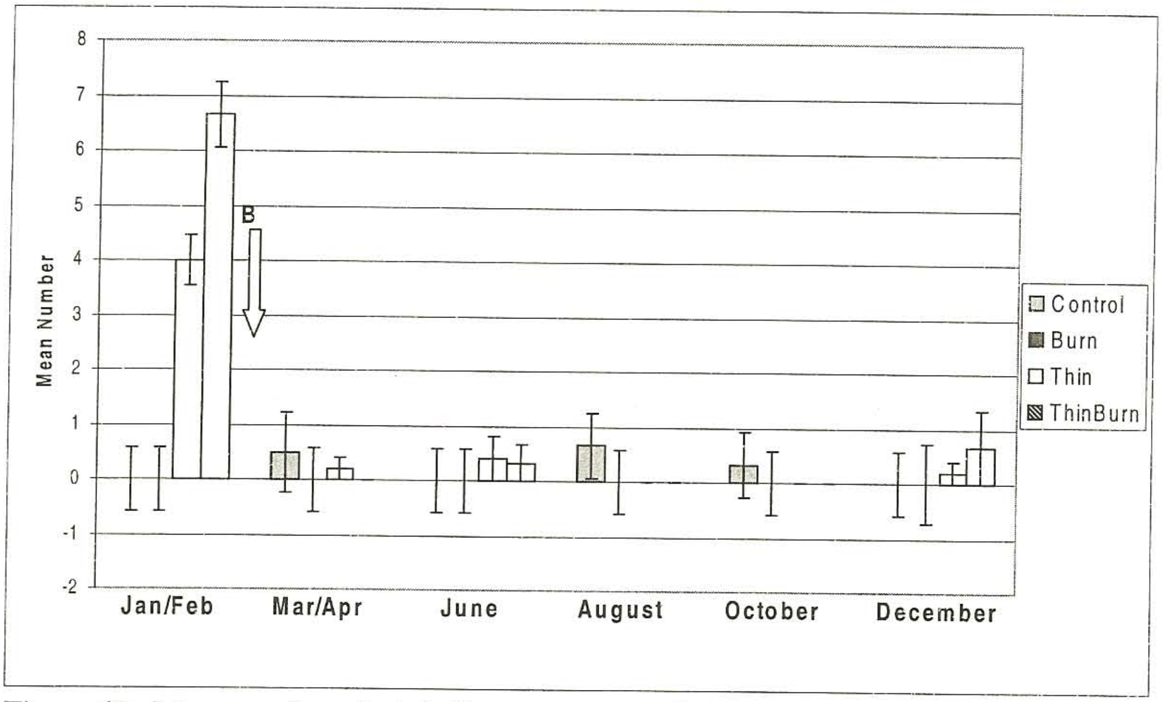

Figure 67. Mean number of adult *Varacosa* spp. collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Pre-burn months include January/February. Post-burn months are March/April, June, August, October, and December. The B indicates when the burn occurred in the thin and burn plots in 2002.

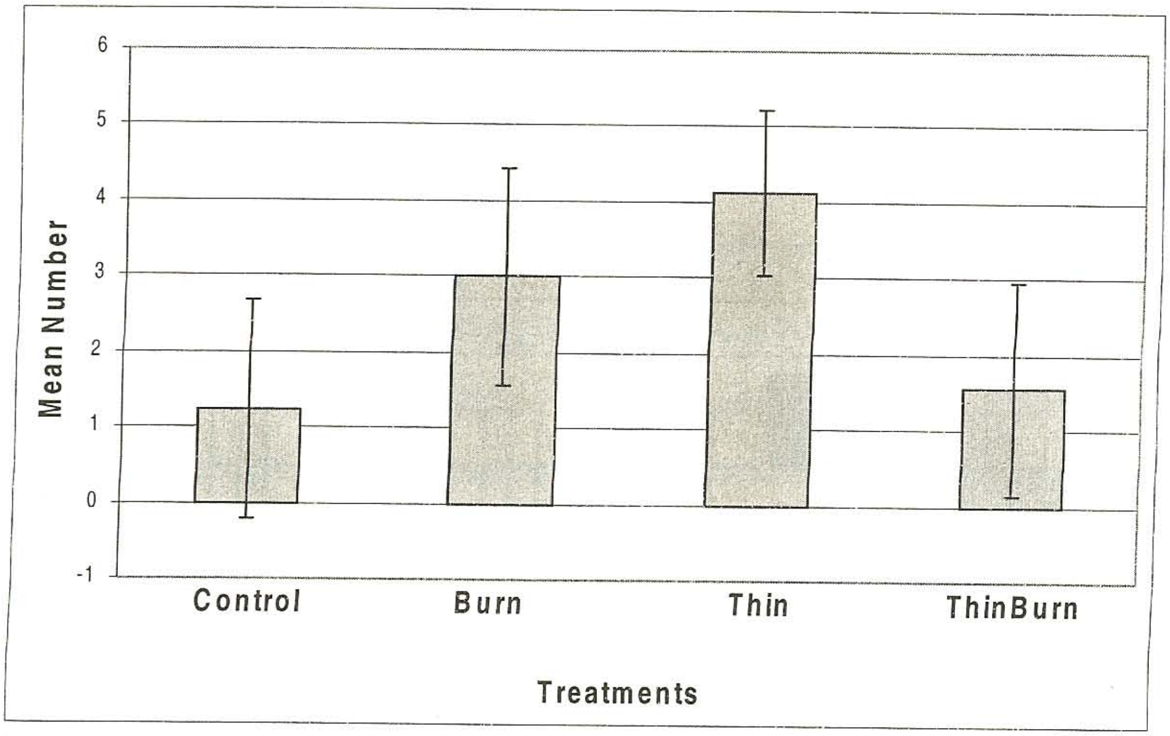

Figure 68. Mean number of immature Lycosidae collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Significant differences were not found among the sampling dates (p=0.05).

nor females (*df*=23, *F*=0.59, *p*=0.9168) (Figure 73) were significantly different among any treatment comparisons.

The numbers of *Schizocosa* spp. were not significantly different (*df*=23, *F*=1.21, *p*=0.2765) among the three treatments and control plots during the six sampling periods (Figure 63). Neither the mean numbers of males (*df*=23, *F*=1.33, *p*=0.1906) (Figure 74) nor females (*df*=23, *F*=1.38, *p*=0.1621) (Figure 75) were significantly different among the treatments and control plots during the six sampling periods.

The numbers of *Varacosa* spp. were significantly different (*df*=23, *F*=3.66, *p*=<.0001) among the three treatments and control plots during the six sampling periods. During January/February, mean numbers in the control plots were significantly lower than thin and burn plots (df=23, p=0.0001). During March/April, June, August, October, and December.than thin only (*df*=23, *p*=0.0049) and thin and burn plots (*df*=23, *p*=<0.0001), but were not significantly different than burn only plots (*df*=23, compared to control plots (*df*=23, *p*=0.0007), burn only (*df*=23, *p*=0.0007), and thin only plots (*df*=23, *p*=<0.0001). No significant differences in mean numbers of *Hogna* spp. were found among the control plots and the other three treatments (*df*=23, *p*>0.05). During January/February, March/April, June, August, or December, no significant differences were found among the three treatments and control plots (df=23, p>0.05) (Figure 50). No significant differences were found in the mean numbers of females in any treatment comparison (*df*=23, *F*=0.53, *p*=0.9201) (Figure 71).

The number of *Pirata* spp. was not significantly different (*df*=23, *F*=0.83, *p*=0.6768) among the three treatments and control plots during the six sampling periods (Figure 59). Neither the mean numbers of males (*df*=23, *F*=1.18, *p*=0.3008) (Figure 72) nor females (*df*=23, *F*=0.59, *p*=0.9168) (Figure 73) were significantly different among any treatment comparisons.

The numbers of *Schizocosa* spp. were not significantly different (*df*=23, *F*=1.21, *p*=0.2765) among the three treatments and control plots during the six sampling periods (Figure 63). Neither the mean numbers of males (*df*=23, *F*=1.33, *p*=0.1906) (Figure 74) nor females (*df*=23, *F*=1.38, *p*=0.1621) (Figure 75) were significantly different among the treatments and control plots during the six sampling periods.

The numbers of *Varacosa* spp. were significantly different (*df*=23, *F*=3.66, *p*=<.0001) among the three treatments and control plots during the six sampling periods. During January/February, mean numbers in the control plots were significantly lower than thin and burn plots (df=23, p=0.0001). During March/April, June, August, October, and December.than thin only (*df*=23, *p*=0.0049) and thin and burn plots (*df*=23, *p*=<0.0001), but were not significantly different than burn only plots (*df*=23,

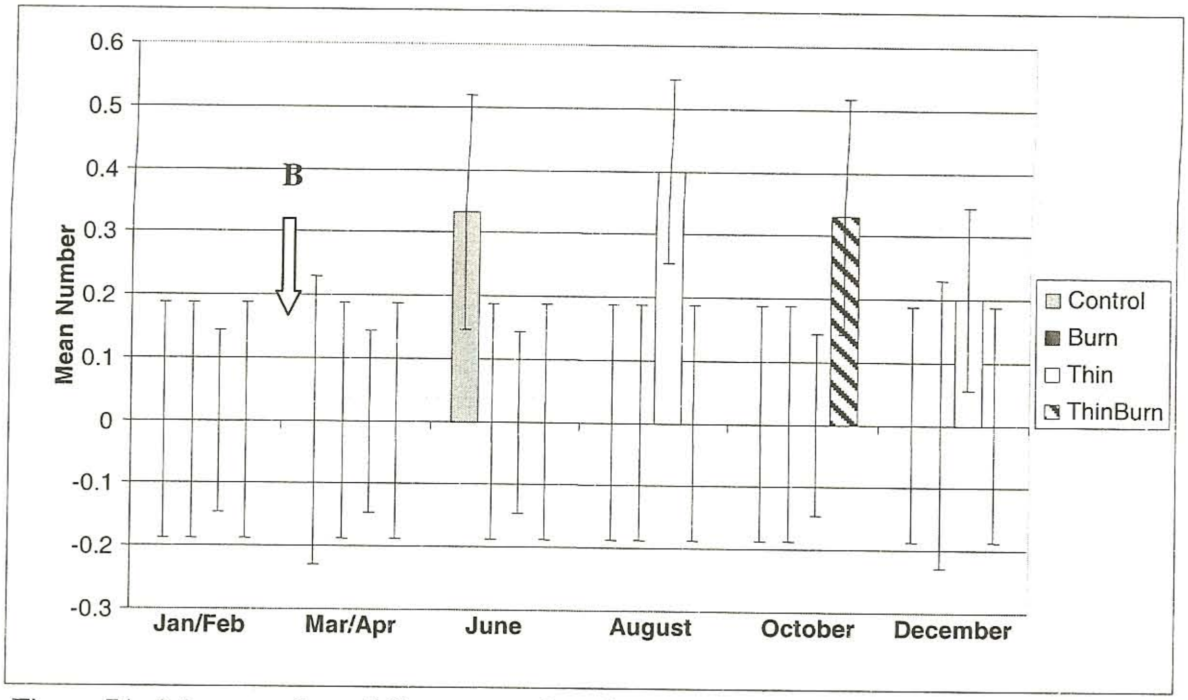

Figure 71. Mean number of *Hogna* spp. females collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Pre-burn months include January/February. Post-burn months are March/April, June, August, October, and December. The B indicates when the burn occurred in 2002

