Maintaining Southeastern Pine Woodlands: Is Mechanical Shearing a Surrogate for Prescribed Burning?

FINAL REPORT

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SYNOPSIS: Mechanical chipping (often referred to as mulching) is now in wide use in southeastern USA pinelands for a variety of objectives, including fuel hazard and smoke reduction, fire behavior modification and vegetation management. With respect to vegetation management, chipping is being used as an initial treatment to reinitiate pine savanna/woodland restoration (usually an initial chip treatment is followed up by resumption of prescribed fire) and, occasionally, as a surrogate for fire in locations where prescribed fire is no longer feasible. Despite the widespread use of chipping, this technique has not been comprehensively evaluated. To investigate these issues we set up demonstration plot experiments across the range of longleaf pine, from South Carolina to eastern Texas. Fire behavior and smoke issues were investigated in the "main" study site in Francis Marion NF, near Charleston, South Carolina. Vegetation management questions were investigated at FMNF and three "peripheral" sites: Sam Houston NF (near Huntsville, TX), Blackwater River State Forest (east of Pensacola, FL), and Savanna River Site (near Aiken, SC). At each site we set up a randomized block experiment intended for three experimental treatments: (1) chipping, (2) burning, (3) combination of chipping and burning. Treatments were randomly assigned and initial chip treatments were carried out at all sites. One set of burn treatments was carried out in FMNF. No burn treatments have taken place in BWRSF or SRS. At SHNF initial chip treatments were carried out as planned, but subsequent chip and burn treatments became confused and the experiment is now severely confounded. There is interest at this site in resuming the treatments, however. The main conclusions were as follows: (1) Chipping appears to substantially reduce smoke if burns are done under conservative conditions e.g. in prescribed fires. This effect may be a simple consequence of more patchy fires in chipped fuels. It is plausible that chipped fuels might smolder and smoke production might be enhanced when fire fires are very dry, e.g. in dangerous wildfire scenarios. (2) Chipping appears to protect against the possibility of dangerous wildfire. However, from a fire safety standpoint, it is not necessary to chip before resuming prescribed fire if initial prescribe burn conditions are carefully selected. (3) Vegetation management conclusions are tentative given problems with burn treatments at three of the sites. From a vegetation management standpoint, it

would appear that chipping is most appropriate when used as a pretreatment on long-unburned sites wherein ground layer vegetation has already been severely compromised. Under these conditions the generally minor detrimental impacts of chipping on plant survival are outweighed by the benefits of reduced woody plant competition and open space for herbs. The most pronounced response is evident among ruderals, but benefits of chipping appear to extend to more “conservative” perennial herbs as well. Chip treatments followed up by prescribed fires produce the optimal response. On the other hand, there was evidence from SHNF and BWRSF that negative impacts of chipping, while relatively minor, may in fact tend to degrade high quality fire maintained diverse ground layer vegetation. At SHNF this appeared to be related to the tendency of chipping to fragment or crumble the higher silt content surface soils, thus damaging plant roots. In the absence of more conclusive or longer term information, we recommend that mechanical chipping not be used as a fire surrogate when the objective is to maintain diverse native ground layer vegetation. At a minimum, repeated use of this management technique, in lieu of or in conjunction with prescribed fire, should be coupled with careful monitoring of impacts to plant and animal communities.

Did our work meet the objectives stated in the proposal? Clearly not, inasmuch as the goal was to establish replicated experiments with three treatments maintained at each site for a period of seven years. Would that goal have been accomplished, we might be in position to make some stronger conclusions, particularly concerning the vegetation management questions. We might say, however, that we do not take full responsibility for the failure to attain that goal. Perhaps some of the failures in communication with the various study areas were our own fault but mostly the issue was that local managers were too overwhelmed with other commitments to deal with our plots. In particular BWRSF can hardly be blamed for a financial crisis in FL government post 9/11 or for Hurricanes Ivan and Dennis. At the two other peripheral locations, changes in key personnel led to some of the confusion. Ultimately it would seem that JFSP or other grant funding agencies must take responsibility for providing funds and perhaps field crews to aid in implementation of large-scale field experiments. Perhaps other researchers with greater clout have had different experiences.

Given the difficulties in carrying out the experimental treatments, we are reasonably satisfied that we obtained the best possible results under the circumstances. Three publications thus far with a fourth reasonably assured seems like a good return on a relative modest investment from our perspective.

We do hope that we may be able to somehow continue the SHNF experiment given renewed commitment from USFS and from the interested public. This experiment in particular may be instrumental in providing data critical to resolving some long-term management controversies.

INTRODUCTION

Mechanical chipping (or shredding) is increasingly used in southern pine forests for fuel modification and ecological restoration objectives either in combination with, or as an alternative to, prescribed fire. Nevertheless, there are a number of important unanswered questions about this technique: (1) Is mechanical chipping as effective as burning in maintaining a species rich ground layer plant community? (2) How precisely does chipping influence fire-fuels and fire behavior? Are the effects different from prescribed fire? (3) One oft advertised benefit of chipping is reduced likelihood of smoke accumulations post-fire. However, there are few data to test this claim.

The objective of this project was to establish a series of experimental sites on public lands throughout the southeastern Coastal Plain to investigate these issues and provide demonstrations to managers of the consequences of mechanical chipping as compared with, or in combination with, prescribed fire. Specifically, we promised to establish one "main site", the Francis Marion NF (FMNF) in the outer SC Coastal Plain, and three "peripheral sites". As it turned out the latter included Savanna River Site (SRS) near Aiken, SC, Blackwater River State Forest (BWSF), northeast of Pensacola in west Florida, and Sam Houston NF (SHNF) south of Huntsville, Texas. Commitments were obtained from each of these sites to protect the plots and maintain treatments for seven years as required by JFSP. Fire behavior, smoke and vegetation data were collected at the main FMNF site. Only vegetation data were collected at the peripheral sites.

The main "deliverable" in this project was the establishment of experimental demonstration plots in different habitats and regions of southeastern Coastal Plain pinelands. Plots were to be designed to illustrate to managers and the interested public the comparative effects of fire versus mechanical chipping, and a combination thereof, on vegetation changes, fire fuels, fire behavior, and smoke. This report will show that we established the plots and collected the data as promised. However due to erratic and/or incomplete treatment implementation the utility of the experiment was compromised to some degree at each of the three peripheral sites. The most serious lapse was failure to accomplish the experimental burns during the primary funding period. Consequently, analyses with respect to the peripheral sites will compare the effects of chipping to lack of chipping. Though fire was not manipulated experimentally, one of the experimental blocks at SHNF and one at BWSF were burned shortly before the start of the study.

Restoration and Management Objectives

Mechanical chipping at the various study areas is being used as a tool for maintaining and restoring open herbaceous dominated ground cover. The target is open pinelands dominated by low-density pine in the canopy and grassy under-story. This goal is relatively non-controversial at FMNF, SRS and BWSF. Federal and state land managers, local environmental groups and conservation organizations alike accept it. These sites are well within the historic range of longleaf pine and there is general agreement on the historic condition and restoration objectives with respect to this endangered ecosystem.

