NATIVE SANDHILL SPECIES REVEGETATION TECHNIQUES

Final Report to the Florida Department of Transportation

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Project Summary

Florida's transportation industry has primarily utilized nonnative forage grasses to vegetatively stabilize rights-of-way. Increasing the use of native species, particularly beyond the clear zone, would be desirable for reasons such as increased consistency with statewide ecosystem management goals, decreased threat of nonnative species invasion into neighboring properties, and decreased costs for maintenance of roadsides. As a result, the Florida Department of Transportation (FDOT 1993) strategy document "Management of Natural Vegetation along Highway Rights-of-Way" called for expansion of research on use of native species. If native species require less management than the nonnatives, a further benefit would be cost savings for maintenance over the long-term. Finally, FDOT now has mitigation sites that require revegetation with native species.

This research expanded on an earlier contract between the University of Florida and FDOT to examine whether and how native upland species could be restored to disturbed areas. While initial research established that mechanical collection and sowing of native species could be successfully accomplished, we found few differences among the treatments in native species cover or richness. As a result, in this project we tested new methodologies to compare several revegetation techniques to better understand methods that could be implemented on rights-of-way. We also extended and initiated research on management of natives on roadsides.

This project had five objectives:

1. Investigate site preparation, sowing methods, and management treatments for effectiveness in establishment and growth of native species;
2. Investigate the use of prescribed fire for vegetation height, flowering response, and control of woody species adjacent to the clear zone;
3. Investigate the propagation of little bluestem (*Schizachyrium scoparium*) for turf development potential and use along roadsides;
4. Continue assessment of experiments on native revegetation and on roadside vegetation management; and
5. Refine recommendations for the use and management of native plants along roadsides.

Presented below are the results of experiments we conducted for each of these objectives. We have included management implications of these experiments in the text of this report. Some of these implications are highlighted here:

- Site preparation for sowing of native seed in longleaf pine systems should depend on the degree of site disturbance.

    In sandhills, if the site is degraded but has undisturbed soil, mechanically sown seeds can establish if the vegetation is burned and then irrigated early in the growing season. If irrigation or fire is not possible, lightly roller-chopping the site will also allow good establishment of species like wiregrass, though not as successfully as the fire and

irrigation management. Burning prior to chopping appears unnecessary. Fire alone will not result in good establishment unless precipitation levels are high. In all cases (below as well), rolling the seed into the soil following sowing enhances seedling establishment.

If native vegetation is present on the sandhill site but the soil will be completely disturbed during the construction or revegetation process, perhaps the most important factor for successful colonization by natives is maintenance of the topsoil on the site. Native species appear to establish well on disturbed soils from both the sown material and the soil seedbank. Microtopographic features left from disking or bulldozing should be smoothed as much as possible to restore soil compaction and prevent seed from washing into depressions. Irrigation appears unnecessary for species establishment in a non-drought year.

If the site is covered with a nonnative species like bahiagrass, site preparation to remove the turfgrass and other nonnative and weedy native species should be conducted for a year prior to sowing native seed mix. Multiple applications of glyphosate herbicide most successfully reduced the nonnative species and increased native species cover and richness in a flatwoods site. Revegetation results also appear to be dependent on site hydrological and soil characteristics.

If the site has subsurface soil or significant quantities of construction materials present, revegetation may not be successful. We did not research whether soil nutrient levels, texture, or compaction contributed to these results. However, if significant soil modification is present, other approaches for revegetation, including using sod of native species, need to be investigated.

- In comparing uses of a hydroseeder, fertilizer spreader, cultipacker, or hayblower for sowing native seed, we found the hayblower to be the easiest and most efficient.

  Greater densities of wiregrass were established in the sandhill plots sown with the fertilizer spreader, but this machine was the most difficult to use based on the time required for preparation and sowing and the uniformity of spreading seeds on the plots. Repeated driving over the plot when using the fertilizer spreader, rather than the spreader action itself, may explain the higher wiregrass establishment observed.

- Re-establishment of native cover on disturbed sandhill soils results in stands able to carry fire within three years.

  Cover of native species in restored areas was within the range of cover in natural areas within three years of sowing. Similarity analysis of cover values between sown sites and reference sites showed high similarity indices within a year of sowing. Wiregrass contributed signficantly to increases in similarity in species composition.

- Mowing frequency should not be more than every three years for controlling the height for woody species outside the clear zone in north Florida.

  After four years, heights of native vegetation on rights-of-way remained below two feet even in years of extreme rainfall and drought. While the results may not be applicable to areas further south in Florida, reducing mowing in north Florida should provide significant savings for the State.

- Regardless of mowing frequency earlier in the season, the height of bahiagrass in the winter decreased to below six inches in north Florida.

  Again, December heights were consistent in years of varying precipitation and temperature. We recommend that mowing schedules in north Florida be re-evaluated based on these data.

- Over the short-term, prescribed fire will not substitute for mowing to reduce woody species density on rights-of-way.

  Fire stimulated stem production in woody species and flowering of herbaceous species, significantly increasing the height of the vegetation. However, repeated fire should reduce woody species (e.g., Glitzenstein et al. 1997). On rights-of-way adjacent to natural areas managed with fire, using fire to control roadside vegetation may reduce mowing costs and impacts to native vegetation. Where such management would not jeopardize the safety of drivers, the result would be a roadside with diverse colors and textures and greater habitat value.

- Little bluestem (*Schizachyrium scoparium*) may form a continuous turf and be useful for revegetation efforts.

  Prescribed fire appeared to increase seed production and germinability in little bluestem, though viable seed is produced without fire. Results showed that this species was sensitive to water availability, and may be more successfully propagated in field rather than greenhouse conditions. Both direct seeding and planting of plugs can be used to establish this species. Further work should evaluate the potential for larger-scale use of this species by FDOT.

- Seed of wiregrass (*Aristida beyrichiana*) may be stored for at least two years and remain viable.

  We found establishment of seed that were stored for two years in paper bags under temperature-controlled conditions. The relationship between seed age and germinability requires further research.

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<u>O BJECTIVE 1</u>: Investigate site preparation, sowing methods, and management treatments for effectiveness in establishment and growth of native species.

<u>Introduction</u>

Historically much of the upland vegetation throughout Florida was dominated by a longleaf pine (*Pinus palustris*) overstory with a highly diverse groundcover of grasses and forbs (Myers 1990, Stout and Marion 1993, Figure 1.1). Various land uses have resulted in alteration of much of the upland vegetation; however, there is great interest in restoring the once extensive community. At The Nature Conservancy's Apalachicola Bluffs and Ravines Preserve (ABRP) an effort has been underway since the mid-1980s to restore the components and function of a severely disturbed longleaf pine/wiregrass (*Aristida beyrichiana*) community (Seamon 1998). While re-planting with longleaf pine is relatively straightforward, re-establishment of the diverse understory has been more challenging. Development of methodologies for accomplishing this revegetation will be relevant for other types of sites as well, including mitigation areas and rights-of-way.

Figure 1.1. Longleaf pine system with a diverse understory dominated by wiregrass. The open stand structure was naturally maintained with fire.

The Florida Department of Transportation has committed to increasing the use of native species for several reasons, including: decreasing the invasion of nonnative vegetation into neighboring properties, increasing consistency with statewide ecosystem management goals, providing habitat for native wildlife, increasing consistency with federal revegetation guidelines, and decreasing the costs for roadside maintenance. This research expanded on previous work funded by FDOT (Gordon et al. 2000) to examine how native upland groundcover species might be used for revegetation beyond the clear zone. While initial research established that mechanical collection and sowing of native species is possible (Hattenbach et al. 2000, Seamon 1998), this research tested new methodologies that may allow development of techniques more appropriate for implementation on FDOT rights-of-way.

Under Objective 1, we discuss three experiments designed to investigate the establishment and growth of native herbaceous species. The first two Experiments, A and B, were conducted in the degraded sandhill at ABRP and were similar in many respects. Site preparation and sowing equipment were varied to test both aspects of revegetation methodology. Experiment C was established on a roadside site requiring revegetation following completion of the Florida Highway 20 Blountstown Bridge repair.

Experiment A: Investigate the effects of two site preparation treatments with and without irrigation on establishment of a native sandhill seed mixture.

Experiment B: Investigate the relative effectiveness of four mechanical sowing methods in both site preparation treatments.

Introduction

Historically the longleaf pine/wiregrass community has been maintained by frequent, low-intensity fire (Myers 1990, Christensen 1988). However, within the last fifty years, fire suppression has been predominant, with many areas managed for timber production or converted to other uses. As the understory community is sensitive to soil disturbance, much of this community component has been lost across the range of longleaf pine systems (Clewell 1989). The result is a loss of species richness and most of the fine fuel that once supported fire. This research continued our work to identify methods for restoring or revegetating disturbed sites with native understory species.

In Experiment A, we investigated whether site preparation influences the number of species (species richness) or percent cover of native vegetation when native seed was sown onto disturbed habitats. The experiment was conducted at the Apalachicola Bluffs and Ravines Preserve (ABRP) in sandhill soils that had been windrowed and planted in slash pine (*Pinus elliottii*) in the 1950s. The site preparation treatments tested included burning prior to sowing seed (increasing light and potential soil nutrient levels without soil disturbance), or roller-chopping (increasing light and disturbing soil), both burning and chopping, and no treatment. Because we suspected that establishment of native species might depend on early spring precipitation, we included irrigation with the burn treatment in a split split-plot design.

Based on earlier research, we hypothesized that native species richness and cover would be higher in the roller-chopped and roller-chopped / burned treatment than in the burned only treatment, but that establishment of natives in the burned plots would be increased by the spring irrigation treatment. We further hypothesized that vegetation in the irrigated / burned treatment would respond similarly to that in the burned / chopped treatment. These hypotheses resulted in three comparisons: burned vs. chopped vs. burned and chopped, burned and irrigated vs. burned, and burned and chopped vs. burned and irrigated.

In addition to site preparation, the sowing methods may influence revegetation success. Mechanical sowing methods have been tried for restoration purposes (Bissett 1996, Seamon 1998, Hattenbach et al. 1998, Miller and Dickenson 1999). In Experiment B, we further tested such methodology, selecting equipment that is currently available to FDOT and its contractors: hay blower, hydroseeder, fertilizer spreader, and cultipacker. Native sandhill seed mix was sown using each type of equipment in two of the site preparation treatments of Experiment A: burned vs. chopped. We hypothesized that there would be no differences in species richness or percent cover of native species, bare soil, and litter among the four mechanical sowing methods within each site preparation treatment.

Methods

Site: Apalachicola Bluffs and Ravines Preserve

The upland portion of ABRP was originally a sandhill community, dominated by a longleaf pine canopy and a rich assemblage of grasses and forbs (Figure 1.2). Wiregrass was a primary component of the understory that carried the frequent fires that maintained the structure and diversity of the community. In the mid-1950s the area was logged and cleared for a slash pine plantation and the remaining vegetation along with the topsoil was piled into parallel windrows. Upon The Nature Conservancy's acquisition of the property in the 1980s the slash pines were harvested and longleaf pine seedlings planted. Groundcover restoration, initiated in the late 1980s included planting wiregrass and other seed collected from areas with no windrows.

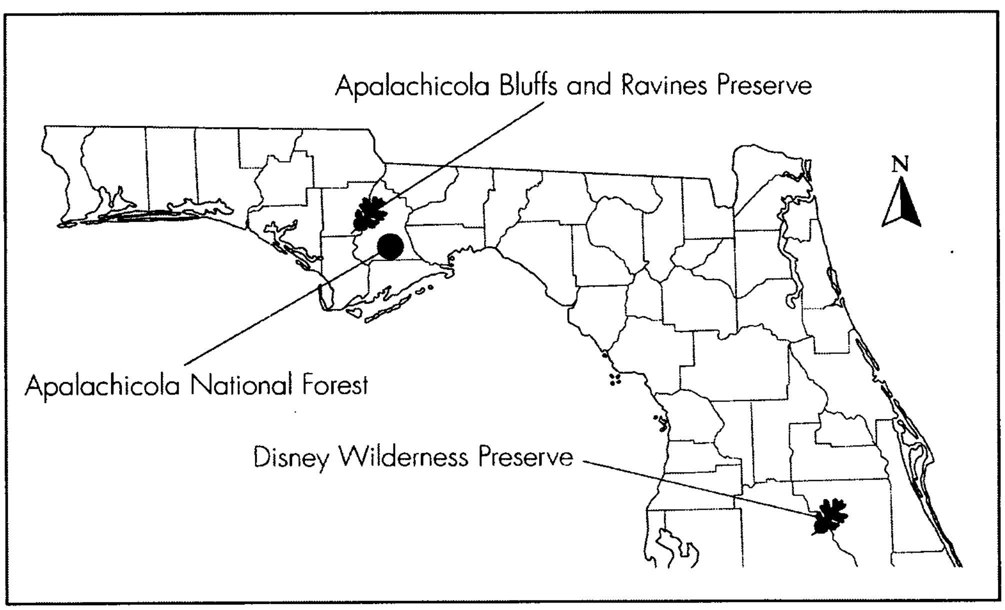

Figure 1.2. Florida study sites mentioned in this report.

The degraded sandhill served as an ideal location for studying the effects of re-introducing native species using several site treatments and various sowing methods. The experimental area consisted of nutrient poor-sandy soil, sparse groundcover with no wiregrass, and intact windrows. In September 1998, the research plots were located in thirty acres of this degraded sandhill.