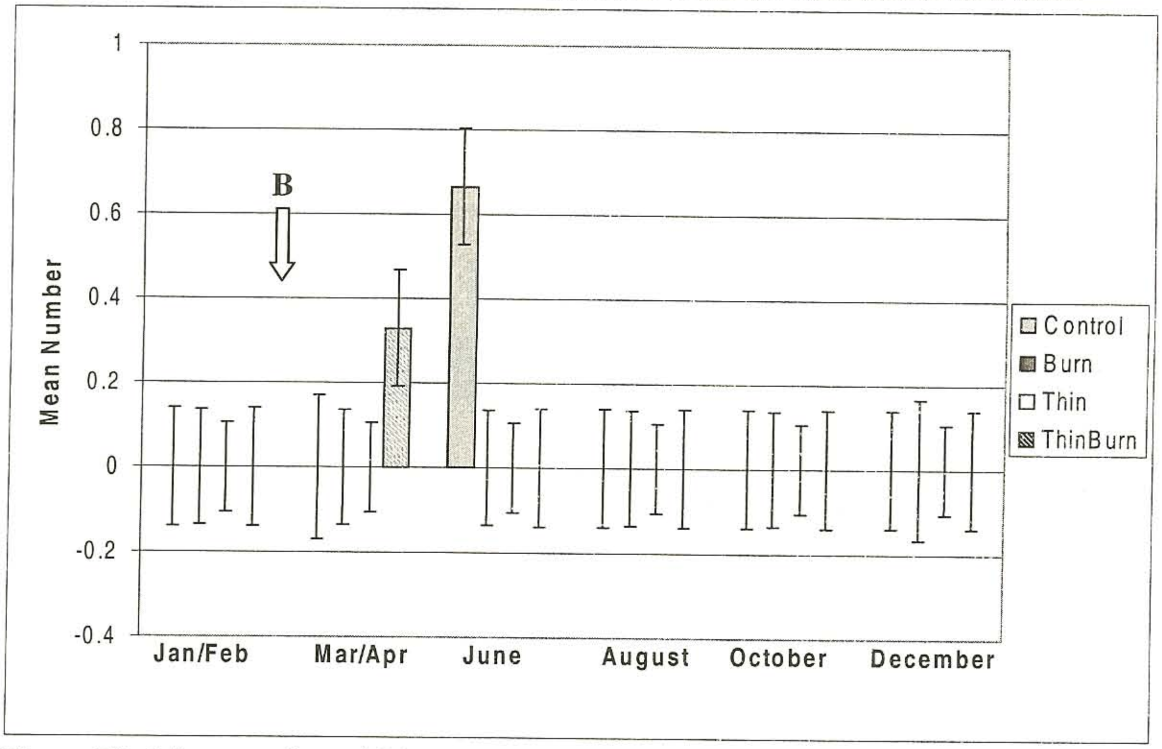

Figure 72. Mean number of *Pirata* spp. males collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Pre-burn months include January/February. Post-burn months are March/April, June, August, October, and December. The B indicates when the burn occurred in 2002.

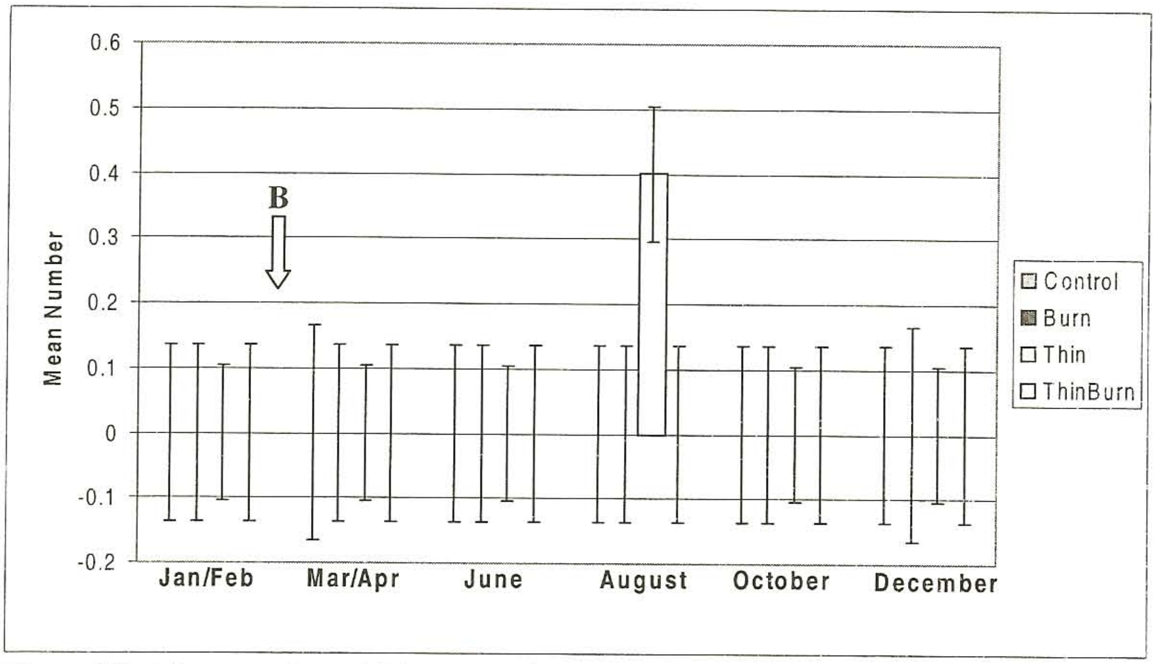

Figure 73. Mean number of *Pirata* spp. females collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Pre-burn months include January/February. Post-burn months are March/April, June, August, October, and December. The B indicates when the burn occurred in 2002.

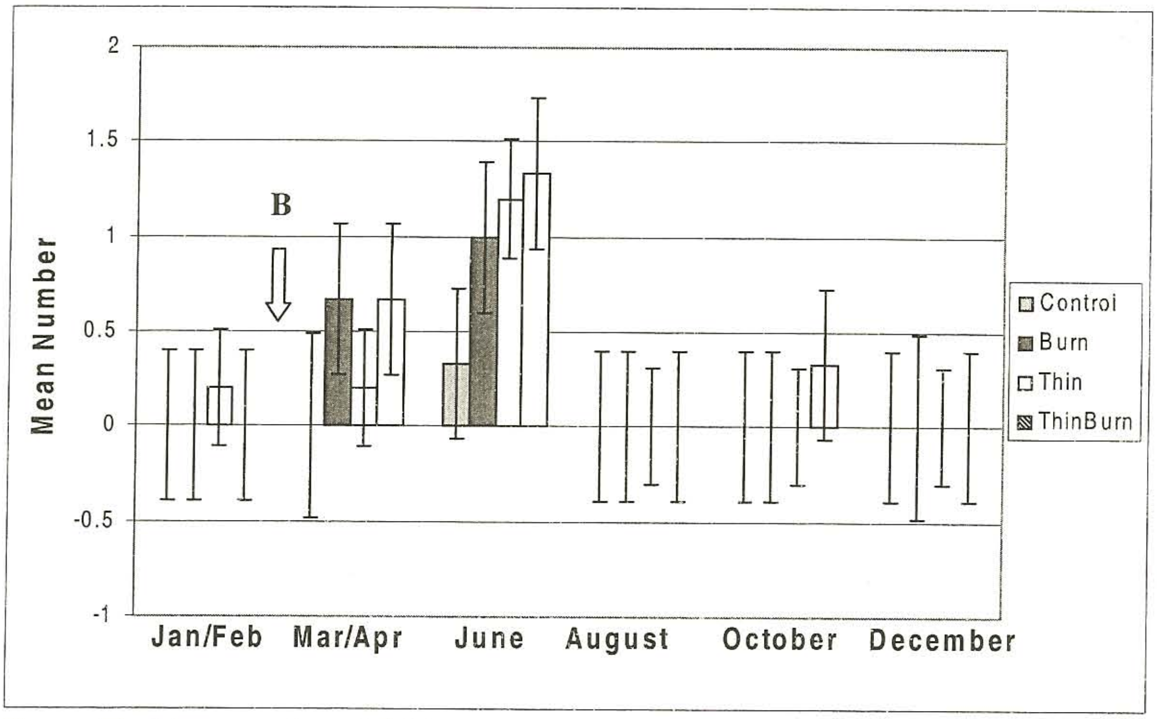

Figure 74. Mean number of *Schizocosa* spp. males collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Pre-burn months include January/February. Post-burn months are March/April, June, August, October, and December. The B indicates when the burn occurred in 2002.