The situation at SHNF is more complicated. This Forest is located in the "piney woods"; a loblolly pine dominated area transitional between longleaf woodlands to the east, post-oak savanna to the southwest and black-land prairie to the east and northeast. Legitimate disagreements exist concerning historic vegetation and appropriate management regimes. It is the position of some east Texas environmentalists that the USFS restoration target of open savanna like habitat is not appropriate for SHNF. These persons suggest that the more appropriate goal is a more closed woodland with a fairly high density of large dry site hardwoods intermixed with the pines. This suggestion is in fact supported to some extent by certain vegetation patterns, in particular the prevalence on many upland sites of *Chasmanthium sessiliflorum, Piptochaetium avenaceum* and *Carex spp* as ground layer dominants. These graminoids are generally considered indicator species for rather shady oak/hickory type woodlands. Given the limited dispersal of "climax" grass species it is doubtful that the widespread dominance of *Chasmanthium sessiliflorum* and *Piptochaetium avenaceum* is due to recent changes in stand structure; more likely sites dominated by these species were in fact characterized by shadier canopies and higher representation of hardwood species. On the other hand, there are also sites with greater abundance of typical pineland herbs that probably were historically open savannas. In all likelihood the historic vegetation was a complex mosaic of prairie, pine savannna and upland forest. Fortuitously, our study blocks at SHNF encompassed both phases of this mosaic allowing for an investigation of chip treatment effects on both hardwood forest herbs and pine land ground layer.

As mentioned above, there is not a similar controversy with the other sites, all of which were clearly longleaf dominated historically. However plots in one SRS block and at BWRSF were situated on slopes extending from longleaf ridge on the high side down into oak-hickory-pine on the lower end. These situations provided additional opportunities to investigate chip effects on hardwood understory herbs as well as longleaf ground layer.

METHODS

Experimental Design

The design common to all sites was a randomized block experiment, no within block replication, with three treatments: (1) prescribed burn only, (2) mechanical chip only, and (3) a combination of chipping and burning. Treatments were randomly assigned to 1-ha plots within the blocks. The original intention was to establish three replicates (i.e. blocks of plots) at each site. In fact, this intention was altered by circumstances. Following 9/11/2001 the state of Florida experienced a severe budgetary crisis and all state agencies were asked to cut frills. In this budget environment the maintenance of an experiment with expensive operator time and machine costs was considered less than a necessity. Ultimately it was decided to reduce the scale of the study to a single block of plots. In part to compensate for the loss of blocks at Blackwater, we expanded the size of the experiment by one block at two of the other locations. Thus there are now four replicates apiece at FMNF and SHNF, three replicates at SRS and one replicate at BWSF.

Status of Treatments

We were not funded by JFSP to carry out treatments, and were therefore dependent on the wherewithal of the various sites to accomplish the experimental treatments. To get the work accomplished we attempted to insert ourselves as much as possible into the normal course of operational scale activities in the compartments surrounding the experimental blocks. Ultimately, this strategy did not prove to be effective at the peripheral sites. The study was plagued by two problems in particular. (a) Actions planned for the surrounding compartments were not implemented as planned during the study period and therefore did not get implemented in the study plots. (B) Liaison personnel with whom we had coordinated during the initial phases of the study left for different jobs. This resulted in delays and intrusive activities in the plots. We accept some responsibility for lack of follow-up and coordination. Status of treatment implementation for the different sites is reviewed as follows.

Francis Marion NF: All the treatment blocks in FMNF are in the same location in compartment 53 of the National Forest. One complete set of treatments was implemented at FMNF. Chip treatments were carried out on 17th December 2001 and burn treatments, including chip and burn treatments, were implemented approximately 13 months later on 12th and 20th February 2003. FMNF has no plans for further chipping in compartment 53 (Bill Twomey, FMNF burn coordinator, personal communication). Ken Outcalt of Southern Research Station indicated during 2005 that he had funds to carry out one additional round of chip treatments. FMNF re-burned the entire compartment during late winter 2005. Chip only plots were flagged and hand lines were put in to keep fire out but follow up checks revealed that chip only plots in the two north blocks (i.e. north of road 136B) were burned anyway. Given that the experimental design was thus compromised we did not pursue plans for additional chipping. The FMNF experiment can be considered as terminated unless there is interest from JFSP and FMNF, and funds are somehow forthcoming to re-initiate the chip treatments.

Sam Houston NF: There are four experimental blocks at SHNF. Blocks 2-3 are located on opposite sides of road 204 in the western part of the Forest. Block 2 in compartment 35 was burned in March 2002 shortly before the start of the study. This site had also been hand-thinned to reduce hardwood stem densities. Pre-treatment vegetation was very diverse moderately high quality ground layer with a substantial component of prairie and pineland species. The other blocks were long unburned, or less frequently burned, with dense shrub and hardwood sapling dominated understory and lower diversity ground layer. Block 1 is in compartment 96 south of the town of Evergreen in the central part of the Forest. Block 4 is relatively close by in compartment 107. This block (the "longleaf site") is in a stand of longleaf pine at the very western range limit for that species. The canopy at the other sites is dominated by loblolly pine in part because of past hardwood removal efforts.

Chip treatments in blocks 2 and 3 were carried out during winter 2003 with no problems. Difficulties began when Wildlife Biologist Dawn Carrie, our liaison at SHNF, transferred to another position during 2004. As the recent summary provided by SHNF indicates (Appendix 1), the treatments in all four blocks are now severely confounded. Despite these issues there is interest on the part of SHNF and Texas environmental groups in continuing the study. Experimental treatments have been resumed, and there is interest in seeking funds for additional monitoring. Nancy Jordan, recently hired as Wildlife Biologist, is the new liaison.

Savanna River Site: Chip treatments at SRS were carried out on 7-8 November 2003. No burn treatments have taken place. Dr. Don Imm, our liaison at SRS, has taken a position outside USFS. There appears to be little interest from SRS Forest Service in carrying out the burns or maintaining the SRS experimental plots.

Blackwater River SF: BWRSF plots were chipped on 15th July 2002. Burns originally planned for growing seasons 2003 and 2004 were put off due to inconvenient weather. Hurricane Ivan, which made landfall close by on September 16, 2004 created considerable damage throughout BWRSF including in the vicinity of the plots. Hurricane Dennis, a weaker hurricane, also passed close by the plots on June 11, 2005 and created additional canopy damage. Few burns have been carried out at BWRSF since the two hurricanes, and none in the vicinity of our study plots. At this point it appears doubtful that the experimental burns will ever occur.

Fuels, Fire Behavior and Smoke: Observations and Models

Methods and results pertaining to the fire behavior and smoke aspects of the study have now been published. These publications deal with data collected at the "main" Francis Marion NF study site. Copies of the relevant manuscripts are attached. Glitzenstein et al. (2006, in press, attached as Appendix 2) deals with fuels, fire behavior observations, and fire behavior modeling. Naeher et al. (2006, in press, attached as Appendix 3) presents the smoke results from a public health standpoint.

Achtemeier et al. (in press, 2006, attached as Appendix 4) discusses smoke results and models related to smoke dispersion issues.

Vegetation Sampling

Vegetation data at FMNF, SHNF and BWRSF were collected within treatment plots in 20 m x 50 m subplots using the North Carolina Vegetation Survey (GOS) plot technique. GOS plots consist of ten 10 m x 10 m modules, four of which are randomly selected for intensive sampling. In each intensive module two corners are selected for nested plot sampling. In each such corner a series of five nested plots is set up with the following dimensions: 10 cm x 10 cm, 32 cm x 32 cm, 1.0 m x 1.0 m, 3.16 m x 3.16 m, 10 m x 10 m. These dimensions are selected so that plot area increases by a factor of ten as one moves to the next larger plot. This method takes advantage of the relation between scale and abundance. Abundant plants are more likely to be encountered at smaller scales, whereas it is necessary to search larger areas to encounter uncommon species. When surveying a GOS plot one therefore records the particular plot scale at which a species is first encountered. Species encountered at the smallest scale are recorded as the number 5, and subsequent levels are recorded as 4,3,2, and finally 1 for plants encountered at the full module 10 m x 10 m scale. In addition to this “level” data one also records cover class data overall and for a number of different different canopy strata. After the intensive modules are sampled the remainder of the plot is searched for additional species. For this study we modified the NCVS methods to take into account appropriate cover strata. In addition we added a rarity determination based on density estimates. At FMNF, NCVS plots were randomly located within treatment plots. At SHNF and BWSF a stratified random sampling scheme was used to enhance homogeneity of vegetation sample plot locations.