Experimental Design

Experimental plots

Experiments A and B shared several of the same site preparation, seed collection, and treatment plots. Experiment A combined site preparation and irrigation in a nonfactorial, randomized split plot design, with fire as the main split, and irrigation as sub-split treatment in the burned area. Six blocks, with ten 15 x 15 m (49 x 49 ft) treatment plots each, were located along the length of the 46 m (150 ft) wide areas between the intact windrows (Figure 1.3). We left a minimum of 10 m (33 ft) between plots. Experiment A utilized four of those plots per block: one each of the site preparation treatments of fire alone, fire and irrigation, fire and roller-chop, and roller-chop alone (Table 1.1). All plots in Experiment A were sown using the hayblower.

For Experiment B, we again used the split plot design and two of the treatments established for Experiment A. Six additional plots were established per block with three each in the burned or roller-chopped areas (Table 1.1). The hayblown seed plot in the fire alone or chop alone site preparations (Experiment A) would be compared with the three other plots in each area, each sown with a different piece of equipment (see below).

Control plots

Responses of the vegetation in both experiments could be compared with two types of control plots that we established in the blocks adjacent to the experimental plots (Table 1.1). The plots (15 x 15 m, 10 m from the closest experimental plot) experienced the same site preparation treatments as Experiment B: burning or chopping, but were not subsequently sown. These allowed us to evaluate the contribution of the sown seed to the cover and composition of the plots. Because of space limitations, only three (rather than all six) of the roller-chopped blocks included these additional unsown control plots. As a second control of both sowing and site preparation, we also established one plot per block in the degraded sandhill adjacent to the burn and chopped site preparation units. These provided a comparison of the naturally occurring vegetation with the vegetation in the treatment plots. As a result, we had both site prepared but not sown controls (cno, fno) and neither site prepared nor sown controls (natv).

Reference plots

Finally, six plots were established as reference areas in frequently burned (3 to 4 year intervals) sandhill that had been left relatively undisturbed by silvicultural practices in the 1950s (i.e.,

Table 1.1. Arrangement of the randomly blocked treatment applications.

	Treatments*												
Site prep.	Chopped				Burned								
Block	ccu	cfe	cha	chy	fhai	fcu	ffe	fha	fcha	fhy	cno	fno	natv
A	4	1	3	2	5	9	8	7	6	10	1	9	15
B	1	2	3	4	5	7	8	6	10	9	--	8	16
C	2	4	1	3	5	6	10	8	7	9	--	7	17
D	3	2	4	1	5	10	7	6	9	8	--	12	18
E	2	4	1	3	5	6	9	10	7	8	2	11	14
F	1	4	2	3	5	8	7	10	9	6	3	10	13

*Treatments are as follows: **ccu** = chop, cultipack; **cfe** = chop, fertilizer spreader; **cha** = chop, hayblower; **chy** = chop, hydroseeder; **fhai** = fire, hayblower, irrigate; **fcu** = fire, cultipack; **ffe** = fire, fertilizer spreader; **fha** = fire, hayblower; **fcha** = fire, hayblower, chop; **fhy** = fire, hydroseeder; **cno** = chop, unsown; **fno** = fire, unsown; **natv** = no site preparation, unsown.

some harvest may have occurred, but the areas were not windrowed or planted with off-site pines). These plots were used to evaluate overall restoration success in the restoration treatments. These "reference" plots were located at ABRP disjunct from the experimental area. All plots were at least 25 meters (82 ft) from either roads or the edge of ravines to reduce edge effects. The reference plots were monitored in October 2000 using the same methodology as for the experimental plots.

This design resulted in a total of 81 plots: 24 experimental plots in Experiment A, 36 plus 12 of the Experiment A plots for Experiment B, 15 control plots used for comparison for both experiments, and six reference plots. Six experimental plots were located in the burned area and three in the chopped but not burned. All sown plots received the same amount of seed (4.5 lb) by weight. All seed were rolled to increase contact with the soil following sowing.

Site Preparation

Burning

On December 16, 1998, twenty acres of degraded sandhill at ABRP were burned to prepare for sowing in January. The prescribed burn was conducted by Northwest Florida Program staff, University of Florida staff, and volunteers. By burning the site before sowing, we maximized the amount of mineral soil available for seedling establishment. Fire removed most of the existing groundcover and top-killed some of the hardwoods, though most resprouted. Burning cleared the site so that more of the seed sown would contact the soil and reduce competition to allow for seedling establishment.

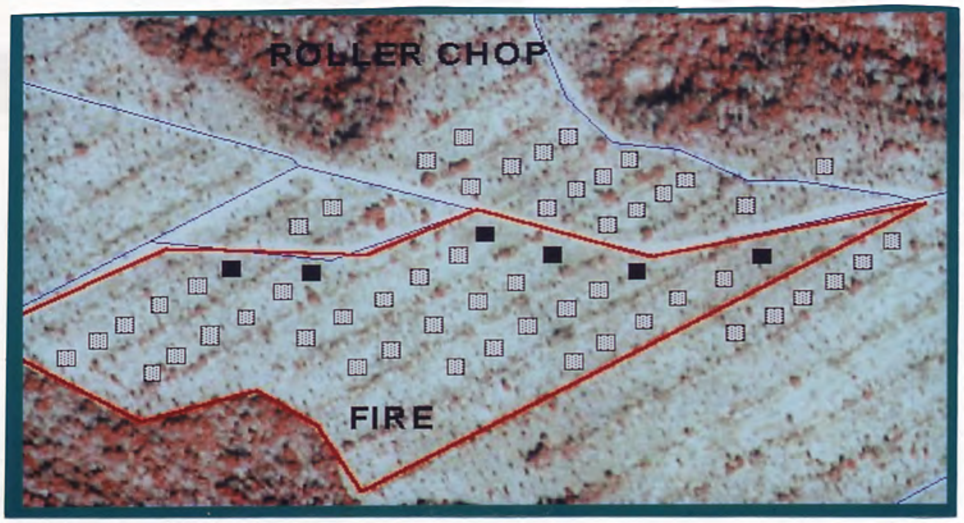

Figure 1.3. Apalachicola Bluffs and Ravines Preserve research site and experimental plot locations.

Roller Chopping

Approximately ten acres of degraded native sandhill were roller-chopped in early January 1999. A 7 ft wide light-duty roller chopper was borrowed from Doug Dedrick with the Florida Division of Forestry in Carrabelle. The chopper weighed approximately four tons without water, which was how it was used. A Massey-Ferguson 65 horsepower tractor pulled the roller-chopper. One pass over the plot was adequate, but it was sometimes necessary to roll plots more than once because of large trees in the way; small trees were cut down. Because the roller chopper left deep grooves in the soil, which might result in deeply buried seeds, the chopped plots were rolled perpendicular to the direction of chopping prior to sowing.

Seed Collection

Native sandhill seed for Experiments A and B was collected from November 12 through December 12, 1998 at ABRP by Northwest Florida program staff, University of Florida staff, volunteers, and an inmate work crew. The seed was collected both mechanically and manually. One of the mechanical seed collectors used at ABRP was a Woodward Flail-Vac seed stripper (Ag-Renewal, Weatherford, Oklahoma), mounted onto the front of an all-terrain vehicle (ATV). When the ATV was driven through stands of wiregrass and other plants with mature seed, a rotating brush in the collector pulled the seed from the stalks into a hopper. This collection method resulted in a heterogeneous mixture of wiregrass seed, seed stalks, dead oak leaves, small twigs, and seed from other species that also mature in late fall.

The other mechanical seed collector was a Portable Seed Stripper (Prairie Habitats, Argyle, Manitoba, Canada). This was a modified weed-whacker, manufactured by Stihl, on which a light duty stripper head rotated and knocked mature seed from the stalks into a mesh hopper. The seed was then deposited into a nylon bag attached to the bottom of the hopper. The Portable Seed Stripper yielded a mixture of wiregrass seed with some stalks and chaff. This seed was collected in either paper lawn and leaf bags or plastic garbage bags and then stored indoors in paper bags in a temperature and humidity controlled environment.

Abundant wiregrass seed was collected by an inmate work crew by cutting handfuls of seed stalks at the base. The stalks were cut into 2-3 inch pieces to aid in their dispersal in the final seed mixture and to insure that they would not clog the machinery used for sowing. This seed was collected in paper grocery bags and stored indoors with the rest of the seed.

Direct Seeding

Northwest Florida Program staff and an inmate work crew mixed together the Flail-Vac mechanically collected seed and then filled 60 bags with 4.5 lbs each (240 lbs total, measured with a hanging dairy scale). This amount is equivalent to 40 lbs of sandhill seed per acre. Percent of wiregrass seeds was calculated at 10 lbs per acre based on the average weight of seeds from ten random samples. Seed viability was tested to determine the percent of seeds capable of germinating. The native sandhill seed mix was applied to the plots using the sowing equipment described below.

Irrigation for Experiment A

A 1.5 inch well was drilled at ABRP in mid-December 1998 to supply water for the irrigated plots. Hayes and Son Well Drilling of Blountstown, Florida installed the 400 ft well and a 1.5 hp pump. A 1.5 inch PVC pipe was buried 2-4 inches deep along the south edge of the driveway from the tank to the plots. Sprinklers released three gallons per minute each. The irrigation system was completed in late December. An automatic timer was installed with the irrigation system and the plots were watered in the early morning hours before sunrise.

The irrigation started on January 25, 1999 and continued through the first of June 1999 (Table 1.2). One direct seeded plot from the burned site treatment in each of the six blocks received the average daily rainfall by month for the 10% of months with the highest precipitation recorded from 1968-1997 (National Climatic Data Center). For example, during that 30 year interval, 1973 (38.82 in), 1983 (31.31 in), and 1991 (38.32 in) had the highest recorded precipitation for those four months. We applied a total of the average of those values (36.15 in) distributed by month using the average percent of the total that had fallen in each month over the 30 year period. Those monthly values were divided by the total number of days per month to obtain daily irrigation amounts. We continued the watering through May because rainfall in 1999 was significantly below average. Irrigation was stopped after the seasonal afternoon rains returned in June 1999.

Sowing Equipment for Experiment B

This experiment compared the effectiveness of sowing the sandhill seed mix from ABRP with four different types of sowing machinery. The Northwest Florida Program owns a fertilizer spreader and rented a cultipacker, hayblower, hydroseeder, and soil aerator for the experiment. For all sowing methods, seed sowing was followed by rolling with the soil aerator. The fertilizer spreader, cultipacker, and hayblower sowing was conducted in January 1999 and the hydroseeding sowing occurred in early February.

Table 1.2. Irrigation for seeded plots from January to June 1999 in Experiment A plots.

Month	January	February	March	April	May	June
Gallons/day	556	376	529	436	193	281
Inches/day	0.44	0.30	0.42	0.35	0.15	0.23

Hayblower - An Easy Lawn straw blower manufactured in Seaford, DE was rented from Rental Services Inc. in Thomasville, GA (Figure 1.4). The hayblower was towed behind a pick-up truck. The seed for each plot was divided into fourths and blown onto the plot from each corner. It was difficult to direct seed into the corner because the blower would not point directly downward. Previous hayblower rentals had flexible hoses that allowed seed to be directed more easily in small areas.

Fertilizer spreader - Four and a half pounds of seed mix were combined with 2.5 lbs of medium vermiculite in a garbage can. Enough water was added so the seeds would stick to the vermiculite (for added weight) and mixed with a shovel.

Figure 1.4. Sowing native sandhill seed mix with a hayblower on research plots.

A Thompson fertilizer spreader was mounted onto the back of a pick-up truck with the tailgate removed. One person rode in the bed and placed the seed mix into the hopper, pushing it through the hole with a stick (Figure 1.5). The roller-chopped plots were seeded by making six passes through each plot with the truck and stopping eight times to seed on each pass. This method was very slow because our seed mix did not flow well through the spreader. Sowing the burned plots was more difficult because the numerous trees and shrubs present prevented driving the machinery straight through the plots. More seed was sown toward the edge than the center because the edge was more accessible by truck. This method did not appear to work well with the wiregrass seed mix.

Plots E4, F4, and F7 were sown on January 22, 1999 on a day with southwest winds. We compensated for the wind by sowing seed from the upwind side of the plots.

Cultipacker - Marty Ard Landscaping was contracted for the cultipacking. The cultipacker was pulled behind a tractor. Each cultipacked plot was mulched with eight bales of pine straw after sowing and before cultipacking. The pine straw was collected from a slash pine plantation in Wewahitchka, 25 mi. south of Blountstown. Pieces of the nonnative Japanese climbing fern (*Lygodium japonicum*) in the bales were removed before distributing the pine straw.

The pine straw was blown onto the plot with the hayblower using two bales in each plot (Figure 1.4). This amount of straw provided about 1 cm (0.25 inch) of mulch. As with the seed, it was difficult to blow the mulch into the corners of the plots. We cultipacked each plot twice, at 90° angles, to accommodate the trees and shrubs present. The cultipacker blades were about 30 cm (12 in) apart. Cultipacking is more effective if the tractor travels at higher speeds, but the tractor was driven slowly because of the small size of the plots and to avoid the trees, shrubs, and logs within the plots.