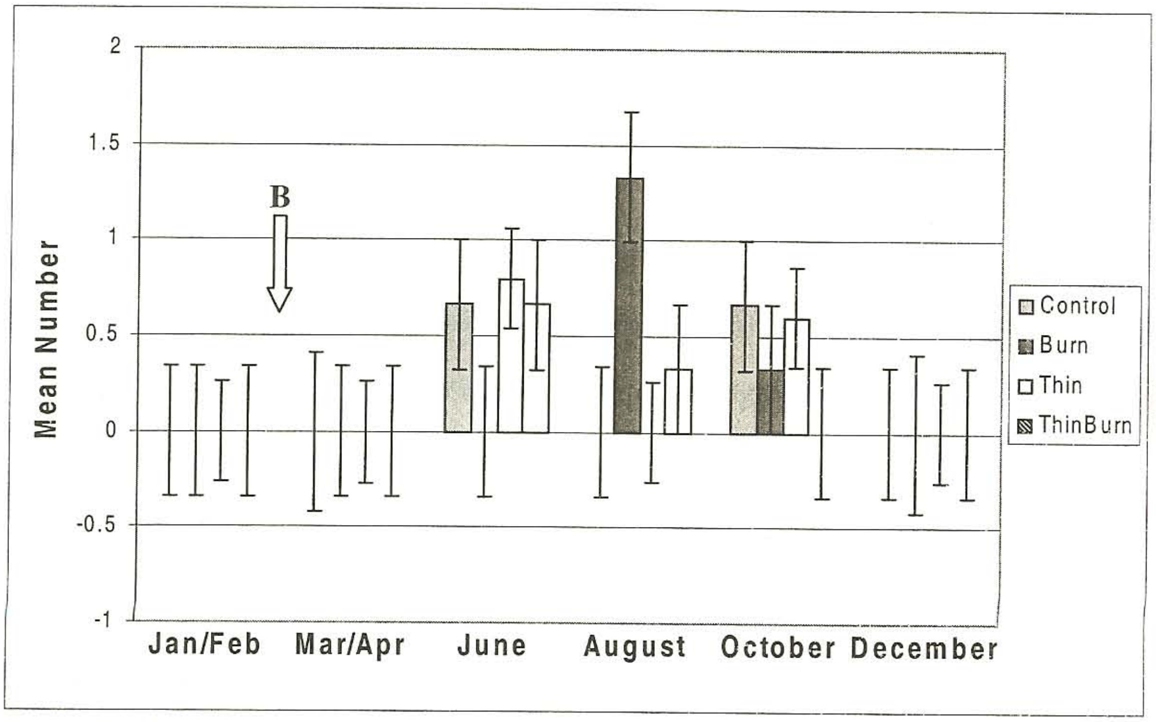

Figure 75. Mean number of *Schizocosa* spp. females collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Pre-burn months include January/February. Post-burn months are March/April, June, August, October, and December. The B indicates when the burn occurred in the thin and burn plots in 2002.

p=1.000). The mean numbers in burn only plots were significantly lower than thin only (df=23, p=0.0049) and thin and burn plots (df=23, p=<0.0001). Mean numbers in the thin only plots were significantly lower than thin and burn plots (df=23, p=0.0062). During March/April, June, August, October, and December, no significant differences were found among the three treatments and control plots (df=23, p>0.05) (Figure 67).

The mean numbers of male *Varacosa* spp. were significantly different during the six sampling periods among the three treatments and control plots (df=23, F=3.33, p=0.0001). In January/February, mean numbers in the control plot were significantly lower than thin only (df=23, p=0.0053) and thin and burn plots (df=23, p=<0.0001), but were not significantly different from numbers in the burn only plots (df=23, p=1.00). Mean numbers in the burn only plots were significantly lower than thin only (df=23, p=0.0053) and thin and burn plots (df=23, p=<0.0001). Mean numbers in the thin only plots were significantly different than in the thin and burn plots (df=23, p=0.0212) (Figure 76). During March/April, June, August, October, and December, no significant differences were found among the three treatments and control plots (df=23, p>0.05). No significant differences were found in the mean numbers of females in any treatment comparison (df=23, F=1.10, p=0.3769) (Figure 77).

The mean numbers of immature spiders were not significantly different during the six sampling periods among the three treatments and control plots (df=23, F=0.44, p=0.9833 (Figure 69).

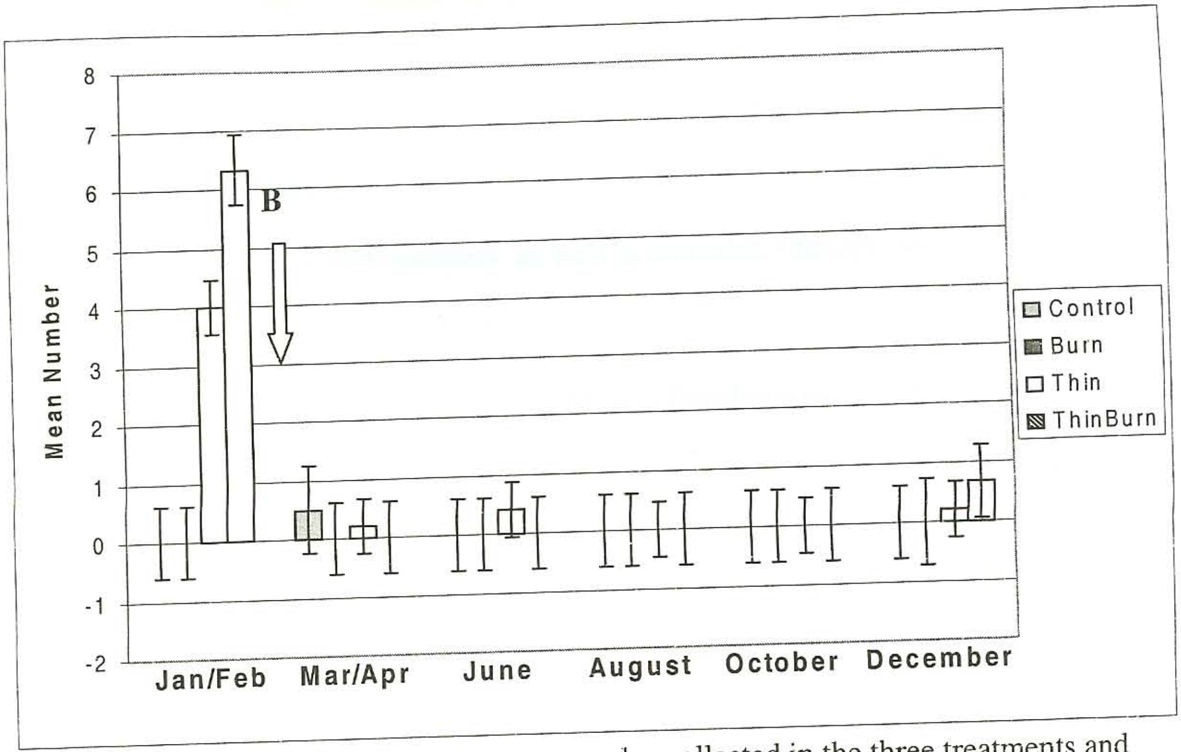

Figure 76. Mean number of *Varacosa* spp. males collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Pre-burn months include January/February. Post-burn months are March/April, June, August, October, and December. The B indicates when the burn occurred in 2002.

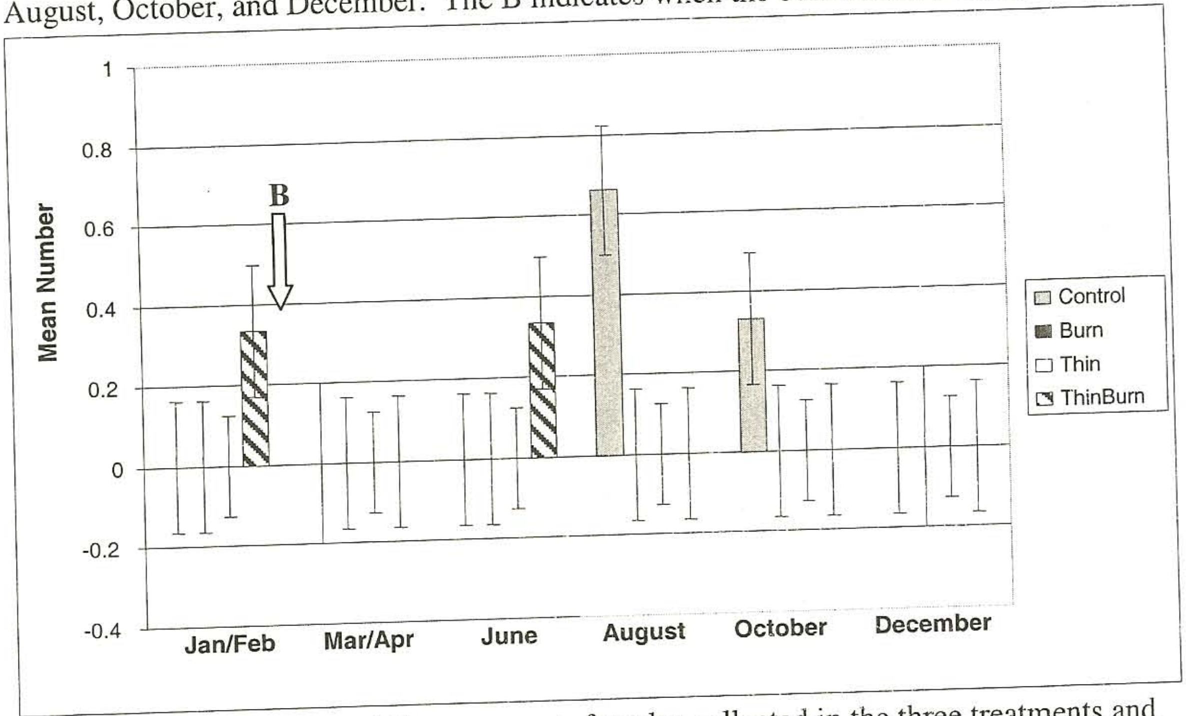

Figure 77. Mean number of *Varacosa* spp. females collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Pre-burn months include January/February. Post-burn months are March/April, June, August, October, and December. The B indicates when the burn occurred in 2002.

Fuel Load Management Treatments on *G. fontinalis*:

Due to large numbers of *G. fontinalis* being collected throughout the six sampling periods, analyses were conducted to determine the effects of time, treatment, and timeversus treatment on total numbers, as well as on males, females, and immatures.