We did not use NCVS methods at SRS. At this site vegetation diversity had been reduced at small and medium scales by past forestry practices, but good diversity of longleaf pine ground-layer species was still evident at larger scales. Consequently the 1-ha treatment plots were subdivided into 5 m wide transects that were then searched for selected grass and forb species using a modified Variable Area Transect (VAT) approach. Species selected for searches were those that in our estimation characterized the old growth longleaf ground layer; “weedy” species typical of disturbed sites were not surveyed.

Post-treatment vegetation data were collected in the FMNF plots in late summer/fall 2003 following the experimental fires. At the other sites we put off post-treatment data collection until the experimental fires could be accomplished. By mid-August of 2004 it was becoming evident that there would be no fires before the end of the funding period, even given the one-year extension. We therefore proceeded to collect post-treatment data despite the lack of experimental burns. Thus the peripheral site results compare only two treatments: chipping versus lack of chipping (i.e. “control”).

The two SHNF blocks chipped in 2003 were re-sampled in late August thru October 2004. Pretreatment data for the newly added SHNF block D was also collected at this time. VAT transects at SRS blocks 1-2 were re-sampled late September- early November 2004 with some follow up checks in June 2005. The third, lowest diversity, block was sampled in June 2005. BWSF was re-sampled in early December 2004 and checked again 9-11 September 2005.

Woody Stem Dynamics, Including Fire Mortality--FMNF: Mortality and re-growth of woody stems > 135 cm tall (breast height) at FMNF were checked during the fall 2003 vegetation recensus. Each stem was identified to species, post-fire mortality noted, and dbh measured. Evidence of sprouting was recorded for hardwood species. In chip plots (both chip only and chip plus burn) we also recorded stem origin of >135 cm stems as “original” or “post-chip sprout”.

Vegetation Analyses

Utilizing the NCVS plot level data, we devised a simple index of vegetation integrity (or, if you prefer, abundance based on scale):

$$I_{GRP(L)} = \sum_{I=1}^{SP} \sum_{K=1}^{L}$$

In this equation "GRP" represents a particular group of "high quality" species, the right hand summation pertains to the sum of level data for a particular species within the group, and the left-hand summation indicates the sum of the individual species sums across all species within the group. If the sum of L is 0 for any particular species and that species is present in the residuals, then sum of L is set to 0.5. An analogous quantity, $I_{GRP(Cov)}$ might be calculated for the cover data, but those data have not yet been analyzed. The term "high quality" is site dependent and is a function of conservation objectives. For FMNF and BWSF "high quality species" were defined as characteristic "conservative" herbaceous and short shrubby species of longleaf pine ground-layer. Ruderal herbs and common trees and shrubs were not included because these plants are overly abundant in the modern fire suppressed and soil disturbed landscape.

For FMNF we also calculated "scale abundance" coefficients for a variety of major species groups, as indicated in Table 1.

In the case of SHNF alternative groupings of species were recognized corresponding to alternative "desired future conditions". Group #1 consisted of conservative herbaceous presumably fire dependent species of pineland and prairie. Maximizing abundance of these species would seem to be consistent with the desired USFS goal of optimizing open habitat conditions. Group #2 consisted of herbaceous species of closed forest or shady woodland. East Texas environmentalists have expressed concern that current USFS management policies, including chipping/mulching may be negatively impacting these plants and other organisms typical of shady woods. Group #3 consisted of native woody plants. Like the closed forest herbs, maintaining woody plant diversity is important if the desired future condition is closed forest or shady woodland. Alternatively, for maintaining savanna vegetation it would be desirable to reduce or at least limit the proliferation of woody plants.

Finally, for SHNF, we recognized two groups consisting of native ruderals and alien invasives. In the case of these groups larger values of I might represent undesirable outcomes; certainly this is true for aliens. However, increases in native ruderals might be acceptable if coupled with increased integrity coefficients for desirable groups.

We used the same groups for BWRSF that were used for SHNF. Partly this was because BWRSF plots, being located in a mesic upper slope position, had some minor representation of oak-hickory or hardwood forest forbs although most of the herbs were longleaf associates.

NCVS data were not collected at SRS. For this site the integrity index was simply the least squares regression coefficient relating post-treatment density to pre-treatment density. Each species was a separate data point. Coefficients greater than one indicated a predominance of increasing species whereas coefficients less than one were indicative of decline. Additional information concerning species responses was available from the residuals. Significant positive outliers indicated species that benefited more than ordinarily from treatments whereas significant negative outliers indicated species with unusually severe declines.

RESULTS AND DISCUSSION

Fuels, Fire Behavior and Smoke: Observations and Models

As noted above, methods and results pertaining to the fire behavior and smoke aspects of the study have now been published. The reader is referred to the published manuscripts, reproduced as Appendices 2-4.

Vegetation

Francis Marion NF

Level ("integrity") Data: A scatter graph of post-treatment versus pre-treatment integrity index values is shown in Figure 1. Also shown is a regression and correlation analysis, with a best-fit regression line. Pretreatment and post-treatment data were strongly correlated, suggesting that treatments did not greatly disrupt pre-existing plant communities. The slope of the regression line was positive indicating that the "quality" species (i.e. characteristic longleaf ground layer plants) tended generally to increase following treatments. Points representing chip and chip+burn treatment plots fell generally above the regression line, while burn only plots fell below the line. Apparently the desired species were least benefited by burn only treatments. This conclusion is supported by treatment means and ANOVA results. Mean changes following treatments were positive for all treatments: +69 for burn only, +119.5 for chip only, and +152.5 for chipping followed by burning. Overall ANOVA results were not statistically significant at the conventional 0.05 threshold, but there was a strong likelihood ($F = 3.46$, $P \sim .10$, $df = 2,6$) that the observed differences might be meaningful. A planned contrast between the two chip treatments and the burn only treatment was statistically significant at the 0.05 level.

Index change values for different species groups were mostly positive and did not differ significantly among treatments (Table 1). However, there were significant treatment effects for three groups of species: non-Asteraceae/non-Fabaceae perennial dicot forbs, *Rhynchospora* spp, and disturbance responders generally. Each of these groups increased markedly after chip treatments generally and slightly more so after chipping followed by burning. Whereas increases in ruderals are often interpreted as indicative of habitat degradation, in the case of this study increases in "weediness" were consistent with, rather than contrary to, generally positive responses among most other species groups.

Woody stem dynamics: The first pair of plots was burned in the early evening of February 12, 2003. The first plot burned that evening was the "smoke control" plot. We have already alluded to the stronger winds, longer flame lengths, and faster spread rates in that plot. Consistent with those findings, the smoke control plot also had the highest (i.e. among all the burn plots) observed rates of shrub and small tree death (topkill for sprouting species) and the largest upper threshold for fire related mortality (Figure 2a,b). The other plot burned that evening, the "smoke study chip plot", had considerably lower kill rates and a lower upper kill limit (Figure 2c,d). Once again, given confounding effects of wind and fire behavior changes, it was difficult to confidently attribute the observed differences between these plots entirely to the different experimental treatments.

The remaining 6 plots (burn only and chip+burn) were burned on February 20 of the following week. Wind speeds for those burns were consistently low, averaging about 2 miles/hr. Kill rates and patterns resembled the February 12 smoke study chip plot. That is, overall kill rates were lower and limited almost entirely to stems less than 2 cm dbh (Figures 2e,f,g,h). Nevertheless, rather substantial density reductions were achieved within the two smallest size classes (0-1 and 1-2 cm dbh).