Hydroseeder - The hydroseeder for this project was loaned to us by Coastal Land Management in Quincy, Florida. The hydroseeder, filled with 250 gallons of water, was pulled to the plots by a pick-up truck. Fifty pounds of mulch (Excel fibermulch with tackifier) were added and agitated for five minutes to mix thoroughly and allow water absorption. The native sandhill seed mix was added, agitated, and the water, mulch, and seed mixture were sprayed onto the plots (Figure 1.6). The green dye in the fibermulch showed how evenly the seed and mulch were spread. In the burned plots, the mixture was applied from more than four locations on the plot perimeter because trees and shrubs prevented even spreading. Initially, the coarse native sandhill mix clogged the hydroseeder. The sandhill mix for these plots was then shredded twice in a leaf shredder to allow for more even flow of seed and mulch through the equipment. Additionally, the recommended 100 gallons of water were increased to 250 gallons for uniform spreading. After each plot application, the hydroseeder was rinsed with 50-75 gallons of water from a water tank on the truck and any remaining mix was spread on the plot.

Roller - A landscape aerator, a roller with three inch metal spikes, was rented from Rental Services Inc. in Thomasville, GA. The three foot wide, one foot diameter landscape aerator was towed with an all-terrain-vehicle (ATV) and all plots were rolled within one day of application

(Figure 1.7). It was not possible to roll every inch of the burned plots because trees, shrubs, and logs were in the way. A larger roller would not be practical to maneuver through areas with trees.

Figure 1.5. Modified fertilizer spreader sowing native seed mix. The person standing over the hopper is pushing the seed through with a wooden pole.

Figure 1.6. Native sandhill seed mix sown on the plots using a hydroseeder.

Figure 1.7. Seed contact with soil was increased in all the treatment plots by rolling over them with a soil aerator roller pulled behind an ATV.

Monitoring

Species richness and quantitative monitoring for Experiments A and B were conducted consecutively. Species richness was censused in each of the 75 plots five times during this study: July and September in 1999 and April, July, and September in 2000. Quantitative data were collected in September and October 1999 and 2000. Included in the census were the native control sites and the "sowing control" sites, which experienced the same site preparation treatment, burning or chopping, but were not subsequently sown with seed. The six reference plots were only monitored in fall 2000, for comparison with the 2000 data in the experimental plots.

Species Richness

Presence or absence of each species was collected in each plot to examine differences in the species that comprise the richness numbers. Data were recorded for each species encountered along a three-meter wide belt transect extended diagonally across the 15 x 15 m (49 x 49 ft) plots and within three meters of the perimeter. Photo points were taken at permanent locations after vegetation monitoring.

Percent Cover and Wiregrass Density

We collected data on percent cover and wiregrass density within each of the experimental and reference plots (fall 2000 only). Four types of cover were ocularly estimated: native vegetation, nonnative vegetation, bare soil, and litter (dead plant material disconnected from a living plant) in 0.5 x 1.0 m (1.6 x 3.3 ft) quadrats using the Daubenmire cover classes (Bonham 1989). Quadrats were placed every five meters on transects randomly located though a restricted randomization of one transect in each of three five meter sections. Density of wiregrass was also determined in each quadrat. This design resulted in nine cover and density sampling sub-plots per treatment plot.

Data Analysis

Although monitoring was conducted simultaneously for Experiments A and B, treatment analyses differed. Experiment A comparisons were made across site preparation treatments: (1) fire vs. fire and irrigation, (2) fire and irrigation vs. fire and chopping, and (3) fire vs. chopping vs. fire and chopping, using one way ANOVA. We included analysis of interactive effects between the four mechanical sowing methods: cultipack (culp), fertilizer spreader (fesp), hayblower (habl), and hydroseeder (hydr) nested within the two site preparation treatments: roller chopping and prescribed fire in Experiment B. Differences among treatments in species richness, wiregrass density, and percent cover data were again analyzed using ANOVA. Data were transformed to increase consistency with the test assumptions where necessary.

The mean frequency of each species by treatment was calculated to evaluate whether species frequency is treatment-dependent. As described above, included in the frequency census were (1) six un-sown plots adjacent to the burn treatment (fno), (2) three un-sown plots adjacent to the chopped treatment (cno), (3) six additional plots in the untreated areas adjacent to each of the experimental blocks (natv), and (4) the six reference plots established in the intact sandhill without windrows.

Using the frequency data we calculated similarity measures that allowed us to evaluate which seeded treatments in Experiment A and sowing methods in Experiment B most resembled the high quality reference plots (Provencher et al. 2001). We calculated a similarity index value for the plant community in each treatment plot with each of the reference plots. The closer the index value to1.0, the more similar the species frequency in the experimental plot was to that in the reference plot. Analysis of variance on the similarity index values then allowed us to evaluate whether any of the treatments resulted in a community with significantly greater similarity to the reference condition than any other treatment. Index values, rather than the raw data, needed to meet the assumptions for ANOVA. Because several similarity indices have been developed (Bonham 1989), each involving somewhat different assumptions, we used two indices and looked for a consensus decision between them for significant differences.

The two indices used were Proportional Similarity (PS) and Bray-Curtis (BC) (actually, 1 - the Bray-Curtis index of dissimilarity) (Provencher et al. 2001). Proportional Similarity uses the relative abundance of species for the comparison, while BC uses the average abundance of species (Bonham 1989), and has recently been well reviewed (Underwood and Chapman 1998). For both indices, plots that share all the same species in the same relative or absolute abundance have a similarity of 1.0, while plots that share no species have a similarity of zero.

Identification of which species contributed the most to the similarity patterns among treatments provides information about the specific factors that made experimental plots most like (or most unlike, if the contribution is negative) the reference plots. Additionally, those factors could be used as positive or negative indicators of the relative success of the plant community restoration. This contribution can be evaluated through correlation of the similarity values from each of the six blocks with the contribution of each species to that similarity value. A positive correlation indicated that the species supported the similarity pattern, whereas a negative correlation meant that the species weakened the similarity pattern. See Provencher et al. (2001) for further discussion of this analysis. We retained only variables with significant correlations for both indices, again using a consensus decision to identify the important contributors.

Results

Experiment A

Species Richness

Mean species richness comparisons (square root transformed) were made across years, blocks, and site preparation treatments in 1999 and 2000 (Appendix B). No difference in mean species richness was seen from 1999 to 2000 within treatments. Richness was significantly higher both years in the fire and irrigation (Figures 1.8 and 1.9) plots compared with fire alone ($F_{(1,20)} = 27.2$, $p < 0.001$; Figure 1.10 a) and across blocks ($F_{(5,20)} = 6.34$, $p < 0.005$). Neither year nor block showed species richness differences between the fire and irrigation and fire and chopping plots. Fire and irrigated plots had significantly higher species richness than fire and chop in 1999 ($F_{(1, 20)} = 20.1$, $p < 0.001$), with a significant interaction of year and site preparation method ($F_{(1, 20)} = 5.01$, $p < 0.04$; Figure 1.10 b). Comparisons of chopping vs. fire alone vs. fire and chopping showed significantly higher mean species richness in 2000 than in 1999, ($F_{(1, 30)} = 20.2$, $p < 0.001$), and in the chopped only plots than in the others ($F_{(2, 30)} = 12.2$, $p < 0.001$; Figure 1.10 c). Block effects were also significant ($F_{(5, 30)} = 3.70$, $p < 0.02$).

Percent Cover

Mean percent cover of native vegetation (log transformed) was significantly higher in the fire and irrigation plots than in the fire alone ($F_{(1,212)} = 52.2$, $p < 0.001$; Figure 1.11a). No differences were noted between years (1999 and 2000) or between blocks. Percent native cover was also significantly higher in the fire and irrigated plots ($F_{(1,212)} = 43.2$, $p < 0.001$) than in the fire and chopped plots. Greater native cover in the fire and chopped plots in 2000 than in 1999 resulted in a signficant year effect ($F_{(1, 212)} = 4.75$, $p < 0.03$; Figure 1.11b). For the three way comparison (Figure 1.11c), in 2000 the burned and chopped plots increased in native cover to become equivalent to that in the chopped plots (year: $F_{(1, 212)} = 12.61$, $p < 0.0004$), exceeding that in the burned only plots (treatment: $F_{(2, 212)} = 11.62$, $p < 0.0001$), resulting in a significant year by treatment interaction ($F_{(1, 212)} = 6.84$, $p < 0.01$; Figure 1.11c).

Figure 1.8. Burned and irrigated plots sown with the hayblower after four months of irrigation.

Figure 1.9. Burned plots sown with the hayblower after four months without irrigation.

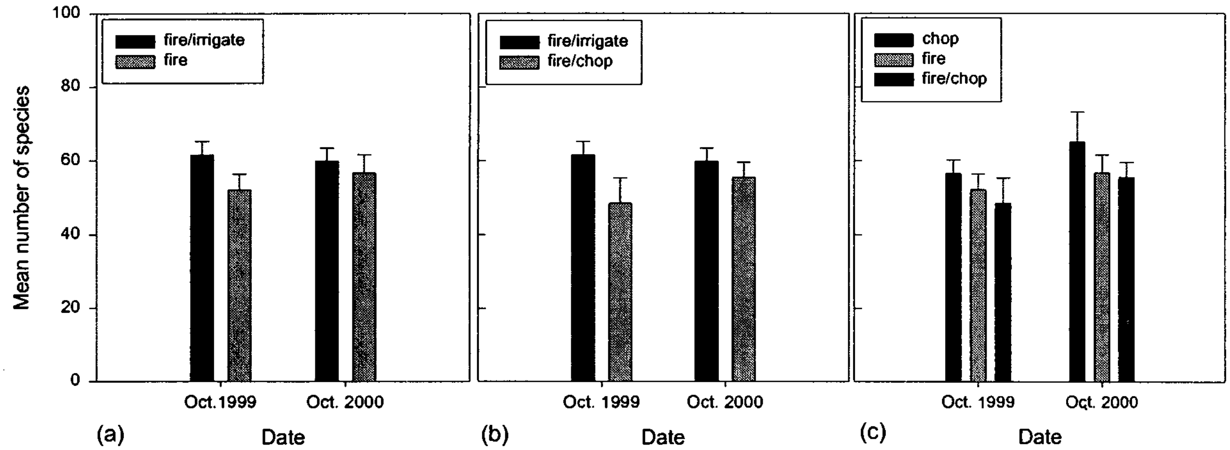

Figure 1.10. Mean (± 1 SD) species richness in plots with different site preparation treatments: (a) fire and irrigation vs. fire treatments; (b) fire and irrigation vs. fire and chopped treatments; and (c) fire vs. chopped vs. fire and chopped treatments in 1999 and 2000. Means accompanied by the same letter (above the bar) are not significantly different from one another.

Bare soil showed opposite trends to percent vegetation cover. Significantly more bare soil was found in the burned only ($F_{(1,106)} = 36.3$, $p < 0.001$; Figure 1.12 a) or burned and chopped ($F_{(1,106)} = 119$, $p < 0.001$; Figure 1.12 b) plots compared to the burned and irrigated plots. Burned and chopped plots had higher cover of bare soil than did either of those treatments alone in 2000 ($F_{(1,159)} = 10.5$, $p < 0.001$; Figure 1.12 c), but not in 1999, again resulting in a significant interaction between treatment and year ($F_{(1,106)} = 10.0$, $p < 0.002$).

Influences on the percent cover of litter were less consistent within and among years (Figure 1.13). Litter levels were lower in the burned and irrigated than in the burned only plots in 1999, but the reverse was true in 2000. As a result, both year ($F_{(1,212)} = 4.47$, $p < 0.04$) and the interaction of year and treatment ($F_{(1,212)} = 6.80$, $p < 0.01$) significantly contributed to litter cover. Block effects also contributed to these patterns ($F_{(5,212)} = 2.52$, $p < 0.03$; Figure 1.13 a). Burned and irrigated plots contained more litter than did burned and chopped plots in both years ($F_{(1,212)} = 38.7$, $p < 0.001$). Significantly higher litter cover was found in 2000 compared with 1999 in the plots with fire and irrigation than with fire and chopping ($F_{(1,212)} = 37.9$, $p < 0.001$; Figure 1.13 b), with a signficant block effect ($F_{(5,212)} = 4.66$, $p < 0.001$). Significantly higher percent litter occurred in the fire only plots than in either the chopped or the burned and chopped plots ($F_{(2,212)} = 16.3$, $p < 0.001$), in 2000 compared with 1999 ($F_{(1,212)} = 6.45$, $p < 0.01$; Figure 1.13 c), with a significant interaction between year and treatment ($F_{(2,212)} = 4.76$, $p < 0.01$).