Effect of Sampling Date on *Gnaphosa fontinalis* Populations:

Mean numbers of *G. fontinalis* per plot were significantly different among the six sampling periods (*df*=5, *F*=10.16, *p*=<0.001) (Figure 78). From January/February to June mean numbers per plot increased, and then decreased in August. After August, mean numbers of *G. fontinalis* increased again. Males were signficantly higher in June (*df*=5, *F*=22.56, *p*=<0.0001) (Figure 79). Numbers of females were significantly different among the six sampling periods (*df*=5, *F*=6.95, *p*=<0.0001), with the highest numbers of females collected in June. After June, mean numbers of females per plot decreased until October (Figure 80). Numbers of immature *G. fontinalis* also were significantly different among the six sampling periods (*df*=5, *F*=3.31, *p*=0.0094). Mean numbers of immatures per plot stayed relatively constant until October, when a significant increase occurred (*df*=5, *p*=0.0037) (Figure 81).

Overall, mean numbers of *G. fontinalis* increased during the early sampling periods and then decreased during the summer months. Males and females were collected in the largest numbers during June and then decreased.

Effect of Treatment on *Gnaphosa fontinalis* Populations:

The numbers of *G. fontinalis* were not significantly different among the three treatments and control plots (*df*=3, *F*=0.07, *p*=0.9757) (Figure 82). No significant

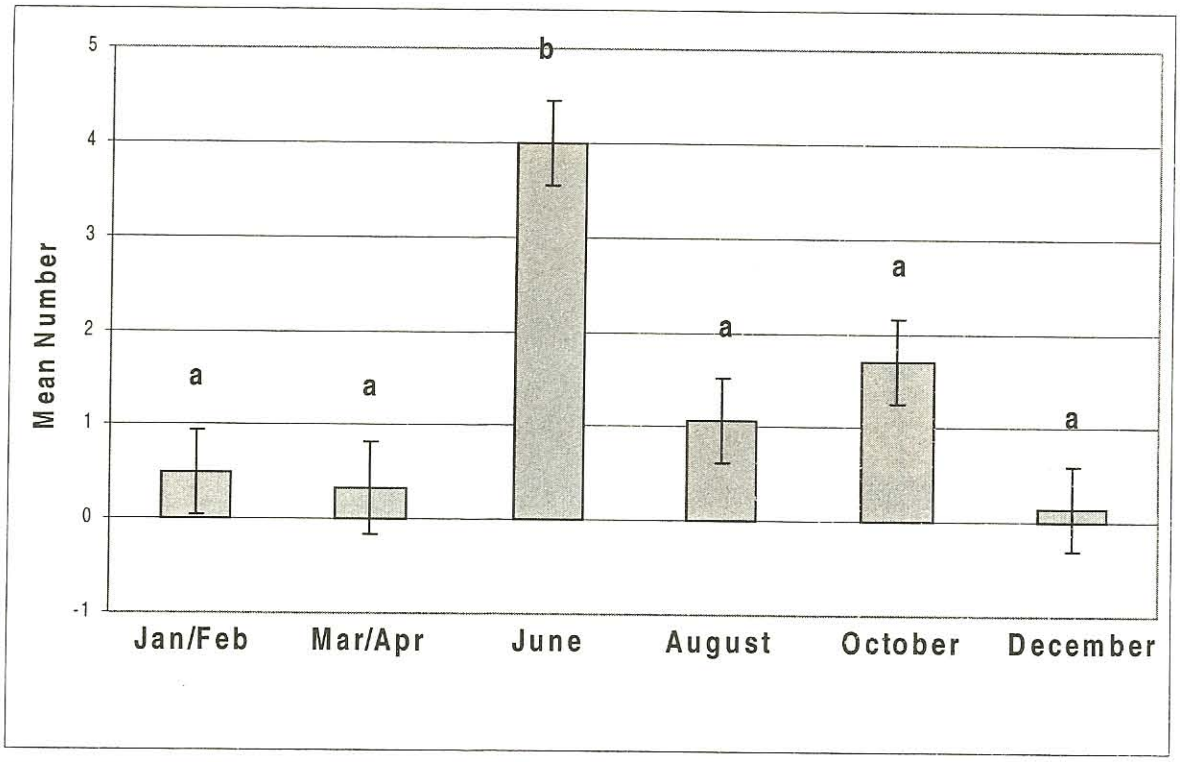

Figure 78. Mean number of adult and immature *Gnaphosa fontinalis* (Gnaphosidae) collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among the sampling dates (p=0.05).

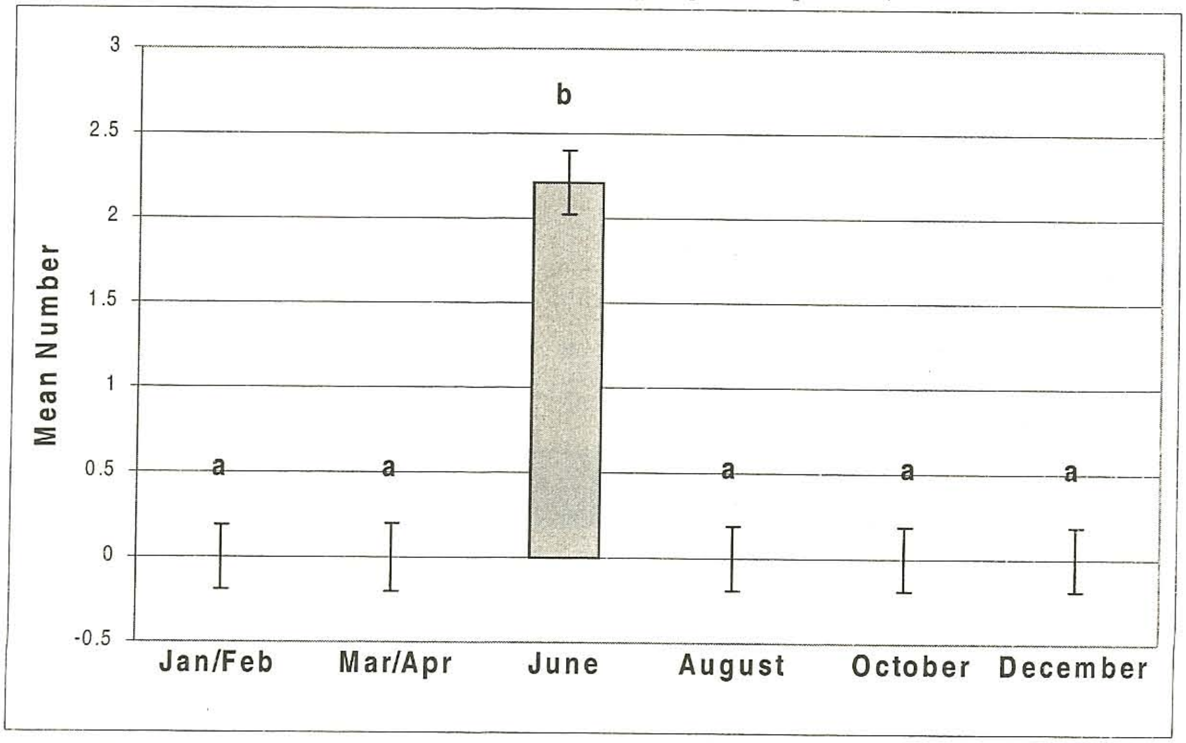

Figure 79. Mean number of *Gnaphosa fontinalis* (Gnaphosidae) males collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among the sampling dates (p=0.05).

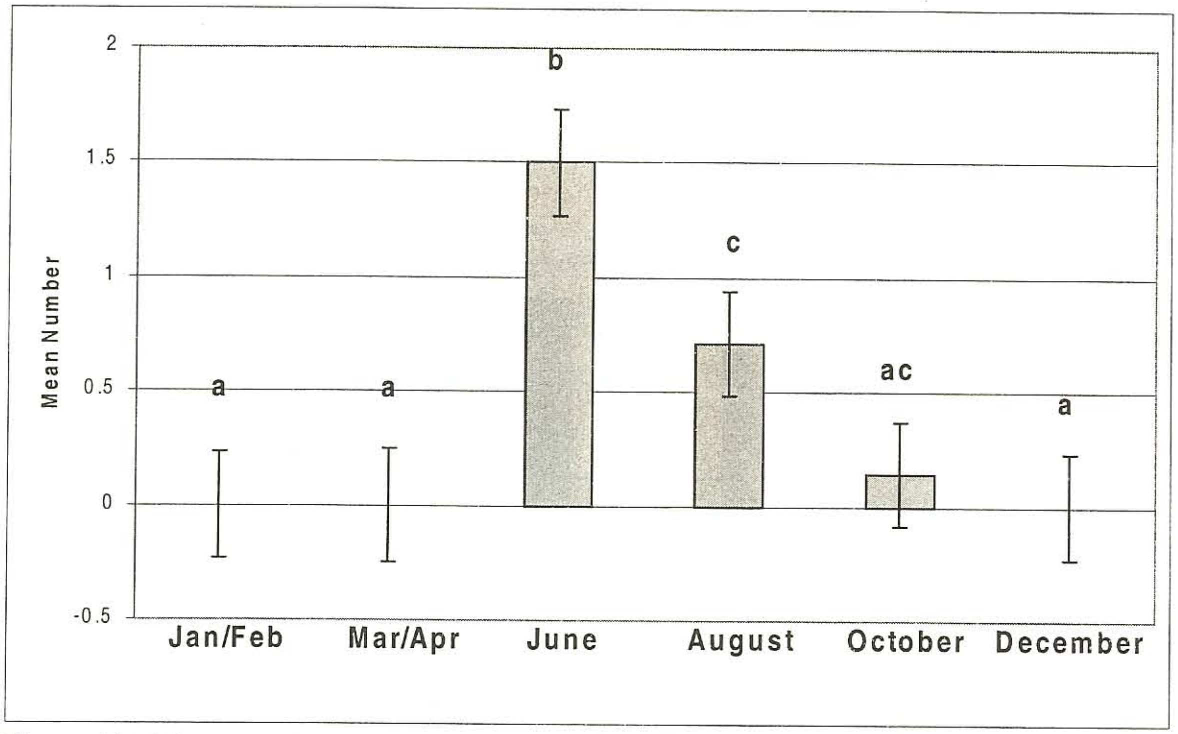

Figure 80. Mean number of *Gnaphosa fontinalis* (Gnaphosidae) females collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among the sampling dates (p=0.05).