Compared to burn only treatments, chip treatments substantially reduced stem densities of both loblolly pine and hardwoods below 15 cm dbh (Figs 2g,h,i,j). However, hardwoods re-sprouted vigorously and substantial numbers had reached breast height by the time the chip burn plots were burned the following winter. As noted above, fires in the chip plots were slow moving with low flame lengths but were surprisingly effective in killing sizeable percentages of smaller residual loblollies and hardwood re-sprouts (Figures 2g,h). Consequently, plots both chipped and burned at least structurally began to resemble typical open pine woodlands in a surprisingly short period of time. In contrast, hardwood sprouts in plots chipped but not burned continued to grow vigorously and sizeable percentages are already approaching the threshold where they will no longer be susceptible to control via prescribed fire (Figures 2i,j). These results emphasize the importance of rapid follow-up burns in areas with mechanical chipping.

Sam Houston NF "Integrity" Analyses

Results for the two SHNF blocks are shown in Figures 3 and 4. Effects of the chip treatment on pineland/prairie herbs differed between blocks. The integrity coefficient for this group decreased in both treated plots in block 2 but increased in the two block 3 treatment plots (Figure 3). In both blocks, control (i.e. no treatment) scores for this group changed little between censuses. Inconsistent results across blocks are perhaps interpretable in terms of pre-treatment conditions. Further mechanical treatment is perhaps detrimental on open fire maintained sites that already support good quality vegetation, as in SHNF block 2. In contrast, chip treatment may be beneficial in fire suppressed sites where fire dependent herbs are competitively stressed by excessive proliferation of woody stems.

Concerns have been raised that chipping might deleteriously impact woody plants and herbaceous species characteristic of shadier habitats. In fact, the data did not support these suggestions. Woody plant frequencies (i.e. integrity index for woody species) increased in all block 2 plots, with the largest increase in the untreated control. In block 3 there was likewise a large woody increase in the control but woody species remained essentially unchanged in the treated plots. These data appear to show that chipping can help to prevent excessive proliferation of woody stems, but large sprout banks are persistent post treatment.

Somewhat surprisingly, herbaceous species with higher affinities for closed canopy situations appeared to benefit from chip treatments, at least in the short term. This finding was consistent between blocks. Despite their shade tolerance these closed forest herbs tended to benefit from reductions in woody plant competition.

As in FMNF, ruderal species increased substantially in chipped plots. As at FMNF, increases in weeds were not necessarily associated with decreases in other groups.

Savanna River Site Regression Analyses

SRS results are in Table 2. Regression (b) coefficients were generally close to 1 indicating that overall vegetation integrity remained unchanged. R^2 values, though highly significant, were considerably less then 1, indicating considerable flux in abundance of individual species pre-and-post treatment. To some extent this is a function of the difficulties of accurate counting in the VAT transects. The two plots with lowest b coefficients were chip plot 2 in block 2 and the control in that same block. The apparent decline in species densities in chip plot 2 may be more apparent than real inasmuch as this plot became rapidly dominated post-chipping by a dense mass of woody vines, i.e. *Vitis spp* and *Gelsemium sempervirens.* It was very difficult to discern herbaceous species within or beneath this dense mat of vines. Whether or not we missed many plants is perhaps irrelevant since without fire or very short interval chipping the vines would no doubt competitively exclude the herbs over a relatively short period. The relatively low regression coefficient in the block 2 control indicates the continued, though gradual, degradation of this important longleaf remnant with continued fire exclusion. The block 2 plots and vicinity encompass some of the most important remnants of longleaf ground layer at SRS. Unfortunately, similar negative trends most likely prevail over much of area surrounding the plots as well.

Blackwater River State Forest Integrity Coefficient Analyses

Results for the single Blackwater River State Forest block are in Table 3. The control plot showed minor declines in "quality" herb groups and increases in the woody index. This indicates that competitive exclusion of herbs by woody plants continued despite hurricane disturbance. One exception was ruderals, which may have benefited from canopy damage inflicted by the storms. Results for treated plots were mixed, with desirable pineland and oak-hickory herb groups increasing in one treated plot and decreasing in the other. As at SHNF and SRS the magnitude of decrease in this chipped plot at BWRSF is troublesome, especially since this was perhaps the most intact plot prior to treatments.

Vegetation Management Conclusions

(1) Mechanical chipping does not lead to catastrophic declines in vegetation diversity or abundance. Effects are either positive or subtly negative. (2) Mechanical chipping is most useful for rapidly restoring appropriate stand structure and reducing woody competition in long fire-suppressed sites with dense loblolly/hardwood mid-story. Positive effects appear to greatly outweight the negatives in such situations. (3) Mechanical chipping coupled with followup fire is the most effective restoration strategy. (4) Sites that already possess a diverse high quality ground layer are best managed with fire only. Negative impacts of mechanical chipping in such situations are sufficiently pronounced so as to discontinue the treatments. To put it succinctly, a one-time chip in a restoration context may be appropriate but repeated chipping is probably not appropriate as a true fire surrogate for maintaining high quality ground cover.

DELIVERABLES

In evaluating how well we kept our promises, JFSP might want to review the history of our grant.

This grant was funded under the demonstration plot section of the JFSP grant program. The main emphasis of this program was to establish permanent (at least 7 years) plots wherein managers and researchers might view effects of specified treatments. We did establish the plots and obtain verbal commitments from the various site locations that the treatments would be carried out. The treatments were not carried out in their entirety at the peripheral site locations though some useful data were collected. At the main FMNF site one treatment cycle was successfully implemented.

Our original grant submission pertained to FMNF exclusively. The format of the grant submission was specified by JFSP. In the section entitled "deliverables" we promised two annual reports and a final report. In the "technology transfer" section we promised only to publish the results, without specifying the number or type of publications. We requested a total budget of $96,900 to carry out this project.

In his letter to Dale Wade, Dr. Bob Clark, at that time the JFSP program manager, expressed interest in our proposal but made three recommendations. Dr. Clark recommended (1) that the scope of the proposal be expanded beyond FMNF to the southern region as a whole, (2) that we improve the smoke-monitoring component of the study, and (3) that we enhance the technology transfer section.

We agreed to these suggestions, in a letter from Dr. Wade to Dr. Clark that took the form of an addendum to the proposal. Of particular importance, Dr. Gary Achtemeier agreed to take charge of the smoke part of the study, with Dr. Luke Naeher as co-PI. Drs. Achtemeier and Naeher requested a budget of $16,558 dollars for a technologically sophisticated smoke study. This was money not budgeted in the original project. Second, the scope of the study was expanded as requested through addition of the three “peripheral” sites. Finally, we expanded the technology transfer section of the proposal to include interpretive signs for each field site, a touring slide show, a web site, and a field tour to be hosted at the main FMNF study site at the conclusion of the study. Given this rather substantial increase in workload we requested a total revised budget of $136,483, an increase of $39,583 (~41%) over the original budget. Dr. Clark accepted the proposal under these specifications, but when funds were allocated the total grant award was cut to $119,925 (some of the difference may have gone to Southern Station for general expenses, but it did not contribute to funding the project). After honoring our commitment to the smoke budget, only $10,838 additional funds remained. This translated to only $3,612 per each peripheral site and very little for additional communication initiatives.

Another consideration is the vegetation monitoring work that ultimately went into each peripheral site. In the addendum we proposed rather cursory vegetation monitoring at each new site. It nevertheless became evident that the project would be much improved if we could use the same detailed methods at all sites. We did more fieldwork than promised for less money than we considered necessary.

We did attempt to carry out our promises. Given the limited funding we have been slow to implement some of the outreach initiatives. The required crosswalk table is in Appendix 5.

Table 1. ANOVA results of sum of level index analyses for major species groups at the Francis Marion NF study site.