Wiregrass density

Wiregrass (*Aristida beyrichiana*) density (log transformed) was significantly higher in 2000 than

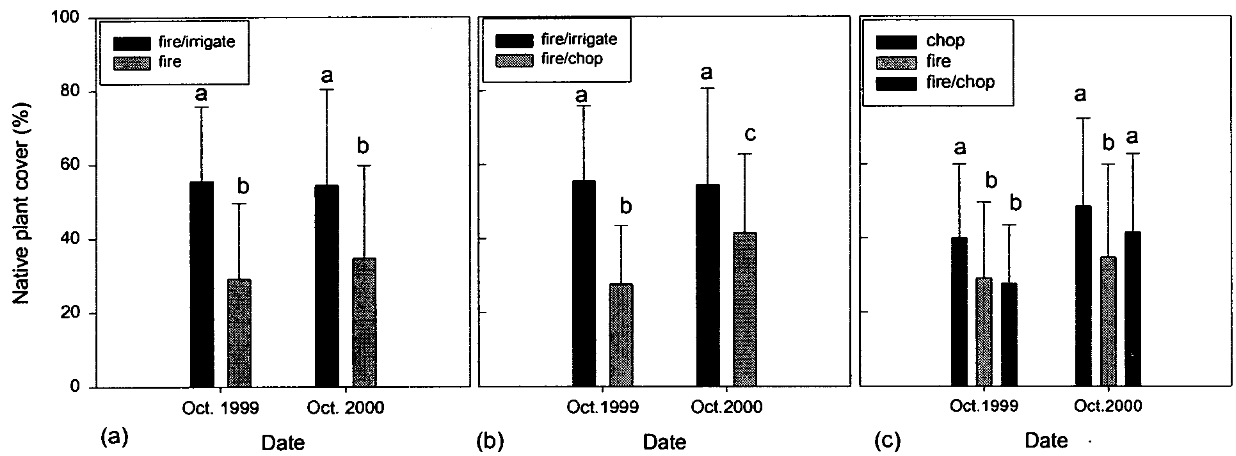

Figure 1.11. Mean (± 1 SD) percent cover of native vegetation with different site preparation treatments: (a) fire and irrigation vs. fire treatments; (b) fire and irrigation vs. fire and chopped treatments; and (c) fire, chopped, and fire and chopped treatments in 1999 and 2000. Means accompanied by the same letter (above the bar) are not significantly different from one another.

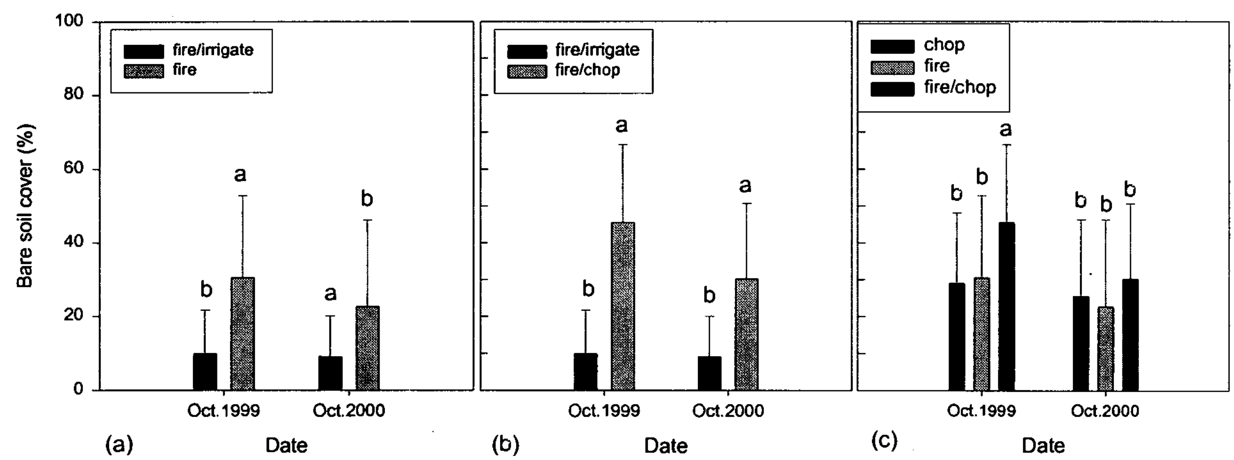

Figure 1.12. Mean (± 1 SD) percent cover of bare soil in plots with different site preparation treatments: (a) fire and irrigation vs. fire treatments; (b) fire and irrigation vs. fire and chopped treatments; and (c) fire, chopped, and fire and chopped treatments in 1999 and 2000. Means accompanied by the same letter (above the bar) are not significantly different from one another.

1999 ($F_{(1,202)} = 13.85$, $p < 0.001$) and in the fire and irrigated plots than in the fire alone plots ($F_{(1,202)} = 4.09$, $p < 0.002$; Figure 1.14 a). The significant increase in density of wiregrass in the irrigated plots in 2000 resulted in a significant year by site preparation treatment interaction ($F_{(1,202)} = 14.79$, $p < 0.001$). In the fire and irrigation and fire and chopped plots, densities were also significantly higher in 2000 than in 1999 ($F_{(1,202)} = 19.4$, $p < 0.001$; Figure 1.14 b). Probably because of high variability, the higher density in the fire and irrigated plots in 2000 (Figure 1.14 b) was not signficant, but the interactive effects of year and treatment on density was marginally significant ($F_{(1,202)} = 19.4$, $p = 0.056$). Interestingly, we did not see the dramatic difference among years in the chop, fire, and fire and chop plots. Site preparation did influence wiregrass density, however, which was higher in the burned and chopped plots than in the chopped alone plots ($F_{(1,202)} = 12.78$, $p < 0.001$; Figure 1.14 c). Lowest densities were in the burned only plots.

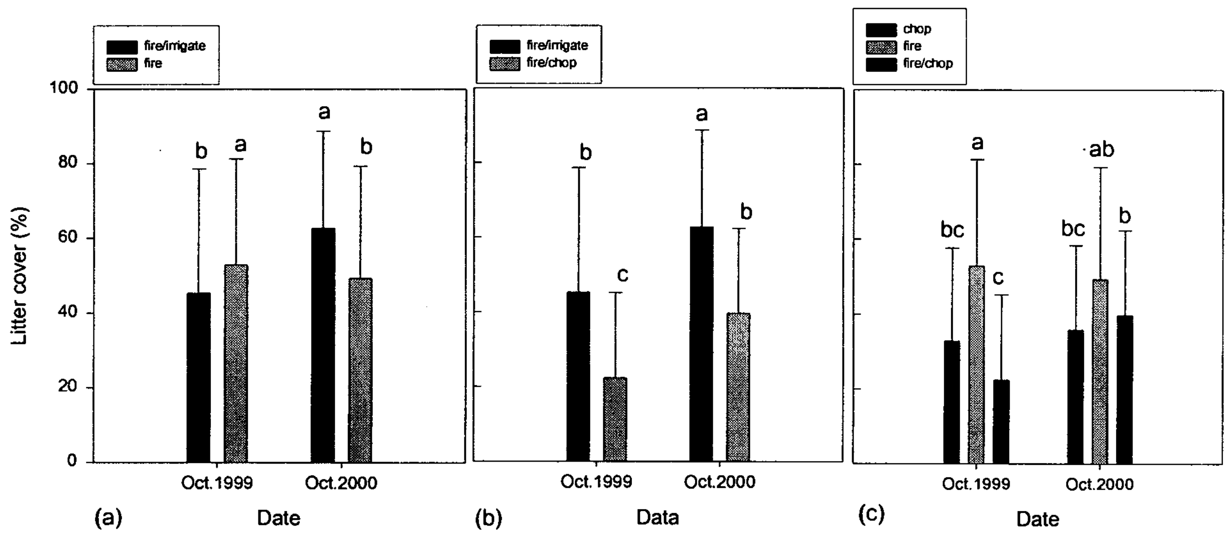

Figure 1.13. Mean (± 1 SD) percent cover of litter in plots with different site preparation treatments (a) fire and irrigation vs. fire treatments; (b) fire and irrigation vs. fire and chopped treatments; and (c) fire, chopped, and fire and chopped treatments in 1999 and 2000. Means accompanied by the same letter (above the bar) are not significantly different from one another.

Similarity analysis

The fire and irrigation plots were significantly more similar to the reference condition plots than were those with fire alone for both species frequency ($F_{(1,5)}$, $p < 0.01$ for both indices) and cover ($F_{(1,5)} = 18.6$, $p < 0.008$ for BC only; Figure 1.15). Fire and irrigation plots were similarly closer to the reference plots than were fire and chopped plots for frequency ($F_{(1,5)} = 8.85$, $p < 0.03$ for BC only) and cover ($F_{(1,5)}$, $p < 0.004$ for both indices; Figure 1.16). Fewer differences in similarity were evident in the three site preparation treatment comparison, although the PS index showed that the chopped treatment was significantly more similar to the reference condition than the burned treatment for frequency ($F_{(2,10)} = 4.16$, $p < 0.05$), but the burned treatment was more similar than the burned and chopped treatment for cover ($F_{(2,10)} = 4.32$, $p < 0.05$; Figure1.17). While we are not presenting statistics for indices that were not significant, in all cases $p < 0.08$, so tendencies were consistent across the two indices. Overall, the similarity data show similar trends as the species richness and cover analyses discussed previously.

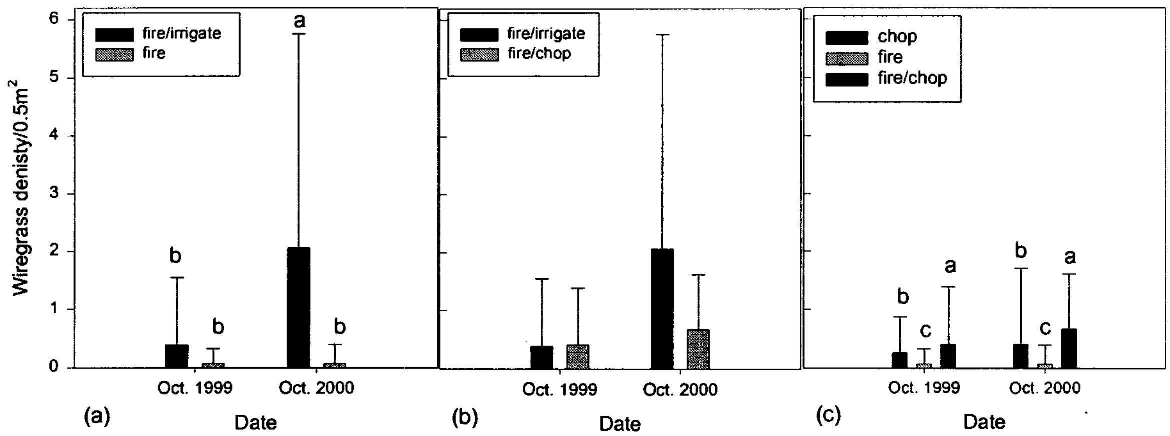

Figure 1.14. Mean (± 1 SD) density of wiregrass plants / 0.5 m^2 (5.3 ft^2) in October 1999 and 2000 under different site preparation treatments: (a) fire and irrigation vs. fire treatments; (b) fire and irrigation vs. fire and chopped treatments; and (c) fire, chopped, and fire and chopped treatments in 1999 and 2000. Means accompanied by different letters (above the bar) are significantly different from one another.

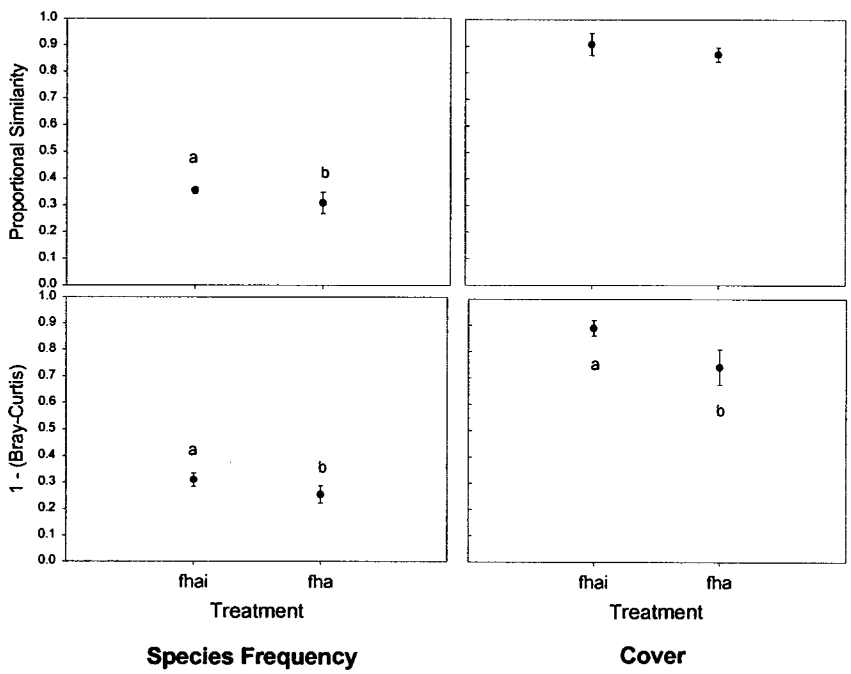

Figure 1.15. Experiment A comparisons of two indices (Proportional Similarity and 1 - Bray-Curtis) for evaluating the similarity of herbaceous ground cover species frequency and cover. Index values approach 1.0 as restoration treatments (fire and irrigated (fhai) or fire alone (fha)) increase in similarity with the reference plots. Means accompanied by the same letter are not significantly different from one another.