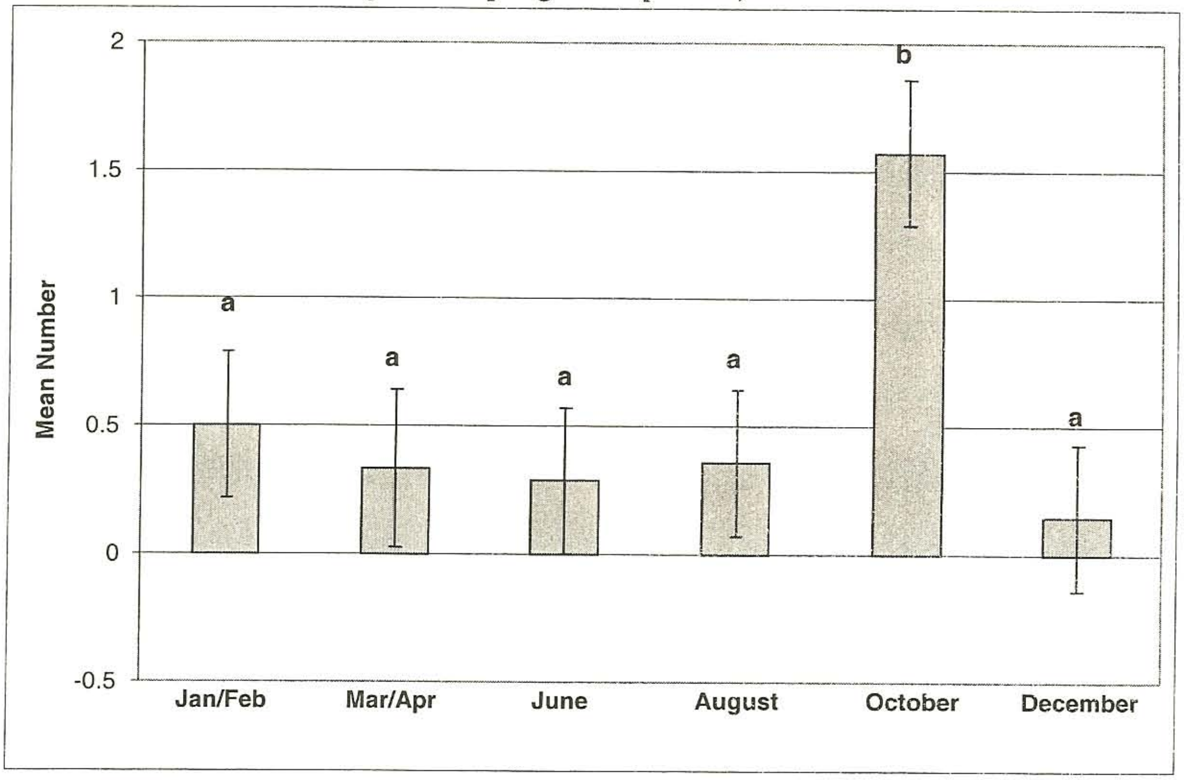

Figure 81. Mean number of *Gnaphosa fontinalis* (Gnaphosidae) immatures collected during the six sampling periods in the Clemson Experimental Forest. A significant difference was found among the sampling dates (p=0.05).

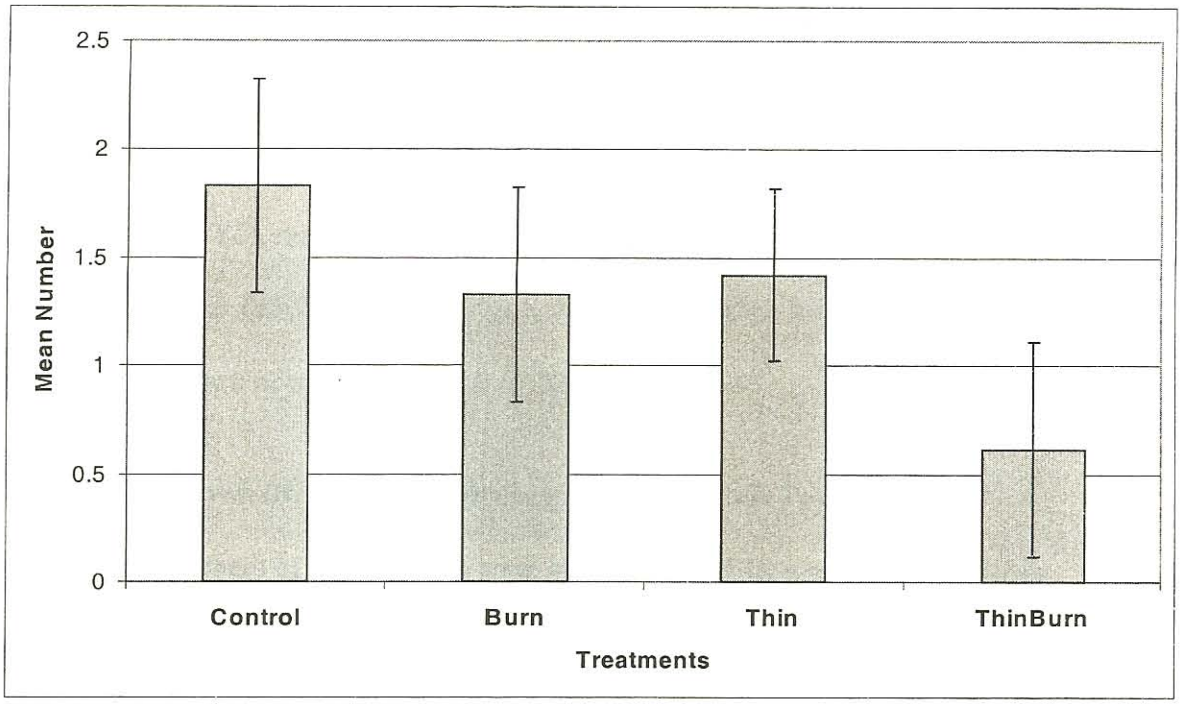

Figure 82. Mean number of adult and immature *Gnaphosa fontinalis* collected in the three treatments and control plots in the Clemson Experimental Forest. Significant differences were not found among the three treatments and control plots (p=0.05).

differences were found among the mean numbers of males (*df*=3, *F*=0.07, *p*=0.9757) (Figure 83) or females (*df*=3, *F*=1.34, *p*=0.2684) (Figure 84) among the three treatments and control plots. No significant differences were found for total individuals (*df*=23, *p*>0.05) (Figure 85), males (*df*=23, *p*>0.05) (Figure 86), females (*df*=23, *p*>0.05) (Figure 87), or immatures (*df*=23, *p*>0.05) (Figure 88) following the burn in the thin and burn plots after the burn occurred in March of 2002.

Effect of Time versus Treatment on *Gnaphosa fontinalis* Populations:

The numbers of *G. fontinalis* were significantly different among the three treatments and control plots during the six sampling periods (*df*=23, *F*=2.61, *p*=0.0017). In June, mean numbers in thin and burn plots were significantly lower than in the control (*df*=23, *p*=0.0127) and burn only plots (*df*=23, *p*=0.0396), but were not significantly different than in the thin only plots (*df*=23, *p*=0.0516). No significant differences were found in mean numbers of *G. fontinalis* between control plots and burn only (*df*=23, *p*=0.6147) or thin only plots (*df*=23, *p*=0.3776). Mean numbers in burn only plots were not significantly different than in thin only plots (*df*=23, *p*=0.7156). During January/February, March/April, August, October, or December, no significant differences were found among the three treatments and control plots (*df*=23, *p*>0.05) (Figure 85).

Mean numbers of males collected in June were significantly higher (*df*=23, *p*<0.05) than the other 5 sampling periods (Figure 86). Numbers of female *G. fontinalis* were significantly different among the three treatments and control plots (*df*=23, *F*=2.12, *p*=0.0110). In June, mean numbers of females per plot were significantly lower in the thin and burn plots compared to control (*df*=23, *p*=0.0018), burn only (*df*=23, *p*=0.0231), and thin only plots (*df*=23, *p*=0.0066). No significant differences were found among the

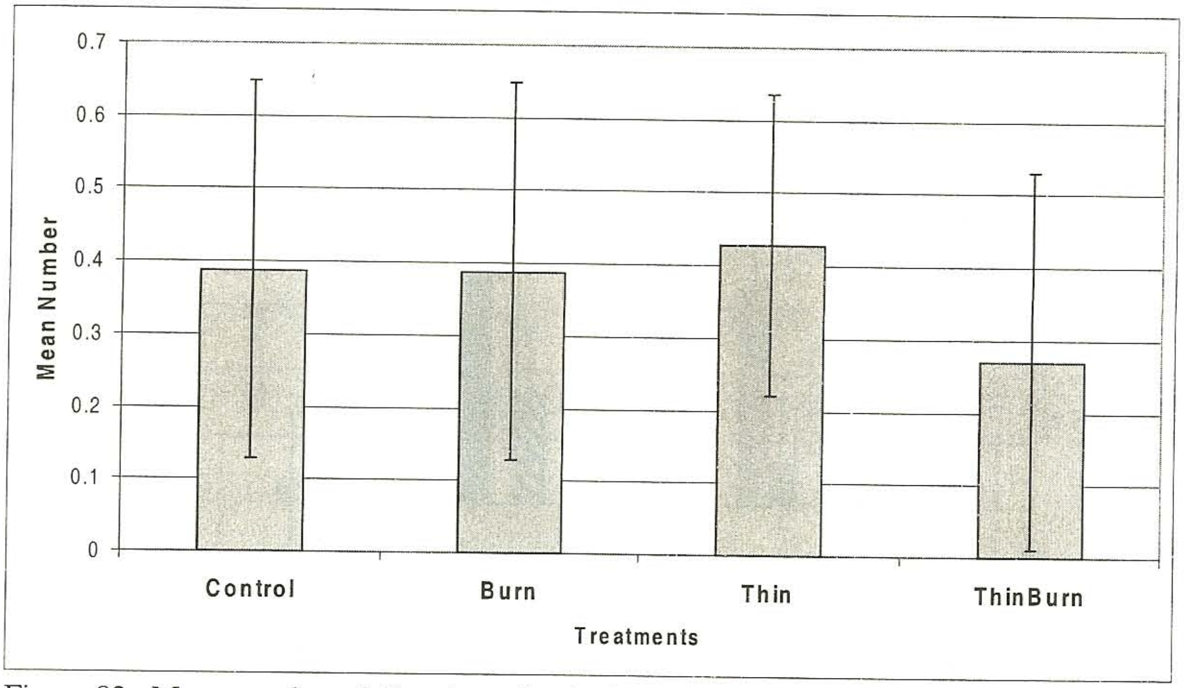

Figure 83. Mean number of *Gnaphosa fontinalis* males collected in the three treatments and control plots in the Clemson Experimental Forest. Significant differences were not found among the three treatments and control plots (p=0.05).