	Burn Only	Chip Only	Chip+Burn	P
Characteristic Savanna Grasses	8.00	13.75	13.25	.73
Dichanthelium spp.	31.00	31.25	45.00	.25
Perennial Asteraceae	2.25	-6.25	14.75	.21
Fabaceae (Legumes)	5.00	7.50	9.50	.69
Other Perennial Dicots	21.25	45.75	50.25	.05
Monocot Forbs	3.75	1.25	3.50	.41
Disturbance Responders	39.25	89.50	119.50	.03
Rhynchospora spp.	15.25	46.00	49.75	.04
Small Shrubs	6.5	12.50	12.25	.60
Large Shrubs	5.75	4.00	0.25	.58
Hardwood Trees	0.50	0.00	5.00	.56
Woody Vines	0.25	6.50	-1.00	.52

Table 2. Regression analysis results of before and after species densities at SRS blocks 1 and 2. Atypically abundant species and extreme outlier species were excluded since those species would otherwise tend to have undue influence on the results.

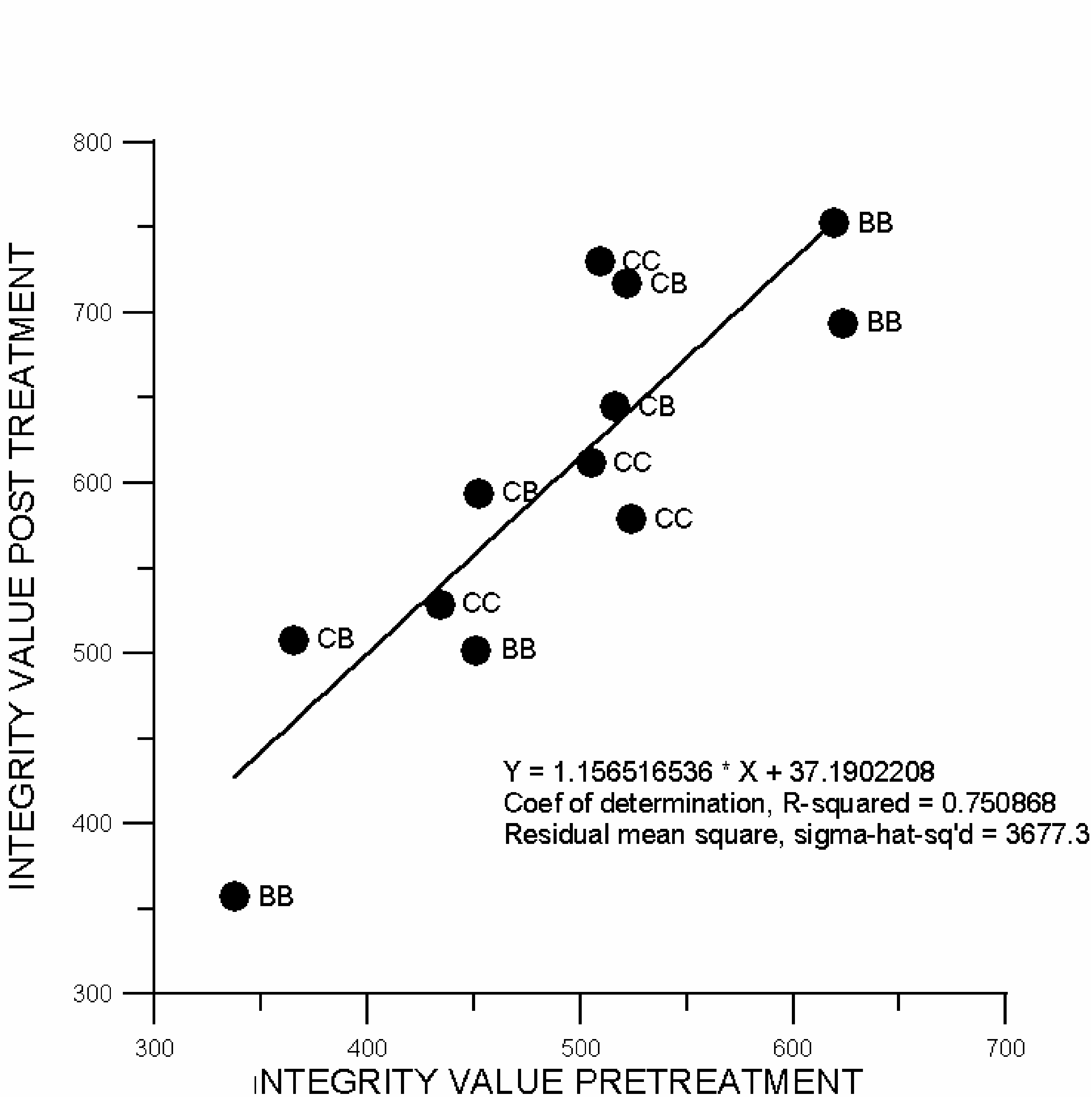
Block	Plot	Treatment	N	b	R^2	P	Species Excluded
1	1	CHIP	58	1.09	0.67	0.00	*Pteridium aquilinum* *Solidago odora*
1	2	CONTROL	61	1.24	0.67	0.00	*Pteridium aquilinum* *Solidago odora* *Carphephorus bellidifolius* *Liatris graminifolia* *Desmodium spp.*
1	3	CHIP	36	0.92	0.78	0.00	*Solidago odora* *Carphephorus bellidifolius*
2	1	CHIP	80	0.59	0.57	0.00	*Aristida beyrichiana*
2	2	CHIP	73	1.32	0.46	0.00	None
2	3	CONTROL	82	0.83	0.55	0.00	None

Table 3. Changes in Integrity Index coefficients at Blackwater River State Forest, western FL panhandle. Hurricane Ivan occurred during the census interval.

Plot	Treatment	Group	Pretreatment	Post-treatment	Change
1	CHIP	Pineland herbs	974.0	1042.0	68.0 (7%)
		Oak-hickory herbs	63.0	91.0	28.0 (44%)
		Woody plants	401.5	464.0	62.5 (15.6%)
		Ruderals	136.5	216.0	79.5 (58.2%)
		Invasive Alien	10.0	14.0	4.0 (40%)
2	CONTROL	Pineland herbs	693.5	681.0	-12.5 (-1.8%)
		Oak-hickory herbs	83.5	78.0	-5.5 (-6.5%)
		Woody plants	476.5	498.0	21.5 (4.5%)
		Ruderals	104.0	136.0	32.0 (30.8%)
		Invasive Alien	2.5	9.0	6.5 (260%)
3	CHIP	Pineland herbs	776.5	739.0	-37.5 (-4.8%)
		Oak-hickory herbs	57.0	55.0	-2.0 (-3.5%)
		Woody plants	381.5	379.0	-2.5 (-0.6%)
		Ruderals	113.5	166.0	52.5 (46.3%)
		Invasive Alien	3.0	3.0	0.0 (0.0%)

FIGURE 1 (FMNF)

CHANGES IN PLOT PLANT COMMUNITY INTEGRITY FOLLOWING TREATMENTS



Francis Marion NF
(Note: This is now figure 2; please ignore labels for former figure 5)