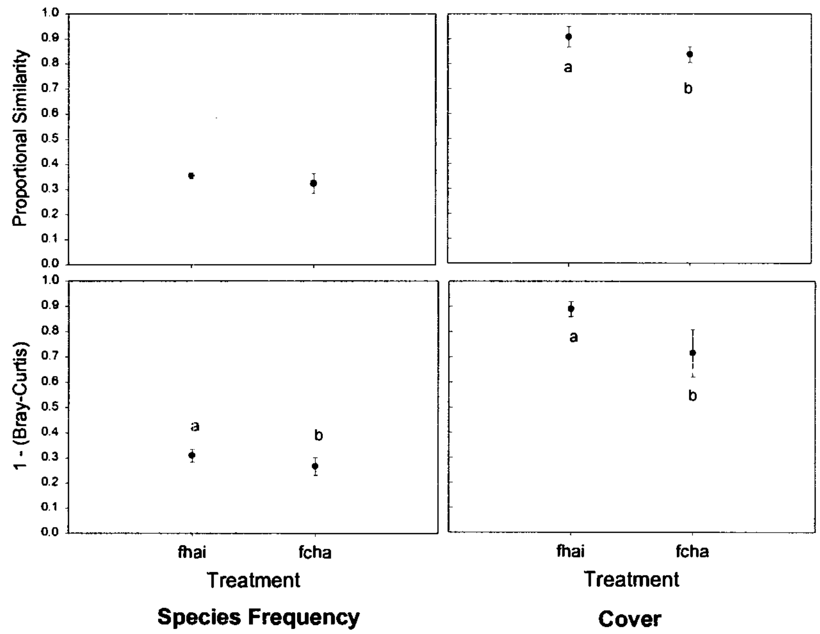

Figure 1.16. Experiment A comparisons of two indices (Proportional Similarity and 1 - Bray-Curtis) for measuring the similarity of herbaceous ground cover species frequency and cover. Index values approach 1.0 as restoration treatments (fire and irrigated (fhai) and fire and chop (fcha)) increase in similarity with the reference plots. Means accompanied by the same letter are not significantly different from one another.

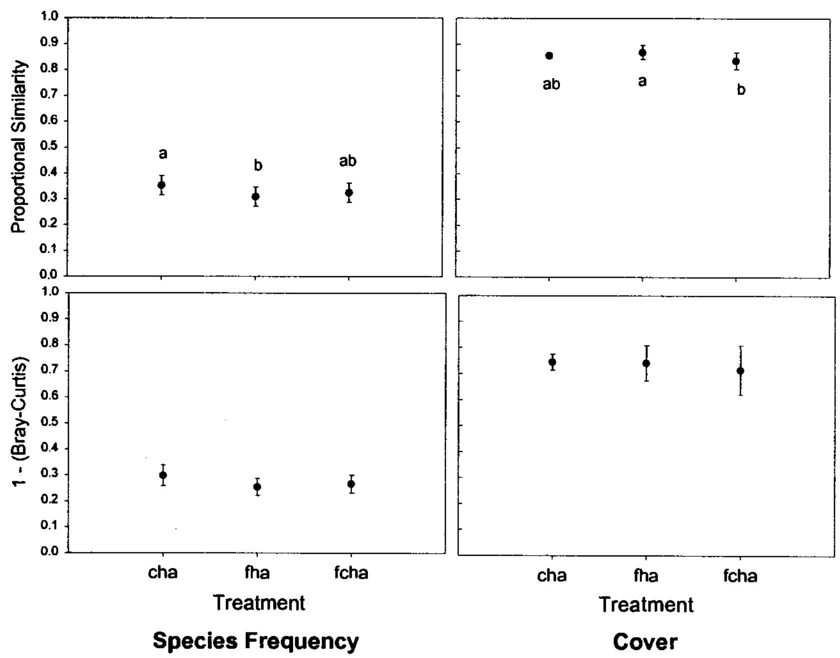

Figure 1.17. Experiment A comparisons of two indices (Proportional Similarity and 1 - Bray-Curtis) for measuring the similarity of herbaceous ground cover species frequency and cover. Index values approach 1.0 as restoration treatments (chop (cha), fire (fha), and fire and chop (fcha)) increase in similarity with the reference plots.

Experiment B

Because we had only three controls for the chopped site preparation treatment (chopped, unsown), we ran analyses of Experiment B two ways: once using all six blocks without the controls, and once using only three blocks and including the controls.

Species Richness

The highest mean species richness in the four sowing methods tested in both chopped and burned site preparation areas was in the cultipacked (culp) plots (64 species) in October 2000. Unexpectedly, the overall highest absolute species richness was found in the chopped, un-sown plots (66 species). Species richness data for all plots are in Appendix B.

Higher species richness in 2000 than in 1999 was seen regardless of whether six ($F_{(1, 76)} = 29.12$, $p < 0.0001$) or three ($F_{(1, 40)} = 17.42$, $p < 0.0002$) blocks are used for the analysis (Figure 1.18). We found significant ($F_{(3, 76)} = 3.97$, $p = 0.01$) but inconsistent differences among the sowing methods and a nearly significant tendency for higher species richness in the chopped than in the burned plots when six blocks were included ($F_{(1, 76)} = 7.70$, $p < 0.07$; Figure 1.18). No significant interaction existed between the year and sowing treatments.

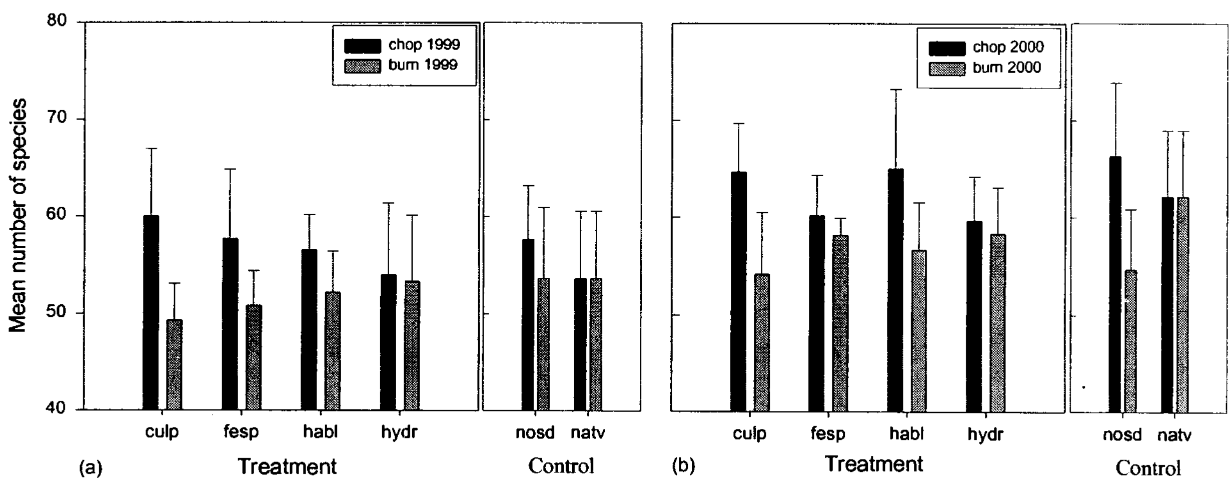

Figure 1.18. Mean (± 1 SD) species richness in Experiment B plots in October, 1999 and 2000 for the two site preparation treatments (c=chop and f=burn) and four sowing treatments: cultipack (culp), fertilizer spreader (fesp), hayblower (habl), and hydroseeder (hydr). Un-sown plots (to the right of the line: nosd and natv) are included for comparative purposes; natv was not included in the analysis. Sample size was six for all but three for the chopped but not sown control (nosd), where n=3.

Percent Cover

Percent cover of native vegetation, like richness, was significantly higher in 2000 than in 1999

($F_{(1,838)} = 82.66$, $p < 0.0001$, n=6). Cover was also significantly higher in the chopped than in the burned site preparation treatments ($F_{(1,838)} = 79.42$, $p < 0.0001$, n=6), with no differences among the sowing methods (p=0.46). In this case, we also saw no significant difference between the sown and unsown plots (Figure 1.19 a, b).

Significant differences were also found between years ($F_{(1,838)} = 19.96$, $p < 0.0001$, n=6) for percent cover of bare soil (Figure 1.20 a, b). Neither site preparation nor sowing treatment affected the soil cover. The highest percent of bare soil was in the chopped not sown control (40%) and the chopped with cultipack sowing treatment (35%) in 1999. Interestingly, all sown plots had lower cover of bare ground than did the the native control plots in 2000 (41%). Percent cover of litter responded signficantly only to the site preparation treatment (Figure 1.21 a, b). Litter cover was independent of year or sowing method, but was higher in the burned than in the chopped plots ($F_{(1,838)} = 158.58$, $p < 0.0001$, n=6).

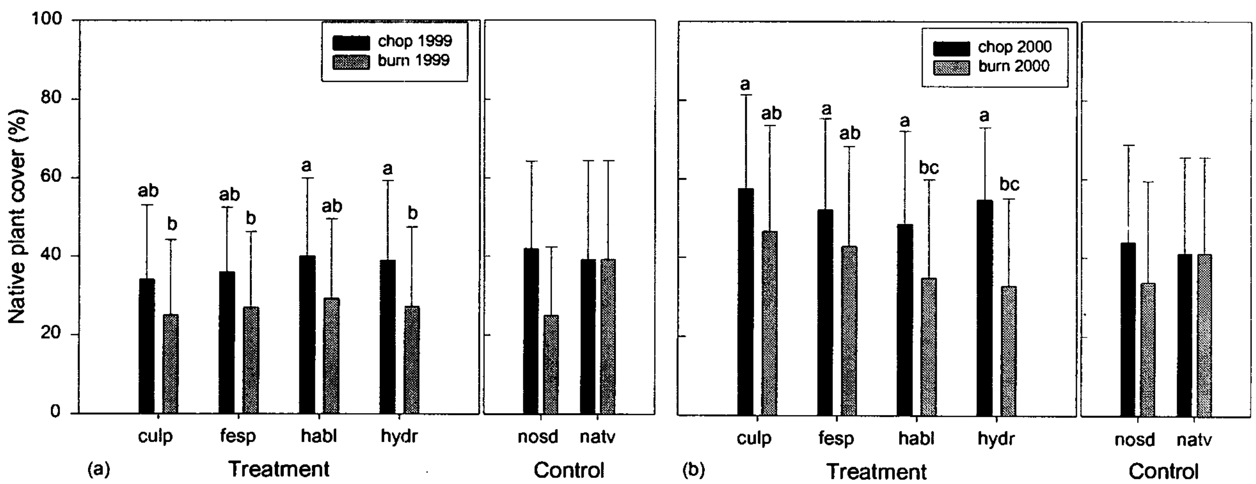

Figure 1.19. Percent cover (± 1 SD) of native vegetation in October 1999 and 2000 by site preparation treatment (c=chop and f=burn) and four sowing treatments: cultipack (culp), fertilizer spreader (fesp), hayblower (habl), and hydroseeded (hydr). Un-sown plots (to the right of the line: nosd and natv) were not included in the analysis. Sample size was six for all but the chopped but not sown control (nosd), where n=3.

Wiregrass Density

Wiregrass densities (log transformed) were clearly significantly higher in the fertilizer spreader plots than in the cultipack, hayblower or hydroseeded plots ($F_{(3,202)} = 134.91$, $p < 0.001$; Figure 1.22). Likely driven by that treatment, we also saw significantly higher densities in 2000 than in 1999 ($F_{(1,202)} = 6.61$, $p < 0.01$). The higher wiregrass density in the chopped than in the burned plots when sown with a fertilizer spreader explains the significant interaction ($F_{(1,202)} = 5.65$, $p < 0.001$) between site preparation and sowing treatment (Figure 1.22).

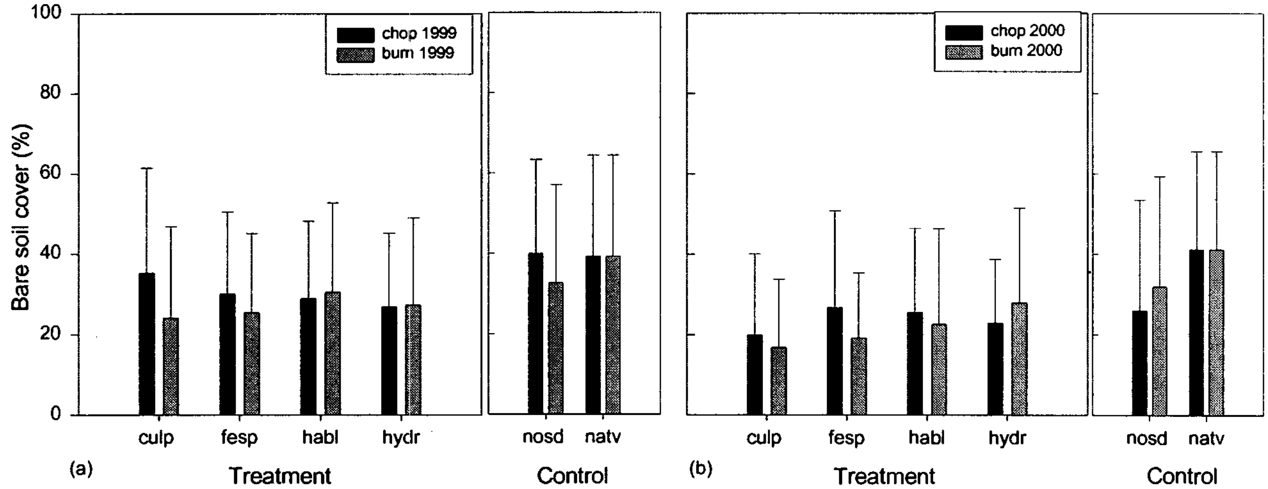

Figure 1.20. Percent cover (± 1 SD) of bare soil in October 1999 and 2000 by site preparation treatment (c=chop and f=burn and four sowing treatments: cultipack (culp), fertilizer spreader (fesp), hayblower (habl), and hydroseeded (hydr). Un-sown plots (to the right of the line: nosd and natv) were not included in the analysis. Sample size was six for all but the chopped but not sown control (nosd), where n=3.