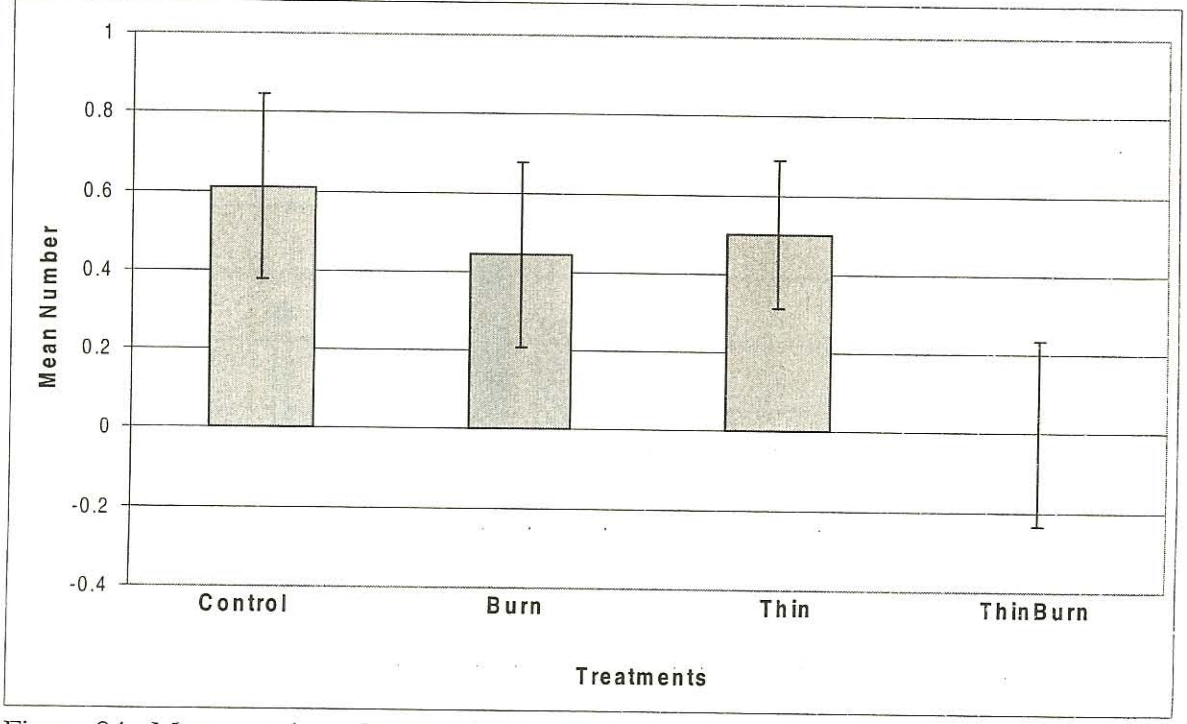

Figure 84. Mean number of *Gnaphosa fontinalis* females collected in the three treatments and control plots in the Clemson Experimental Forest. Significant differences were not found among the three treatments and control plots (p=0.05).

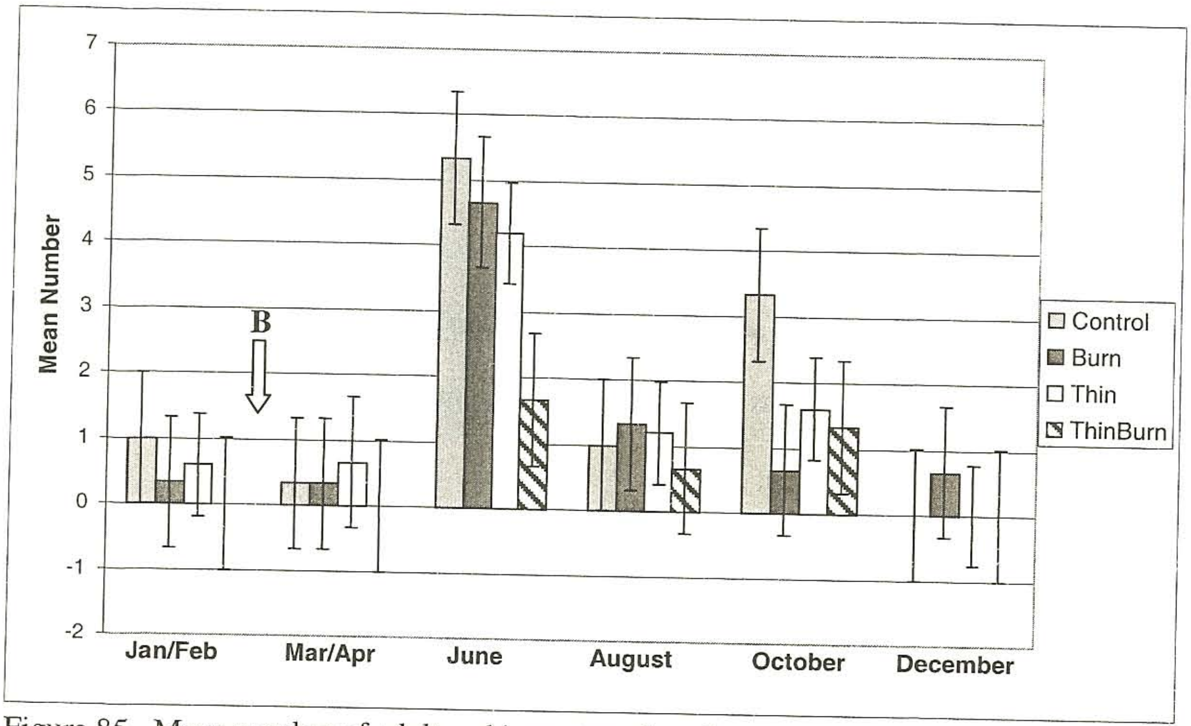

Figure 85. Mean number of adult and immature *Gnaphosa fontinalis* collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Pre-burn months include January/February. Post-burn months are March/April, June, August, October, and December. The B indicates when the burn occurred in the thin and burn plots in 2002.

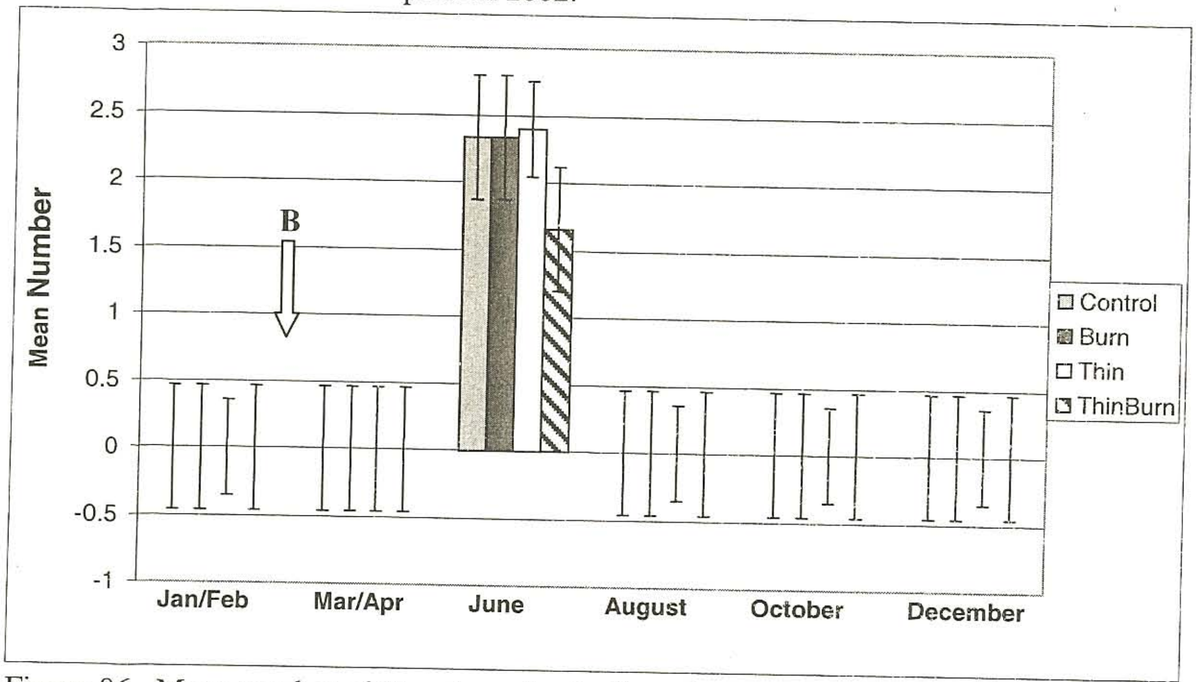

Figure 86. Mean number of *Gnaphosa fontinalis* males collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Pre-burn months include January/February. Post-burn months are March/April, June, August, October, and December. The B indicates when the burn occurred in 2002.

burn only, thin only, and control plots (*df*=23, $p>0.05$). During January/February, March/April, August, October, or December, no significant differences were found among the three treatments and control plots (Figure 87). Numbers of immature *G. fontinalis* were not significantly different among the six sampling periods (*df*=23, $F=1.16$, $p=0.3193$) (Figure 88). Treatment effects over the six sampling periods, for *G. fontinalis*, had various effects on mean numbers of totals, males, females, and immatures.