FIGURE 2A

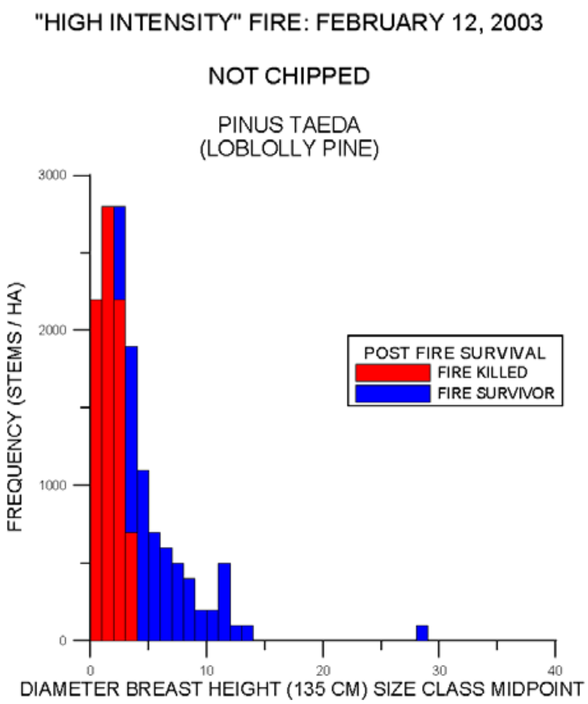
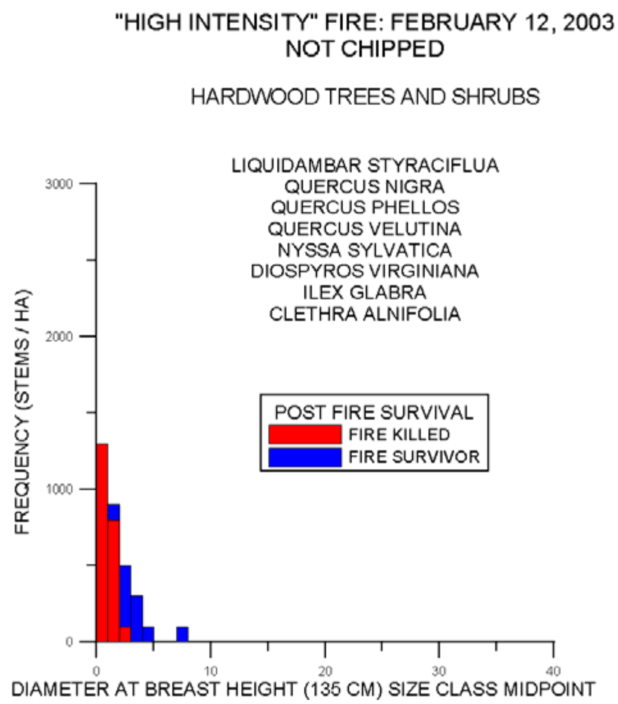
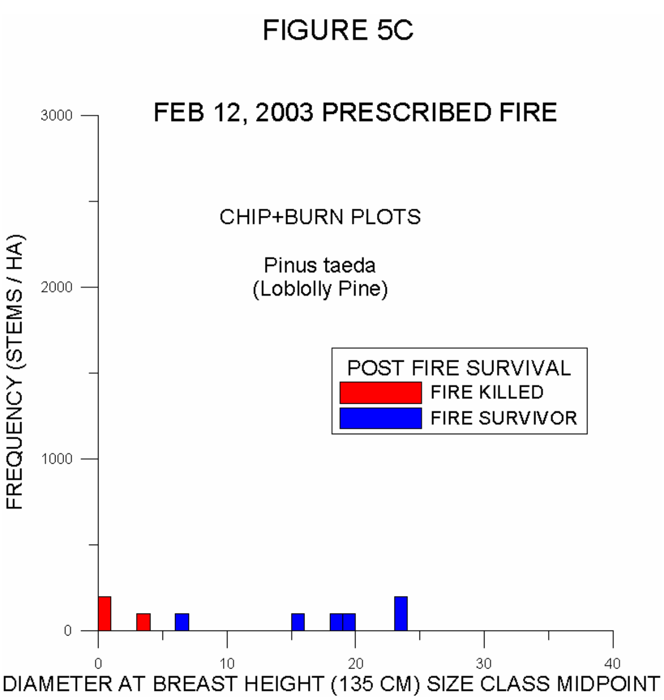