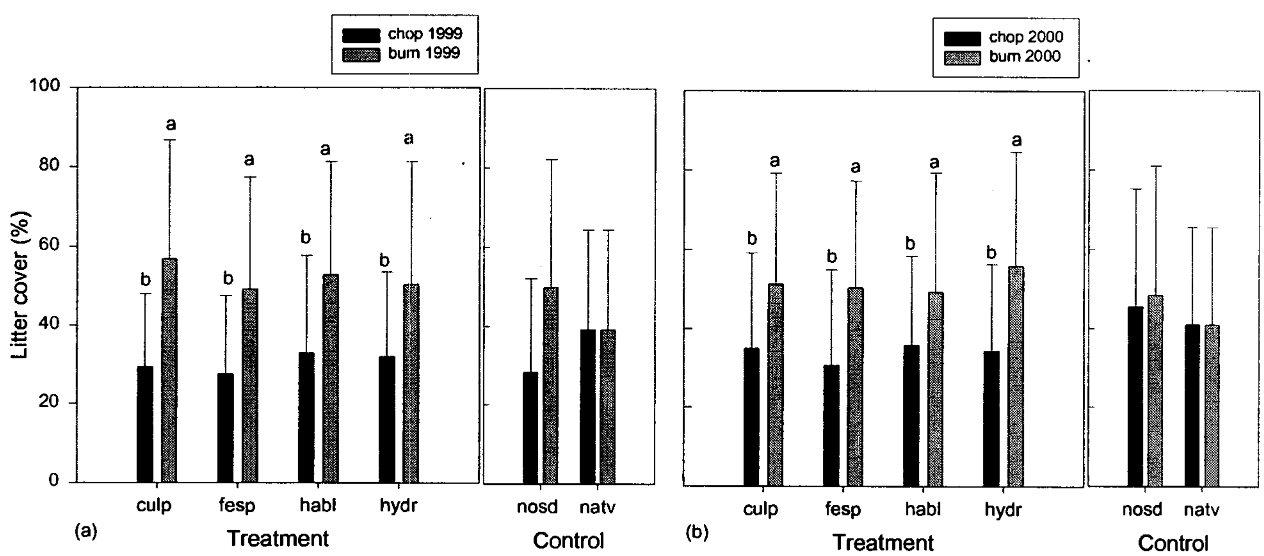

Figure 1.21. Percent cover (± 1 SD) of litter in October 1999 and 2000 by site preparation treatment (c=chop and f=burn and four sowing treatments: cultipack (culp), fertilizer spreader (fesp), hayblower (habl), and hydroseeded (hydr). Un-sown plots (to the right of the line: nosd and natv) were not included in the analysis. Sample size was six for all but the chopped but not sown control (nosd), where n=3.

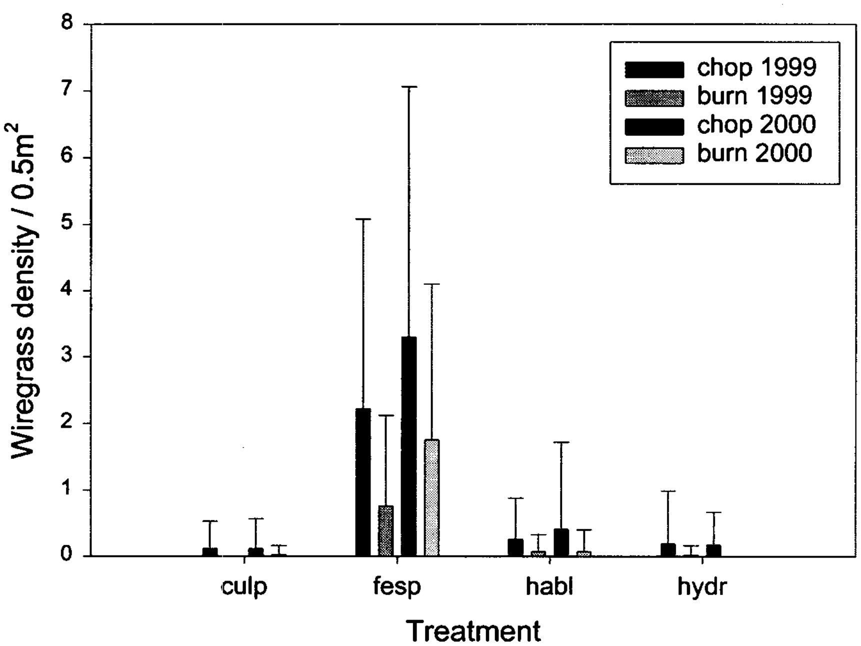

Figure 1.22. Mean (± 1 SD) density of wiregrass plants / 0.5 m^2 (5.3 ft^2) sampling plots for October 1999 and 2000 by site preparation treatments (chop and burn) and four sowing treatments: cultipack (culp), fertilizer spreader (fesp), hayblower (habl), and hydroseeded (hydr).

Similarity Analysis

For species frequency, but not cover, the two similarity indices showed signficant effects of site preparation, with vegetation in chopped plots more similar to that in reference conditions than in burned plots ($F_{(1,38)}$, $p < 0.008$ for both indices; Figure 1.23). Across the sowing methods, the fertilizer spreader plots were significantly more similar (37%) to the reference conditions in species frequencies for both indices ($F_{(3,38)}$, $p < 0.002$ for both). An inverse relationship was determined for cover, as the fertilizer plots had significantly lower PS indices than the other sowing treatments except for the hydroseeder ($F_{(3,38)} = 7.85$, $p < 0.0003$). As in Experiment A, cover for all seeded treatments was more similar to the reference conditions than were species frequencies.

All Plots

Species Richness

One hundred sixty-three species were recorded for the 75– 15 x 15 m (49 x 49 ft) research plots in October 1999 and 166 in October 2000 (Appendix A). The net gain of three species obscures the loss of approximately 12 species noted in 1999 but not in 2000, and the increase of 15 species in 2000. Species observed for the first time included Carolina rock-rose (*Helianthemum carolonianum*), sand bur (*Krameria lanceolata*), and dwarf dandelion (*Krigia virginica*). Many of the species not seen in 2000 were early colonizer or weedy species, including ragweed (*Ambrosia artemisiifolia*), horseweed (*Conyza canadensis*), and southern crabgrass (*Digitaria ciliaris*). Six and eleven species occurred in all plots (100%) in 1999 and 2000, respectively. Three herbs (*Calamintha dentata, Croton argyranthemus*, and *Polygonella gracilis*) and one shrub (*Rubus cuneifolius*) were present in all plots for both years. The species present in both Experiment A and B plots may be examined in Appendix A.

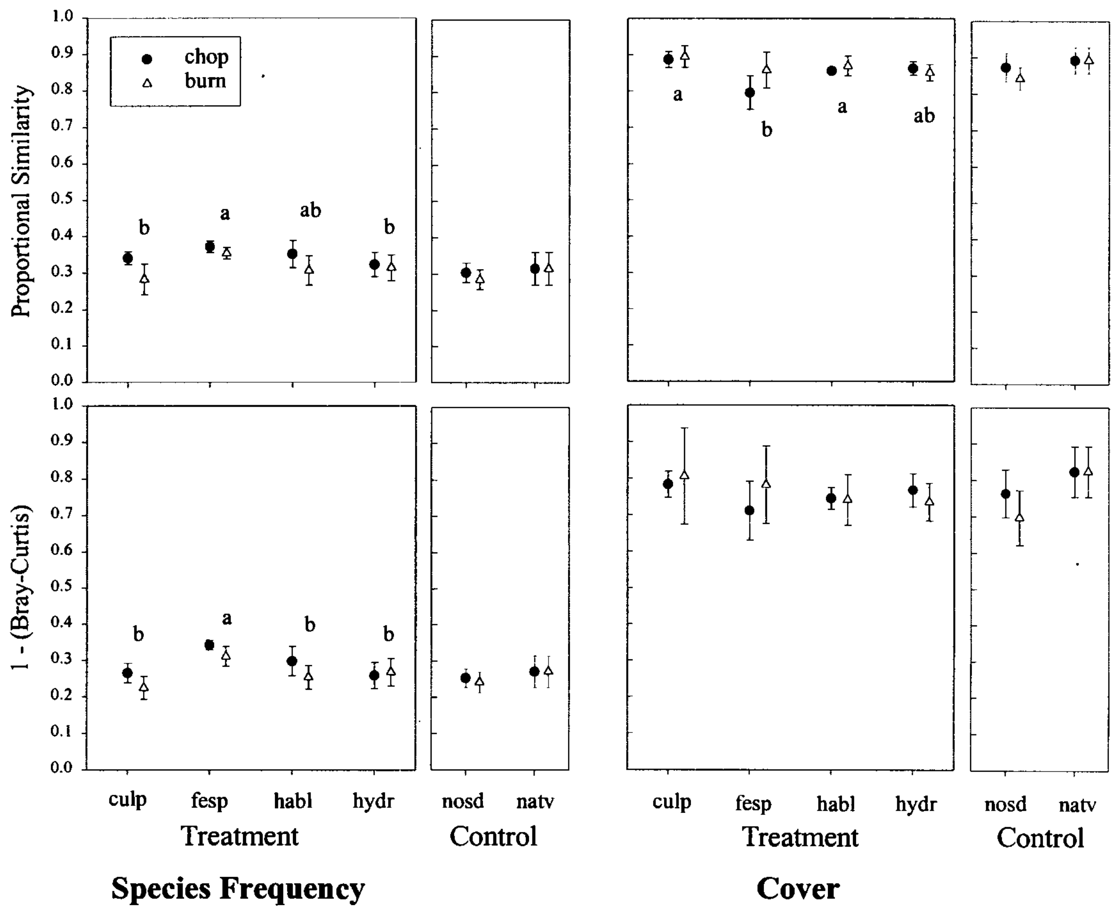

Figure 1.23. Experiment B comparisons of two indices (Proportional Similarity and 1 - Bray-Curtis) for measuring the similarity of herbaceous ground cover species frequency and cover. Index values approach 1.0 as restoration treatments (site preparation: c=chop and f=burn; sowing treatments: cultipack (culp), fertilizer spreader (fesp), hayblower (habl), and hydroseeded (hydr)) increase in similarity with the reference plots. Plots to the right of the line (nosd and natv) were not included in the analysis. Means accompanied by the same letter are not significantly different from one another.

Although the nonnative species centipede grass (*Eremochloa ophiuroides*), crabgrass (*Digitaria ciliaris*) and bahiagrass (*Paspalum notatum*) were noted in the larger 15 x 15 m plots in 1999, only bahiagrass was present in the 0.5 m^2 sampling plots in 2000. Because of low cover, data for nonnative species are not presented below.

Species Frequency – Contributers to community similarity

Nineteen species across both experiments A and B were shown contribute significantly to the patterns of similarity at ABRP (Table 1.3). The similarity values for Proportional Similarity and 1-Bray-Curtis for these 19 species were calculated from 114 species that occurred in the treatment and the reference plots. The 114 species represent 73% (114/156) of the total species that occurred in the treatment plots in 2000. The correlation coefficients for eight of the 19 species were determined by both indices showing strong contributions to the sandhill patterns.

Cover comparisons with the reference plots show higher correlations (PS=0.696, 1-BC=0.726) than the species (Table 1.4). The highest correlations occurred in the bare soil and the lowest in the native cover.

Table 1.3. Similarity and correlation coefficients for frequency similarity measures. Correlation coefficients for PS = proportional similarity and BC = 1 - Bray-Curtis. Coefficients for species contributing disproportionately to similarity are bolded.

		Correlation coefficients	
SPECIES SIMILARITY	**life form**	**PS**	**BC**
Andropogon longiberbis	grass	0.283	
Aristida beyrichiana	grass	**0.519**	**0.685**
Aristida purpurescens	grass	**0.553**	0.377
Dichanthelium acicularis	grass	0.427	
Eragrostis refracta	grass	-0.250	
Schizachyrium scoparium (green)	grass	0.242	
Schizachyrium tenerium	grass	0.320	0.291
Bulbostylis ciliatifolia	sedge	0.228	
Rhynchospora grayi	sedge	-0.247	
Commelina erecta	herb	0.242	
Euphorbia exserta	herb		0.277
Galactia volubilis	herb	0.394	0.336
Hypericum gentianoides	herb	-0.245	
Liatris chapmanii	herb	0.256	0.273
Rhynchosia cytisoides	herb	0.276	0.290
Solidago odora	herb	0.413	0.385
Vaccinium arboreum	shrub	0.372	
Callicarpa americana	shrub	-0.408	-0.36
Quercus hemisphaerica	tree	0.244	

Table 1.4. Correlation coefficients for cover similarity measures. Correlation coefficients for PS = proportional similarity and BC = 1 - Bray-Curtis. Coefficients for species contributing disproportionately to similarity are bolded.

	Correlation coefficients	
COVER (percent)	**PS**	**BC**
Native	**0.501**	0.457
Bare soil	**0.696**	**0.726**
Litter	**0.669**	**0.661**

Discussion

The hayblower was the easiest and most efficient of the four mechanical methods for sowing the sandhill seed mix. The hydroseeder was our second choice followed by the cultipacker and then the fertilizer spreader. We based this evaluation on the ease of using the equipment, the time required for preparation and sowing, and the uniformity of spreading the seeds on the plots. While higher density of wiregrass established when the fertilizer spreader was used, the difficulty of use of that equipment precludes our recommendation. However, further investigation of methods that might mimic the improved effect of the fertilizer spreader appears warranted (see below). We suspect that the greater wiregrass establishment rate resulted from the compaction of seed into soil caused by the repeated driving over the plot when using the fertilizer spreader, unlike the other sowing equipment. If this contact, rather than any action associated with the fertilizer spreader itself explains the results, increased use of the roller following sowing may be equally effective.