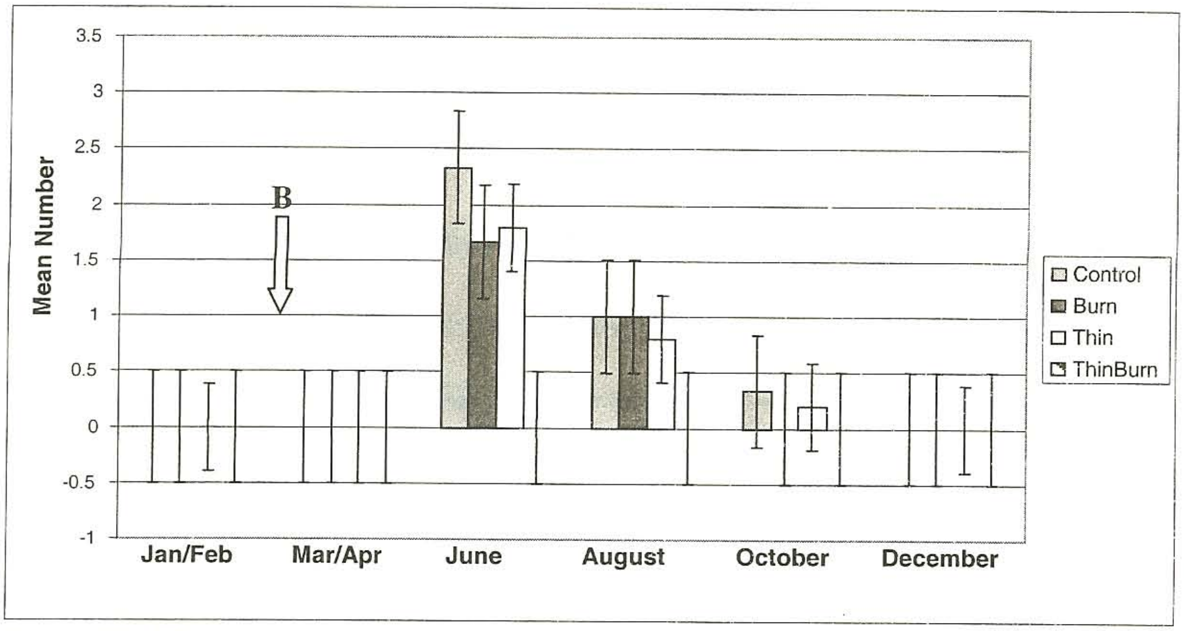

Figure 87. Mean number of *Gnaphosa fontinalis* females collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Pre-burn months include January/February. Post-burn months are March/April, June, August, October, and December. The B indicates when the burn occurred in the thin and burn in 2002.

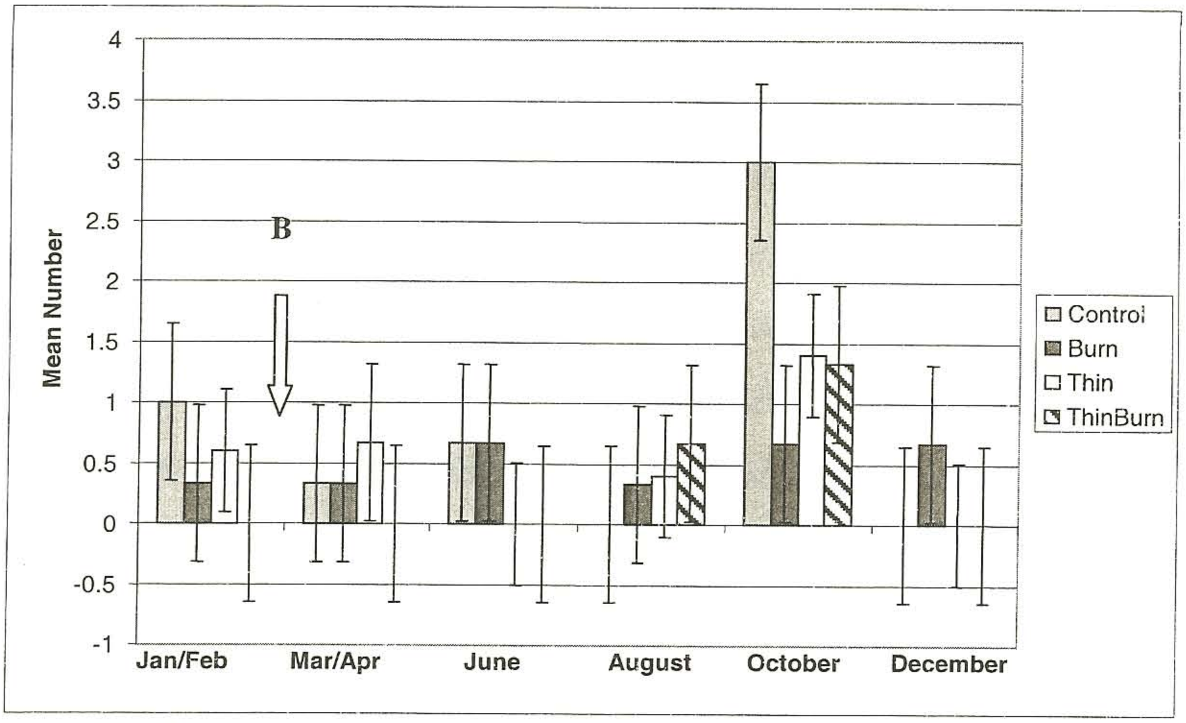

Figure 88. Mean number of *Gnaphosa fontinalis* immatures collected in the three treatments and control plots during the six sampling periods in the Clemson Experimental Forest. Pre-burn months include January/February. Post-burn months are March/April, June, August, October, and December. The B indicates when the burn occurred in the thin and burn in 2002.

DISCUSSION

Effect of Sampling Date on Family Spider Populations:

Of the 13 families collected, 11 exhibited significant differences among the six sampling periods (Table 4). Families of spiders were grouped into three basic patterns, 1) those in which the mean numbers decreased over the six sampling periods, 2) those in which numbers were lowest in winter and highest in summer months, and 3) those that exhibited no obvious pattern.

The Agelenidae, Linyphiidae, and Theridiidae exhibited a dramatic decrease in the mean number of spiders per plot from January/February to June and then remained fairly stable through December. The large numbers of spiders collected during January/February in all treatments could be due to a high level of activity of male spiders foraging through the leaf litter. During this time, prey availability is low due to cold temperatures and most insects being in diapause. Some web-building families will leave the web if food availability is low (Turnbull 1964; Olive 1982; Bradley 1993). Linyphiids and theridiids have been referred to as winter-active spiders (Aitchison 1984a; Aitchison 1984b; Foelix 1996), which are those species that are active at rather low temperatures (Aitchison 1984a; Aitchison 1984b; Foelix 1996). Agelenid spiders are considered to be winter-inactive spiders (Aitchison 84a; Aitchison 1984b). My results do not corrobate these findings; agelenid spiders were collected in large numbers during January/February when these spiders should be over-wintering. The large numbers of agelenid spiders collected in pitfall traps were identified as *Cicurina* spp. and

Wadotes spp. Males and females of *Cicurina* spp. are active from late-August to early-January (Bennet 1985); whereas, adult *Wadotes* spp. spiders are active during mid-September to late-March (Bennet 1987). The high numbers that I collected could be due, in part, to active spiders leaving webs to search for other areas to construct webs to catch prey. If pitfall trap sampling was conducted in 2003, I predict that mean numbers would again be high during January/February. Also, in January/February 2002, increased temperatures occurred which may have resulted in spiders emerging from over-wintering causing increased mean numbers.

Four families, Gnaphosidae, Oxyopidae, Pisauridae, and Salticidae, exhibited lowest numbers during winter and highest during the summer. Spiders, in general, have peak populations in midsummer and decline as autumn approaches (Uetz 1975; Dean & Sterling 1990; Reddy & Venkalaiah 1990; Zimmerman & Spence 1998).

The families Clubionidae, Hahniidae, and Thomisidae exhibited no distinct temporal patterns. Clubionidae and Hahniidae had two peaks. Clubionid numbers peaked in March/April and again in August whereas; hahniid numbers peaked in March/April and October. Huhta (1971), in a study conducted in Finland, reported that adult spiders, in general, have two general peaks that occur during their life cycle, one during spring and another in autumn. Thomisidae mean numbers were highest in June, and then decreased from August to October. Althought it was not distinct, thomisids appeared to reach peak densities during midseason and then decline as autumn approaches. Only three Atypidae were collected during the six sampling periods, and these were most likely atypid spiders that fell into the pitfall traps.

The spider family Lycosidae, had population densities that did not vary significantly during the six sampling periods. Only five araneids were collected during the six sampling periods and were probably spiders that randomly fell into pitfall traps. However, Lycosidae were collected in all three treatments and the control plots during each of the six sampling periods. Lycosid mean numbers per plot exhibited an increase during the summer months, peaked in October, and then decreased in December. Large numbers of Lycosidae could have been collected due to wandering adult spiders increasing their foraging time and searching for potential mates (Persons & Uetz 1997; Persons 1999). Also, adults will move from one area to another if food availability is low (Hebets *et al.* 1996). Mean numbers of Lycosidae were highest during the summer and early fall. High mean numbers during this time suggest that this is a result of seasonal activity of adult and immature lycosid spiders. My data indicate that adult and immature spiders were collected in large numbers throughout the sampling periods, and both adults and immature spiders were collected in pitfall traps.

Several pitfall traps, during our study, were found to have up to 10 immature lycosid spiders per trap. Also, during pitfall trapping, lycosid females with newly hatched spiderlings were captured in pitfall traps. In one pitfall trap, a single female was collected with 46 spiderlings. Emerging lycosid spiderlings will attach to a female's abdomen after hatching. Studies have shown that there can be well over 100 spiderlings on a female's abdomen (Foelix 1996).

Overall Treatment Effect on Spider Family Populations:

Of the 13 families collected, Agelenidae, Gnaphosidae, Hahniidae, Pisauridae, and Thomisidae, exhibitied overall significant changes in mean spider populations due to fuel load management treatments.

Burning

Overall, plots that were burned in April 2001 had significantly lower mean numbers of Pisauridae and Thomisidae per plot suggesting that a year after burning, populations of these two families were still reduced by burning. Pisaurids and thomisids are considered to be wandering spiders; however, each of them has different predatory behaviors. Pisauridae actively hunt prey items, whereas, thomisids are considered to be sit-and-wait predators. However, thomisids have been observed to forage by running and pouncing on prey (Uetz 1975). Burning could have caused a decrease in their mean numbers due to fire mortality. Other factors, such as a desiccated environment, accumulated ash, and a change in vegetation composition, a decrease in prey abundance could have caused increased mortality of these two families after the burn occurred (Reichert & Reeder 1972). These factors also could have resulted in a slow recovery.

Eleven families did not have significantly different numbers in burn versus control plots. Spiders may be able to escape the burn by either burrowing into the ground or by hiding in a burn-free location. Also, recolonization of treatment plots could result in the recovery of mean spider numbers.