FIGURE 2B





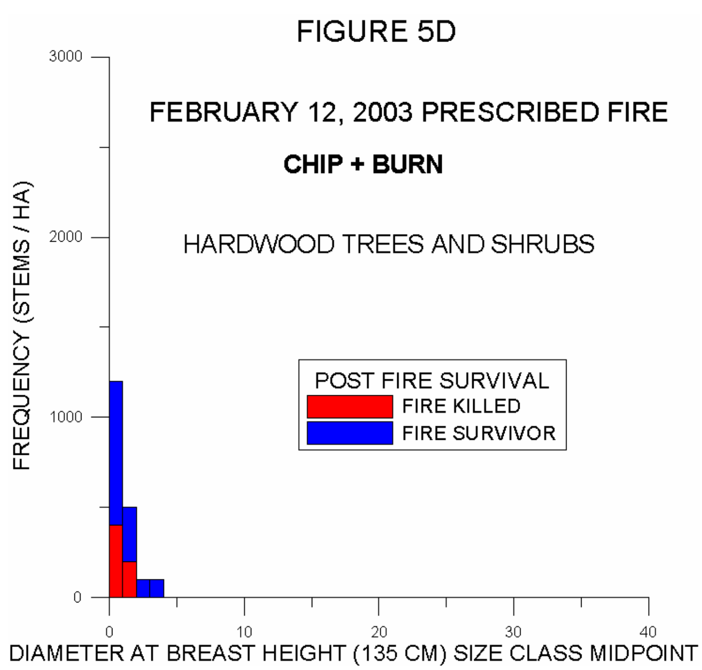


FIGURE 5E

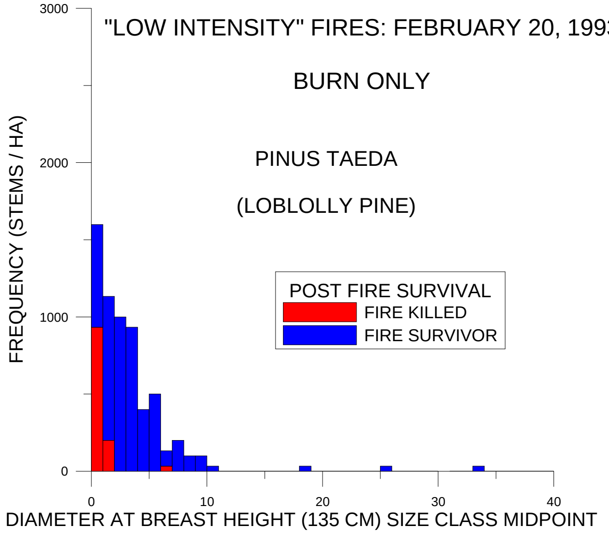


FIGURE 5F

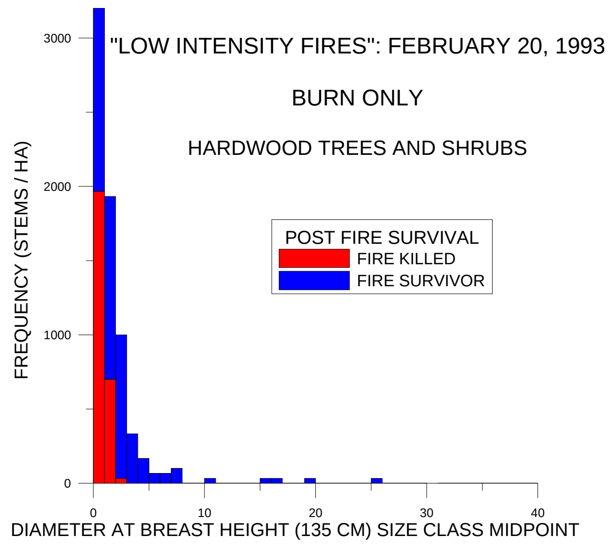


FIGURE 2G

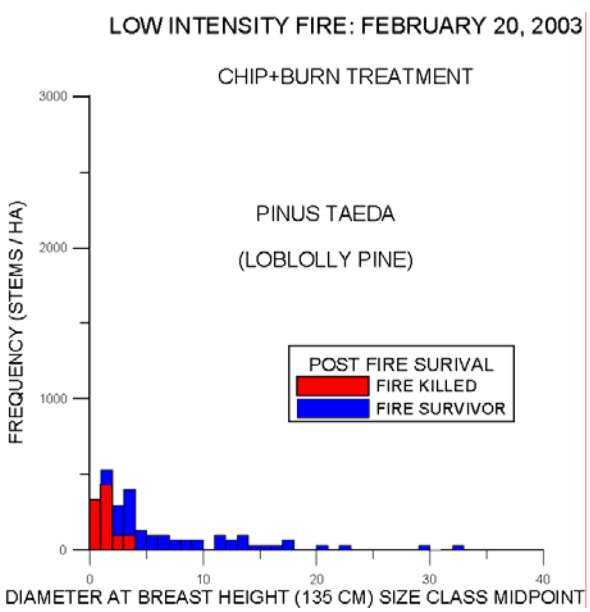


FIGURE 2H

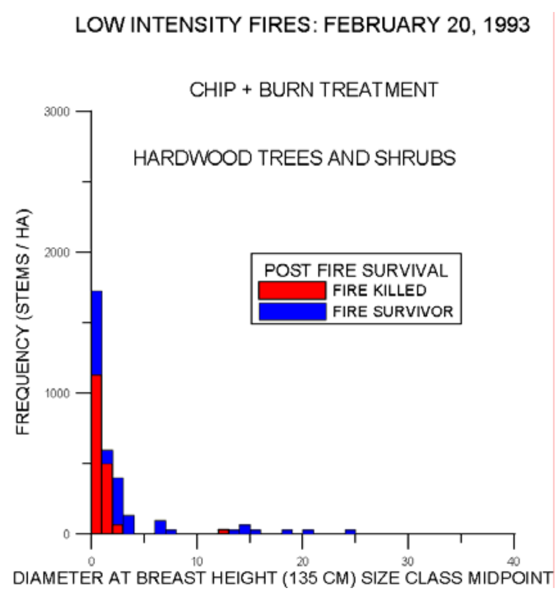


FIGURE 2I

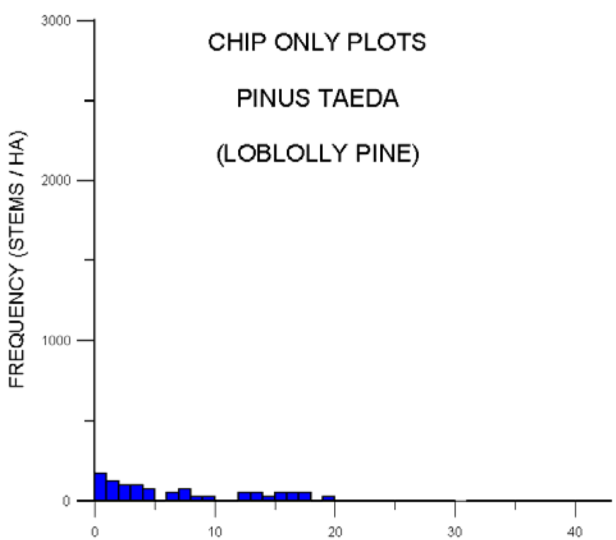
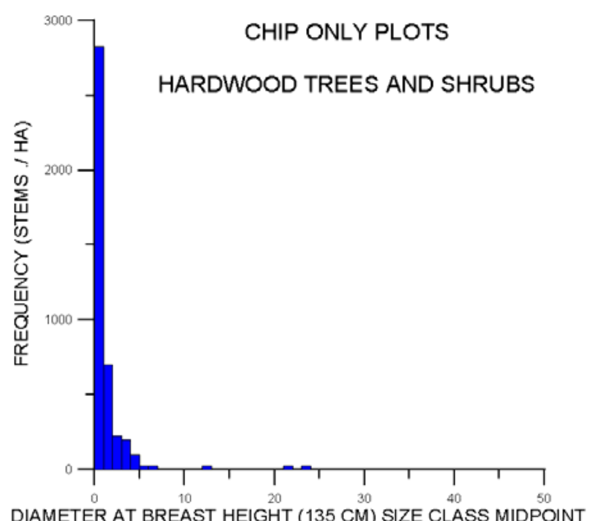


FIGURE 2J



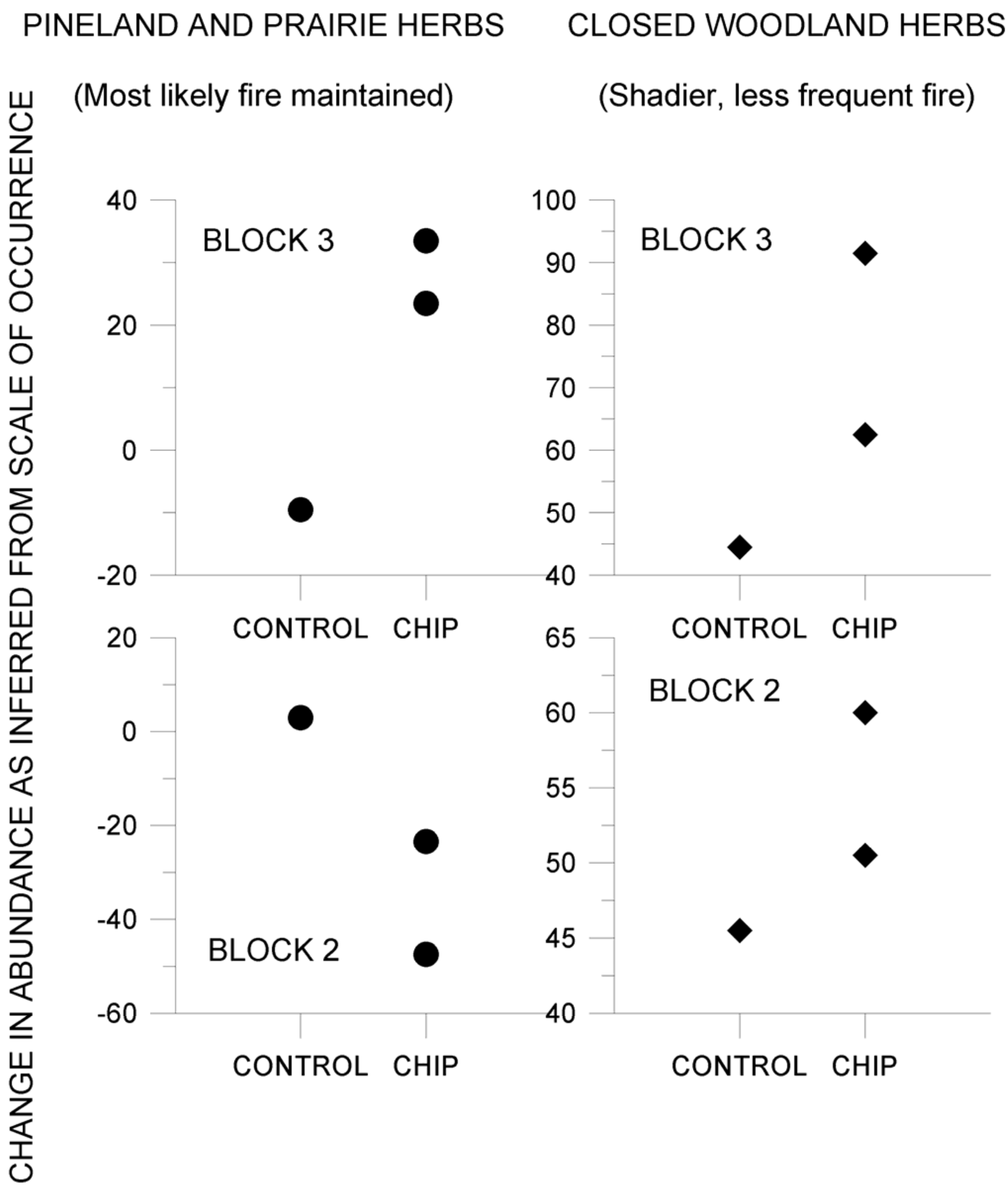


FIGURE 3. SHNF "Integrity coefficient" results: part I.