Species Richness

Consistent with the results of previous restoration research in this system (Gordon et al. 2000), sowing seed had little effect on species richness aside from adding in a few species, particularly wiregrass, that appear not to disperse into the plots naturally under the conditions tested. The first year after sowing, species richness was highest in the irrigated plots compared with all treatments and controls, showing early benefits of watering to seed germination. Two years after sowing, species richness remained higher in all chopped treatments than in the un-irrigated burned treatments indicating that soil disturbance may stimulate seed germination by breaking up the crust and aerating the soil. Seed germination would be enhanced not only for the seeds sown by direct seeding methods but also from adjacent areas or from the seed bank present in the soil. Two nonnative grasses, crabgrass and centipedegrass, were noted in the chopped plots and not in the burned plots, but both were present in an abandoned roadway adjacent to the plots, so it is unlikely the seeds were brought in on equipment. By the second year of the study, crabgrass was not present in the study plots suggesting it is early successional species, but centipede grass was noted in three additional sowing plots verifying the invasive character of a mat-forming turf grass.

Percent Cover

Percent cover of native species followed the results of species richness, though differences were greater. Cover was highest in irrigated plots. When only chopped versus burned plots were compared in Experiment B, chopped plots had consistently greater native vegetation cover, and we saw cover increase from 1999 to 2000. Not surprisingly, cover of bare ground showed the inverse pattern to that of vegetation, while that of litter was intermediate and more variable. Cover of nonnatives in the plots was negligable.

Wiregrass Density

In both years, wiregrass density was highest in the fertilizer spreader treatment, suggesting a contribution from some mechanical treatment. In this sowing method the seed mix was manually pushed through the machine before being rolled into the soil. A wooden dowel was used to force the seed through the fertilizer spreader and, as a result, the awns, or bristles may have been stripped from the seeds, allowing the closer seed/soil contact. The addition of vermiculite may also have improved soil quality for germinating seedlings. Additionally, the fertilizer spreader was pulled through each treatment area several times by the GMC truck. Truck tires likely compress seeds into the soil more than the ATV and roller, which may account for the high densities. None of these hypotheses have been tested.

Wiregrass densities increased significantly the second year of the study. However, wiregrass densities overall were still lower (0.86 ± 2.18 clumps/0.5m^2) in this study than in the second year (4.38 ± 4.40 clumps/0.5m^2) of the previous study (Gordon et al. 2000). Germination experiments showed that the 12 -13% germination of wiregrass collected in 1998 was considerably less than the higher (45%) germination in the 1997 study. The highest density in the fertilizer spreader plots of approximately 5 plants/m^2 was considerably less than the 14 plants/m^2 in the native, rye, rolled and watered plots in the first study, but consistent with densities found in native sandhills of 5.3 plants/m^2 as recorded by Clewell (1989). Interestingly, the significant increases in wiregrass densities the second year of this study supports recent evidence that wiregrass seeds may remain dormant beyond one growing season (Seamon 1998, BA 523).

Bare soil in the research plots generally showed opposite trends than percent cover and species richness. Mean percent bare soil of 28% and 25% after the first and second years was consistent with the 10-30% range noted by The Nature Conservancy (1997). These values are low, compared with the 50-61% in the previous study (Gordon et al. 2000); however, that research was conducted on bulldozed windrows, and this research was established between windrows.

Similarity Analyses

The analyses we conducted using the similarity values allowed us to determine restoration success by comparison of the results we obtained with those in the reference plots. Predictably, wiregrass (*Aristida beyrichiana*) contributed the most to the species frequency similarities (Table 1.3) and was most highly correlated with the index values. Other species commonly found in sandhill, *Aristida purpurescens, Solidago odora, Schizachyrium tenerium,* and *Galactia volubilis* were also shown as significant contributors. *Callicarpa americana*, beauty berry, showed a negative correlation for both indices, thus weakening the pattern in the sandhill. While this woody shrub is a native species in pine dominated upland communities, high frequencies of shrubs are not characteristic of sandhills.

For all analyses (Figures 1.15-1.17) the PS index showed higher values than the 1 - BC index. Proportional Similarity (PS) accounted for the relative abundance of the species and therefore discounted the importance of species that may have been infrequent in the plots. The cover values were closer to the reference values, but may be more difficult to interpret.

Management Implications

The Florida Department of Transportation has shown its interest in the use of native vegetation through the funding of a number of research projects dealing with native vegetation restoration and establishment. The knowledge gained from the above-referenced work, among others, indicates that the use of native vegetation for areas outside the clear zone can be accomplished with negligible effort in some areas. If native vegetation is already present and irrigation is possible, prescribed fire and irrigation might be the best site preparation. If irrigation is not possible, light roller chopping prior to sowing appears appropriate. The sowing equipment tested is all commercially available and fairly simple to operate. In all cases we recommend using a roller to press seed into the ground following sowing. The straightforwardness of use and the minimal amount of seed preparation allow for easy seed sowing and establishment. Seed availability and soil quality on rights-of-way may be the largest impediments to revegetation with natives.

Experiment C: Establish a pilot seeding study of native sandhill mix on a roadside site.

Introduction

The Nature Conservancy's work with groundcover species establishment at Apalachicola Bluffs and Ravines Preserve (Seamon 1998) led to the next step of a pilot seeding study of native sandhill community mix on a roadside site. During road construction there is little native seedbank remaining within and adjacent to the clear zone. We hypothesized that the disturbed roadside could be revegetated by augmenting the existing soil with soil from an intact site and then sowing with native sandhill seed mix. The results from Experiment A suggest that right-of-way native vegetation might then be similar to that found in the intact natural community.

We worked with FDOT staff in 1998 to identify a site requiring revegetation. A large, level site was identified following completion of the Blountstown Bridge repair in Liberty County, Florida. The site was on the Bristol side of the bridge structure on the north side of State Road 20. Existing dirt and construction debris had been bulldozed into a level surface along the road right-of-way adjacent to a mixed slash pine-hardwood forest. The site had also been sown with annual rye (*Lolium perenne*) and bahiagrass (*Paspalum notatum*) prior to initiation of this experiment.

Methods

Site Preparation

In early January 1999, 3% Roundup© (glyphosate) solution was applied to the bahiagrass and ryegrass growing in the 10 x 15 m (33 x 49 ft) plot on the Blountstown Bridge right-of-way. The dead biomass was raked from the plot two weeks later, and the herbicide treatment and raking repeated.

The plot was divided into two 7 x 10 m (23 x 33 ft) plots with a meter-wide (3.3 ft) strip separating the two plots. Three cubic yards of soil were taken from a windrow at ABRP and spread to form a 0.5 inch thick layer on one 7 x 10 m plot. The soil was assumed to contain mycorrhizae and seeds of associated sandhill plant species. We tested for the presence of mycorrhizae by conducting a mycorrhizal inoculum potential (MIP) analysis.

The plots were disked and then cross-disked to break up the hardened soil on the bridge roadside (Figure 1.24). The bare soil plot was disked prior to the plot with the added soil to prevent soil movement into the bare plot. Both plots were planted and rolled. Aluminum flashing (10 in wide) was placed around the perimeter of each plot and buried to a depth of five inches to prevent the invasion of bahiagrass from outside the plots. Because we only had one plot per treatment, only preliminary conclusions can be drawn from this pilot experiment.

Seed Collection

Seeds for this project were collected from Torreya State Park in the fall of 1998, with the assistance of the park manager, Paul Rice, and the park's inmate work crew. Both wiregrass (*Aristida beyrichiana*) and little bluestem (*Schizachyrium scoparium*) seed were collected by hand in fall 1998. Wiregrass stems were cut at the base; the stems with seeds were placed in paper bags for later cutting. Little bluestem seed was collected by stripping the seed from the stems. Both these methods are efficient ways of collecting fairly large quantities of seed by hand. The seed was stored indoors in paper bags until sowing. Seed germinability was tested in petri dishes. Germination tests continued for 10 weeks for wiregrass and six weeks for little bluestem.

Sowing

The two 7 x 10 m (23 x 33 ft) plots were sown on March 4, 1999. The seed mix was hand-spread on each plot because the leafblower seeder was not powerful enough to pick up the wiregrass stems. Seed mix contained approximately 8% wiregrass seed (0.5 lbs per plot) of the 6.5 lbs for each 70 m^2 (759 ft^2) plot. Little bluestem represented 2.6 oz. (0.16 lbs) of the seed mix, in flowers and seeds (<10%) with no stems. The plots were watered once a week during April because no rain fell. Each plot received 110 gallons of water from a slip-on unit mounted on the back of a GMC truck.

Figure 1.24. Tractor disking the Blountstown Bridge plots.

Seed Viability

Seed viability experiments were conducted to determine the percent germination of the wiregrass and little bluestem seed from Torreya State Park. Ten replicates of 10 seeds each were placed in germination envelopes and kept moist daily. Envelopes were checked weekly and the number of seed that germinated were recorded. Little bluestem seeds were difficult to remove from the flowers; as a result flower plus seeds were tested, giving an approximation of viability.

Monitoring

In May and October each year, we monitored the species richness and cover in the central 2 x 6 m (6.6 x 19.7 ft) area of each treatment (Figure 1.25). Richness was determined by identifying every species in each plot. Native species, nonnative species, and bare soil cover were determined by ocular estimation in 15- 0.5 x 1 m (1.6 x 3.3 ft) sampling quadrats. Evidence of erosion in the plots was recorded, and photographs were taken during each monitoring period.

Data Analysis

Species richness data were analyzed using Contingency Table Analysis between the soil addition and no soil added treatments and the three sampling periods (June and October 1999 and May

2000). Percent cover data for native, nonnative vegetation, and bare soil were analyzed using three-way ANOVA's between three sampling periods, treatment (soil and no soil added), and percent cover.

Results

Mycorrhizae

The mycorrhizal inoculum potential analysis (a qualitative assay of mycorrhiza density and viability) of the windrow soil conducted in David Sylvia's laboratory at the University of Florida, indicated 40% vesicular-arbuscular mycorrhizal colonization. This level is considered to reflect moderate inoculum density (D. Sylvia, personal communication).

Species Composition

Germination tests resulted in 5% seed viability for both wiregrass and little bluestem. Although species richness increased from June to November in 1999, we saw similar declines in richness from November to May 2000 in both the no soil added (from 21 to 14 species) and the soil added plots (20 to 14 species; Figure 1.26, 1.27). Contingency table analysis revealed no significant differences in richness between the two sites for the three sampling periods (Pearson Chi-square $X^2 = 0.88$, df = 2, P = 0.67).

Many species observed in the plots were weedy or ruderal (R) species that readily colonize disturbed soil (Appendix C). These species were well established outside the plots on the adjacent roadside. Ruderal species listed for all sampling periods included ragweed (*Ambrosia artemisiifolia*), crabgrass (*Digitaria ciliaris*), and dog fennel (*Eupatorium capillifolium*). Native species direct-seeded into the plots included little bluestem (*Schizachyrium scoparium*), and beauty berry (*Callicarpa americana*), a shrub that germinated from the seed bank in the soil added plot. Few of the native species occurred in high numbers and generally only one or two individuals were represented in the plots.

Nonnative species cover dominated over the native species cover regardless of the addition of native soil to the plots (Figure 1.28 a, b). A three-way interaction between sampling periods (June 1999 to May 2000), treatment (no soil added and soil added), and cover (nonnative and native) was significant ($F_{(4,126)} = 37.2$, $p < 0.001$). Average nonnative cover was significantly higher than native cover during all three sampling periods across both treatments. The interaction term resulted from the significantly higher average cover in November 1999 (73.3%) and May 2000 (64.4%) than during the first sampling period in June 1999 (16.7%) in the no soil plots (Figure 1.28 a, b).

Native cover was negligible, but highest in the no soil added plot in November 1999 (3.3%) than in other sampling periods (<1.0%). Thus, adding soil appeared to provide neither an advantage for the natives sown nor additional seedbank that moved with the soil, as either would have increased the cover of natives. Percent bare soil showed opposite trends as nonnative cover

(Figure 1.28). Percent bare soil was significantly dependent on date and the interaction between date and treatment ($F_{(2,84)} = 21.3$, $p < 0.001$). As plants colonized the area, bare soil cover decreased. The increase in bare soil from November to May 2000 was attributed to dead crabgrass and other plants vulnerable to drought conditions. We saw no evidence of erosion.