Effect of Sampling Date on Burn Only Treatment Means:

When spider families were analyzed over the six sampling periods in burn only plots, several families exhibited significant changes in mean numbers in different sampling periods. During March/April, the mean number of linyphiids was lower in burn only plots compared to control plots. In August, mean numbers of clubionids were lower in burn only plots compared to control plots. In October, mean number of gnaphosids were lower in burn only plots compared to control plots. Salticid and theridiid families exhibited an increase in the mean number of spiders in the burn only plots compared to control plots. This suggests that changes that occurred in individual sampling dates could be a result of seasonal population fluctuations.

Thinning

The families Agelenidae, Gnaphosidae, and Thomisidae were negatively affected by thinning. Agelenidae and Thomisidae are commonly found on foliage, and a reduction in habitat could result in decreased numbers. Gnaphosids are wandering spiders that can move from one area to another. Increased disturbance in the surrounding environment could result in an emigration to different areas or could result in mortality.

Effect of Sampling Date on Thin Only Treatment Means:

When spider populations were compared among treatments on individual sampling dates, several families had differences among treatments in the mean number of spiders. During March/April, the mean number of linyphiids was lower in thin only plots compared to control plots. In August, clubionids had lowest numbers in thin only plots. In June, the theridiid mean numbers were higher in thin plots than control plots. This suggests that changes that occurred in individual sampling dates could be a result of seasonal fluctuations in populations.

Burn versus Thin

Agelenidae had significantly lower mean numbers in thin only compared to burn only plots. This suggests that for the Agelenidae, thinning had a more negative effect than burning. However, Agelenid spiders were not significantly affected by burning. Agelenid spiders could have moved into their retreats, or simply moved from burned areas to unburned areas. Hahniidae and Pisauridae had significantly higher numbers in thin only plots than in burn only plots.

Effect of Sampling Date on Burn versus Thin Treatment Means:

When individual sampling dates were analyzed, the mean numbers of spiders were significantly different in both burn and thin compared to control plots. During January/February linyphiid numbers were lower in burn only plots compared to thin only plots. Oxyopid mean numbers, in June, were lower in burn only compared to thin only plots. In August, pisaurid mean numbers in burn only were lower than in thin only plots. However, salticids, in October, and thomisids, in June, had higher mean numbers of spiders in burn only compared to thin only plots. However, salticids, in October, and thomisids, in June, had higher mean numbers of spiders in burn only plots compared to thin plots. This suggests that the changes that occurred in individual sampling dates could be a result of seasonal fluctuations in populations.

Thin and Burn

The only family to be negatively affected by thinning in the thin and burn plots was the Hahniidae. The families Agelenidae, Gnaphosidae, Pisauridae, and Thomisidae were not affected by thinning in the thin and burn plots. This suggests that hahniid spiders were negatively impacted by thinning in the thin and burn plots. Thinning could have resulted in lower prey availability which increased mortality. The families Agelenidae and Linyphiidae were significantly affected by burning in the thin and burn plots after the burn occurred in March 2002. These results suggest that these two families were negatively impacted by burning in the thin and burn plots due to fire mortality.

Effect of Sampling Date on Thin and Burn Treatment Means:

When individual sampling dates were analyzed, several families had significant differences in mean population numbers between thin and burn treatments. During January/February, agelenid numbers were lower in thin and burn plots compared to control plots. In March/April, linyphiid numbers were lower in thin and burn plots compared to control plots. Thomisid mean numbers were lower in thin and burn plots compared to control plots in June. In August, clubionid and pisaurid mean numbers were lower in thin and burn plots compared to control plots. Gnaphosid mean numbers, in October, were higher in control plots compared to thin and burn plots. Changes in mean numbers could be a result of seasonal changes in the environment occurring in the thin and burn plots, such as temperature and rainfall, in an area that has little or no vegetation. This could result in lower mean numbers. Also, changes in mean numbers suggest that seasonal fluctuations could be occurring in populations.

Effects of Sampling Date on Selected Spider Genera:

***Wadotes* spp. (Agelenidae)**

Wadotes spp. mean numbers were significantly different among the six sampling periods. Mean numbers per plot were highest during January/February and then dramatically decreased. Even though *Wadotes* spp. males and females are active during the winter months (Bennett 1987), *Wadotes* is considered to be winter-inactive. Toti et al. (2000) collected *Wadotes* spp. spiders during the fall in an Appalachian grassbald, which is normally when these spiders are active. Their data do not compare favorably to our findings. My data, like those of Bennett (1987), suggest that this genus is winter-active, and that *Wadotes* spp. males were active during the winter months and that females were active throughout the year.

***Schizocosa* spp. (Lycosidae)**

Schizocosa spp. mean numbers varied significantly among the six sampling periods. Mean numbers per plot increased from January/February until June. This increase in mean numbers suggests that adults may have been foraging for potential prey items or potential mates. Also, over-wintering spiders are becoming active at this time due to increasing temperature, which could have caused a higher number of spiders to be collected. Uetz (1975) reported that wandering spiders, such as Lycosidae, have a peak in midseason.

***Varacosa* spp. (Lycosidae)**

Varacosa spp. mean numbers were significantly different during the six sampling periods, although mean numbers per plot were highest during January/February and then decreased. Toti et al. (2000) reported *Varacosa* spp. was most abundant during the spring in an Appalachian grassbald, which does not agree with my findings.

Changes in mean populations for these two species could be a result of the 2 month time period between sampling times.

Effects of Treatment on Spider Genera:

***Wadotes* spp. (Agelenidae)**

Wadotes spp. were not significantly affected by burning, but were negatively affected by thinning. *Wadotes* spp. create a silken funnel web that allows them to retreat in response to disturbances. They may have been able to move into their retreats during the burn allowing them to survive. However, the removal of trees and surrounding shrubs due to thinning may have resulted in higher mortality. The removal of trees and surrounding shrubs decreases areas for spiders to create webs to capture prey. Also, mechanical thinning machinery could directly increase mortality rates for those spiders that are not able to escape.

Wadotes spp. numbers were significantly different when burn only plots were compared to thin and burn plots, but were not significantly different when thin only plots were compared to thin and burn plots. After the burn occurred in March 2002, *Wadotes* spp. populations were affected in the thin and burn plot. This suggests that even though they are web building spiders they were not able to escape mortality due to burning in the thin and burn plots, but were not affected by thinning. *Wadotes* spp. may have recolonized the thin and burn plots after thinning had occurred in 2001.

Effect of Sampling Date on Treatment Means:

When individual sampling dates were analyzed, significant differences in *Wadotes* mean number were found among the three treatments and control plots. During January/February, mean numbers of *Wadotes* spp. per plot were significantly different among the treatments. Control plots had higher mean numbers compared to burn only, thin only, and thin and burn plots. The highest mean number of spiders was collected in January/February. However, mean numbers were also high during June and August. This suggests that even though fuel load management practices could have affected mean numbers, Agelenidae experienced seasonal fluctuations in the mean number of spiders.

Lycosidae

Only one of the genera collected, *Varacosa* spp., in the family Lycosidae were affected by fuel load management treatments. Lycosid spiders may have been unaffected by these practices because of the wandering behavior and ability to burrow in the ground.

***Varacosa* spp. (Lycosidae)**

Varacosa spp. exhibited lower mean numbers after the burn occurred in March of 2002. Suggesting that the other lycosid genera collected may of had the ability to escape possible mortality from burning by moving from burned patches to unburned patches (Reichert and Reeder 1972). *Varacosa* spp. were collected in large numbers during January/February followed by a dramatic decrease in March/April (Figure 48).

Effect of Sampling Date on Treatment Means:

Varacosa spp. exhibited significant differences among treatments during the six sampling periods. In January/February mean numbers of *Varacosa* spp. were lowest in control plots when compared to thin only and thin and burn plots. No differences were found between control and burn only plots. Burn only plots had significantly lower numbers than thin only plots. These results suggest that *Varacosa* spp. were positively impacted by thinning when compared to control plots. However, these results could have occurred because of increased activity of adult and immature spiders that have over-wintered and are becoming active in early February. The other four genera and immature spiders did not exhibit significant differences among the six sampling periods.

Effect of Sampling Date on *G. fontinalis* Populations:

Gnaphosa fontinalis Keyserling mean numbers per plot were significantly different during the six sampling periods. Means increased from January/February until June and then decreased. Males and females were collected during June. Immatures were also collected in large numbers throughout all six sampling periods. *G. fontinalis* mean numbers were highest during the summer months, which indicates, that they had a peak during midseason and then exhibited a decrease in mean numbers during fall. This suggests that seasonality is occurring in this species.

Effect of Treatment on Spider Species Populations:

G. fontinalis was not significantly affected by fuel load management practices, suggesting that they had the ability to escape mortality, due to thinning and burning, by either moving from disturbed areas to undisturbed areas, recolonization, burrowing into the ground, or hiding in cracks and crevices.

Effect of Sampling Date on Treatment Means:

G. fontinalis exhibited two peaks, one in June and another peak in October in the control plots. Mean numbers were lower in all three treatments than controls during both of these sampling dates. This suggests that the differences in the three treatments and control plots during the six sampling periods are a result of seasonality of the spider populations.

CONCLUSION

A year after fuel load treatments were applied in the Clemson Experimental Forest, spider populations exhibited various patterns of recovery. In both the burning and thinning plots, populations recovered and were similar to those in control plots. In this study, spiders exhibited seasonal fluctuations in population numbers. Families exhibited three types of seasonal fluctuations: 1) peaks in the winter months followed by a decline, 2) peaks in the summer months and lows in winter, and 3) a peak in the spring and a decline until fall.

Following burning in the thin and burn plots in March 2002, four taxa (Agelenidae, Linyphiidae, *Wadotes* spp., and *Varacosa* spp.) exhibited a significant decrease in mean numbers when the first post-burn samples were compared to the immediate pre-burn samples. The time difference between pre-burn sampling and post-burn sampling was two months. By the second post-burn sample, the mean numbers of spiders in these taxa were not significantly different than those in control plots.

This information corroborates other studies that have examined the impacts of management burning and thinning by determining that spiders were either not affected, or were able to recover from, fuel load treatments (Merrott 1976; Haskins and Shaddy 1986; New and Hanula 1998). This information helps establish spiders as possible biondicators. If land managers need to determine the effects of burning and thinning over a short period of time, then examining these results could give useful insight into whether or not spiders were recovering. However, if land managers were conducting studies over a longer period of time, this information might be less beneficial.

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