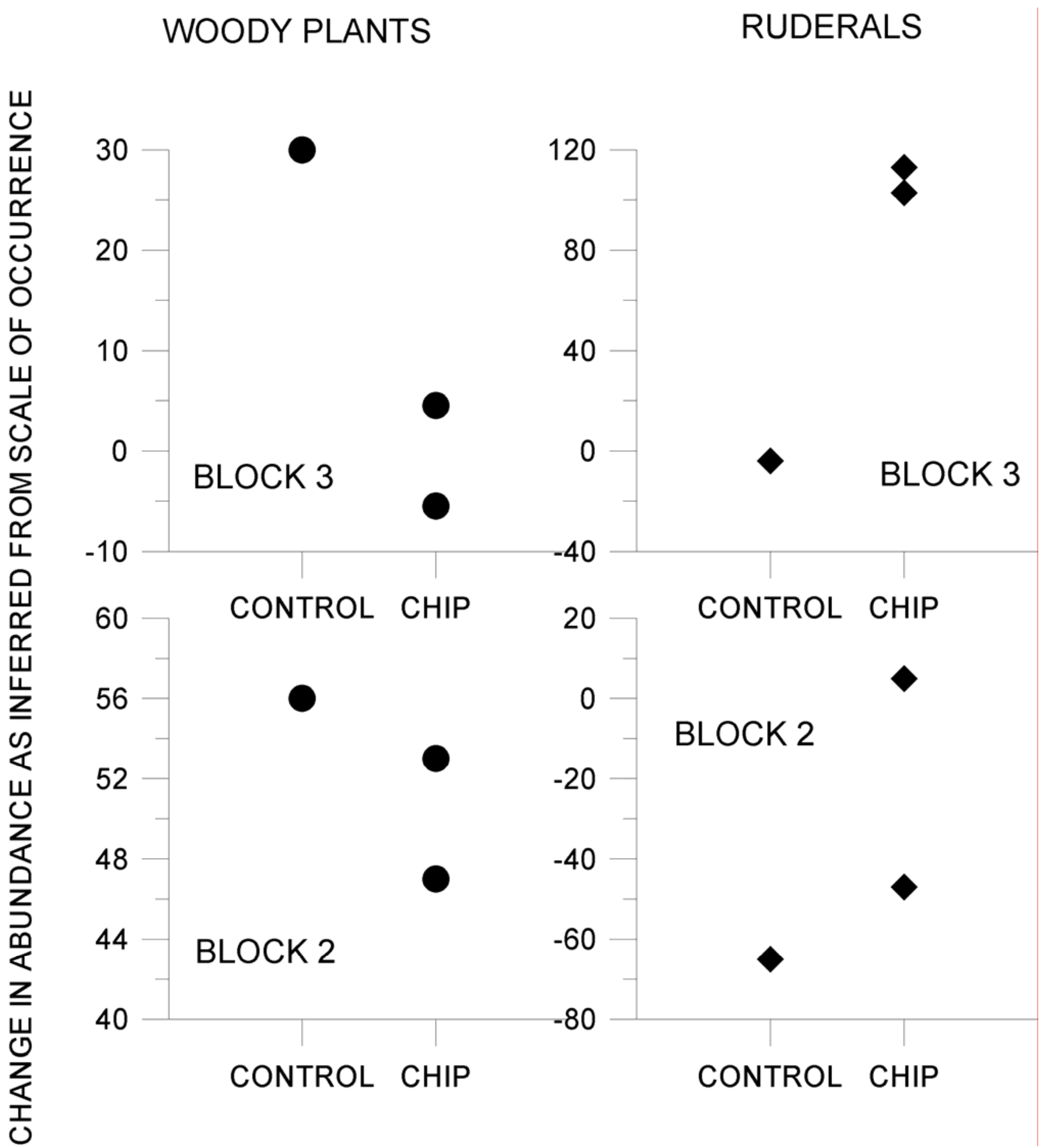


FIGURE 4. SHNF “Integrity Coefficient” Analyses: Part II

Appendix 1. History of treatments at SHNF research plots indicating confounding of treatments during the latter part of the study. (Provided by SHNF).

Compartment # 35	Type of Treatment	Date
Mulch only	Burned* Mulched Burned** Mowed	03/02 04/03 04/05 08/05
Burn only	Burned* Burned	03/02 04/05
Mulch/Burn	Burned* Mulched Burned Mowed	03/02 04/03 04/05 08/05

* Before plots were initiated
** Improper treatment for the specific plot

Compartment # 38	Type of Treatment	Date
Mulch only	Mulched Burned** Mowed	09/04 04/05 07/05
Burn only	Burned	04/05
Mulch/Burn	Mulched Burned Mowed	09/04 04/05 07/05

** Improper treatment for the specific plot

Compartment # 96	Type of Treatment	Date
Mulch only	Mulched	10/04
Burn only	Mulched**	10/04
Mulch/Burn	Mulched	10/04

** Improper treatment for the specific plot

Compartment # 107	Type of Treatment	Date
Mulch only	Mulch	12/04
Burn only	Mulch** Burn	12/04 04/05
Mulch/Burn	Mulch Burn	12/04 04/05

** Improper treatment on ½ of the plot

Appendix 5. Crosswalk between proposed and delivered outreach activities as indicated in the technology transfer section of our proposal addendum, 12 December 2000. See discussion in text concerning ambiguity with respect to JFSP expectations on communication suggestions.

Proposed	**Delivered**	**Status**
Interpretive Signs	Signs are posted at each site and block. One large sign explains the treatments and objectives. In addition, there are smaller signs in front of each plot indicating the assigned treatment.	Done
We proposed to publish the results. We did not specify any particular number or schedule of publications.	Three manuscripts have been accepted for publication and are in press: (1) Achtemeier, G.L, J. Glitzenstein and L.P. Naeher. 2006. Measurements of smoke from chipped and unchipped plots. Southern Journal of Applied Forestry. (2) Glitzenstein, J.S., D.R. Streng, G.L. Achtemeier, L.P. Naeher and D.R. Streng. 2006. Fuels and fire behavior in chipped and unchipped plots: implications for land management near the wildland/urban interface. Forest Ecology and Management. (3) Naeher, L.P, G.L. Achtemeier, J.S. Glitzenstein, D.R. Streng, and D. McIntosh. 2006. Real time and time integrated $PM_{2.5}$ and CO from prescribed burns in chipped and non-chipped plots: firefighter and community exposure and health implications. Journal of Exposure Science and Environmental Epidemiology.	One manuscript, in preparation, remains to be published. This concerns treatment impacts on vegetation dynamics: Streng, D.R., J.S. Glitzenstein, D.D. Wade and L.P. Naeher. Is mechanical chipping a surrogate for prescribed fire in vegetation management of southerneastern pine woodlands? (To be submitted to Forest Ecology and Management).
Web Site	http://ttrs.org/chip/	In progress, anticipated completion spring 2007.

Powerpoint Presentation	Is mechanical chipping a surrogate for prescribed burning in southeastern pinelands?	In progress, anticipated completion autumn 2007.
Field Demonstration Conference	Field trips were held at two of the sites. (1) The main FMNF plots were one scheduled stop on a field tour held as part of the South Carolina Native Plant Society Meetings in April, 2003. (2) A field tour of the SHNF plots was held for various members of two Texas environmental groups in July 2005.	Holding a full-scale conference as originally promised became impractical given JFSP cuts in the proposed budget. Future tours of SHNF plots may be considered inasmuch as that site is the only one likely to maintain the treatments from this point onwards.