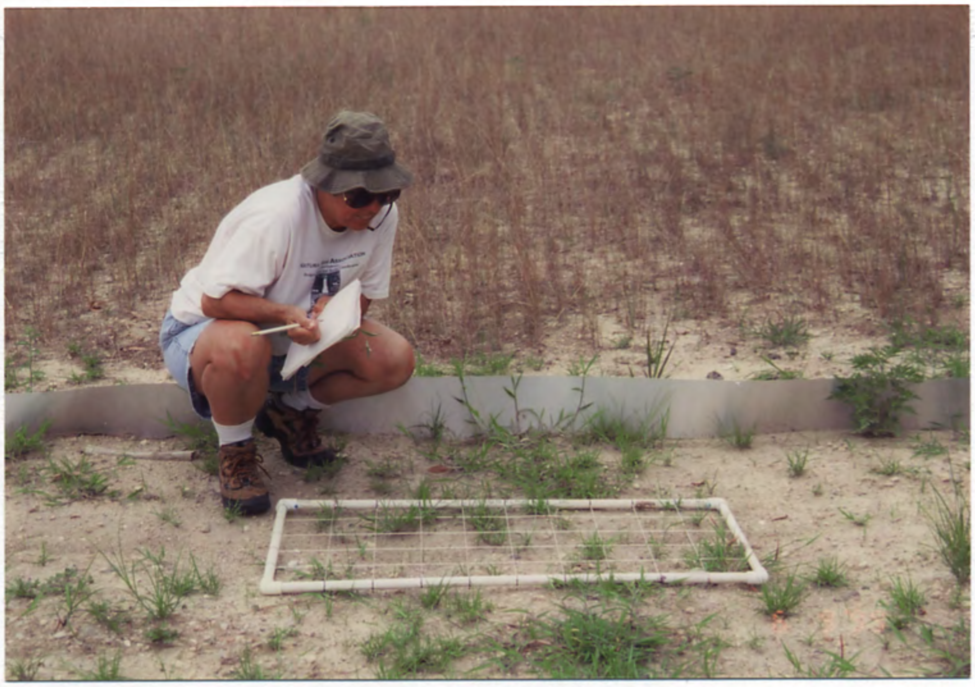

Figure 1.25. Monitoring Blountstown Bridge plots eight months after sowing seed.

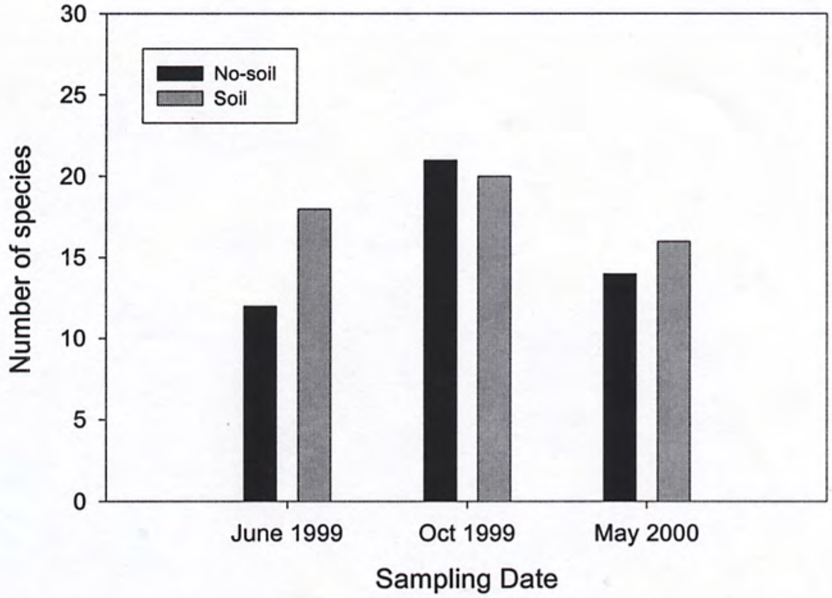

Figure 1.26. Species richness for three sampling dates in 7 x 10 m plots on the Blountstown Bridge right-of-way with and without sandhill soil added.

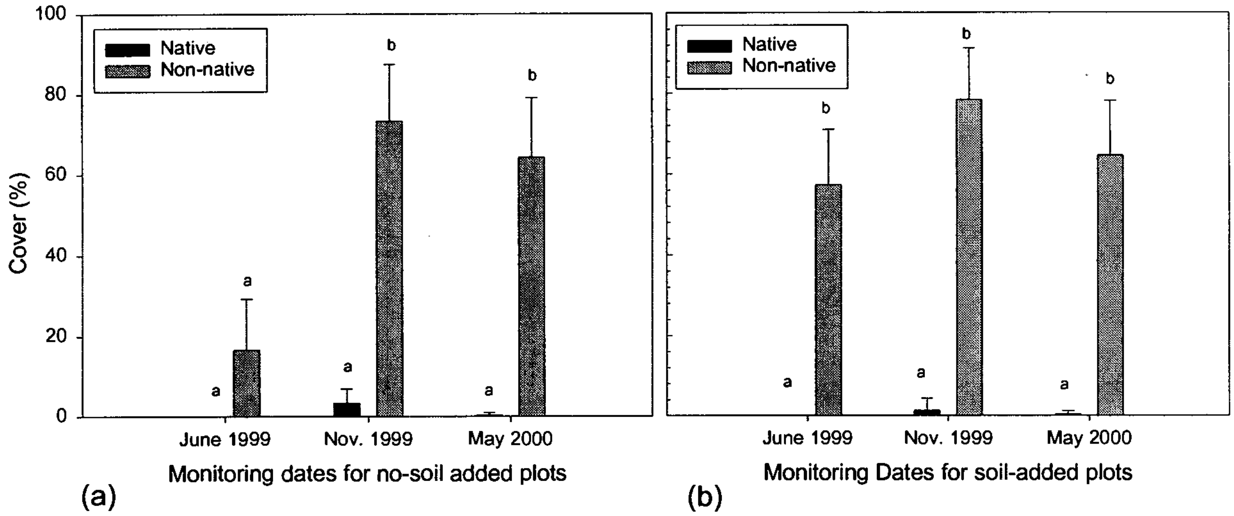

Figure 1.27. Percent cover (± 1 SD) of native species and nonnative species in the (a) no soil added and (b) soil added plots on the Blountstown Bridge.

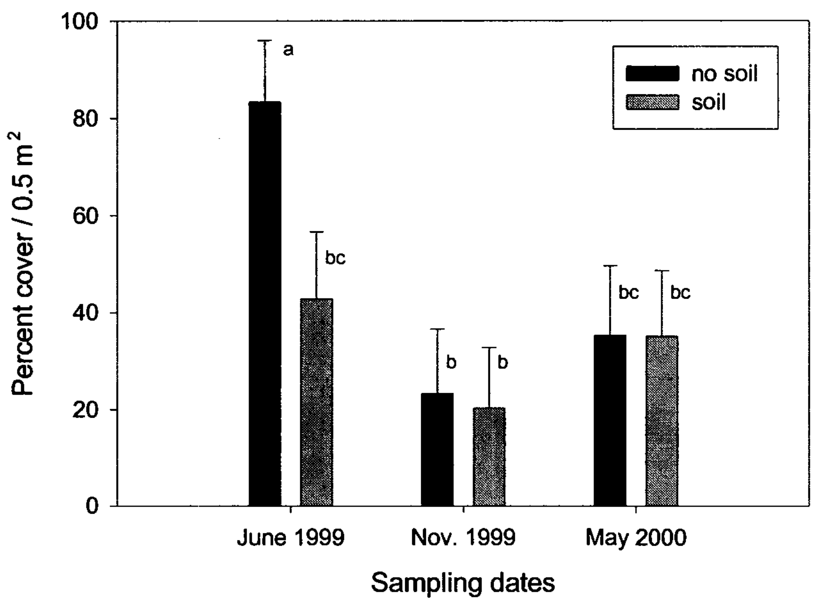

Figure 1.28. Percent cover (± 1 SD) bare soil in no soil added or in soil added plots on the Blountstown Bridge. Different lower case letters indicate significant differences among means by treatment over time ($p < 0.05$).

Discussion

The results of this study show that successful restoration of road construction sites may require more effort than augmenting existing soils with soil from an intact site and sowing additional native seed mix. The leveled road construction site contained rocks and gravel and had been planted with rye and bahiagrass prior to this study. We found at the Disney Wilderness Preserve (Gordon et al. 2000) that two years are required to restore improved pasture to native vegetation by repeated herbicide or disking and herbicide treatments. The hardened soils on road construction sites may require more disking and several applications of native soils to provide suitable soils for native species growth. Although we tested the soils for mycorrhiza in the intact site before augmenting the bridge site, we did not test the soils for mycorrhiza after planting. Soil compaction and soil chemistry tests were also not conducted.

Even though many native plant species were observed in the plots (Appendix C), nonnative and ruderal species dominated the cover as these weedy species readily colonized disturbed soils. Bahiagrass persisted in both plots despite the two herbicide treatments. The ruderal species component could be attributed to seed dispersal from adjacent areas outside the plots. Of the 14 natives listed for the plots, four remained after a year and only one or two individuals of those were noted.

The decline in richness may have resulted from a combination of the increased cover of bahiagrass and the lack of germination and establishment of other species in spring 2000, due to drought conditions. However, we are not confident that the soil in the plots could support native species even in a "normal" rainfall year. Since there were no differences in species richness between the two sites for the three sampling periods, the addition of sandhill topsoil did not enhance establishment of native species.

Management Implications

Restoration of roadsides with construction debris and soil compaction may require removal of the soil substrate and replacement with native soils. Multiple disking and herbicide treatment will be necessary to eradicate bahiagrass in areas to be planted with natives. The vegetation composition of the adjacent areas may pose problems as seed invasion of undesirable species may hamper restoration efforts. If soil and vegetation are significantly altered, revegetation with a native community mix may be difficult.

OBJECTIVE 2: Investigate the use of prescribed fire for vegetation height, flowering response, and woody species control adjacent to the clear zone.

Introduction

The Florida Department of Transportation maintains the clear zone along roadway rights-of-way (ROW) through the use of mowers. Often the vegetation outside of the clear zone is also mowed to control the height and number of woody species established. In many natural communities of Florida, native vegetation height and composition have historically been maintained by lightning- and human-ignited fire. In addition, much research has shown that fire introduced in the growing season will stimulate flowering and seed production of native species, facilitating perpetuation of the natural community (Robbins and Myers 1992). Within this objective we continued the roadside mowing frequency experiment initiated under another FDOT contract (Contract No. BA 523; Experiment D current contract), and compared the effects of mowing versus fire on the height and density of native woody vegetation on roadside rights-of-way in the Apalachicola National Forest (Experiment E).

> **Experiment D:** Continue the mowing experiment on roadsides that was initiated in 1997 in order to examine multiple-year effects of different mowing treatments on vegetation height and composition.

Introduction

In 1996, research was begun under FDOT Contract No. BA 523 (State Study No. 785, WPI 0510785, State Job No. 99700-3352-010) to study the effects of different mowing frequencies on seasonal trends in vegetation height and composition adjacent to the clear zone. However, because the long-term impacts of mowing treatments, particularly in woody species growth, may not have been apparent after only two years, this experiment was continued in the current contract. Gordon et al. (2000) reported that frequent mowing during the growing season reduced vegetation height more effectively than did annual mowing or no mowing. The hypothesis of this work was that bahiagrass and native vegetation show similar growth patterns throughout the year and that the height of the vegetation would be tallest during the grass flowering season. In addition, native and introduced vegetation would require less than annual mowing frequencies to reduce the height of vegetation outside the clear zone on the ROWs, and taller woody species beyond the clear zone may be suppressed by mowing at longer than annual intervals.

Methods

Experimental Design

Height of bahiagrass and native groundcover species were compared under three mowing management treatments on vegetation beyond the clear zone: (1) not mowed, (2) mowed once a year in October, the end of the growing season, and (3) mowed three times a year in June, August, and October. The experiment was conducted from March 1997-2000. Vegetation height was monitored five times a year, in March, June, August, October, and December. Photographs were taken for each monitoring date.

Six blocks of the three mowing treatments were established in mixed native and bahiagrass vegetation along roadsides in collaboration with FDOT and the U.S. Forest Service (Gordon et al. 2000). Two blocks of three treatments each were located on Highway 20 (8 mi. west of Hosford), Highway 65 (5 mi. north of Hosford) and Forest Service Road 113 (off County Road 379, approximately 20 mi. south of Bristol). At each location, three 30.5 x 3.6 -5.5 m (100 x 12-18 ft) plots were separated by at least 10 m (33 ft); the long side of the plots were placed parallel to the road. A random transect was located within each of six 4.3 m (14 ft) sections along the length of the plot. The height of the tallest vegetation intercepting the line was recorded to the nearest centimeter at three points along each transect.

One complication we experienced during this experiment was that plots were sometimes accidentally mown by FDOT contractors despite our communication with them and signage on the plots. As a result, the treatments were not applied as strictly as intended. We did not include plots within the analyses if the effects of unplanned mowing were visible. However, we did include those plots at later dates if full recovery was apparent. Not all plots were mown out of sequence during the four years of data collection. This continuing problem during the experiment potentially confounded our interpretation of the results.

Data Analysis

Bahiagrass and native vegetation heights in each treatment were compared using repeated measures analysis of variance on treatment, block, and season effects. Data were log transformed to increase consistency with test assumptions. Blocks 113 A and B in the Apalachicola National Forest were excluded from the bahiagrass analysis as these plots contained no bahiagrass.

Results

The mean heights (cm) of roadside vegetation of bahiagrass and native vegetation under the different mowing frequency treatments were compared for the three years (1997-1999). The final monitoring was conducted in March 2000.

Bahiagrass

Mean height of vegetation was significantly influenced by treatment within block ($F_{(8)} = 14.93$, $p < 0.0001$) and season of sampling (spring, early summer, late summer, fall, and winter) ($F_{(4)} = 74.2$, $p < 0.0001$, but not by block ($p = 0.01$) or year ($p = 0.25$). Differences in vegetation heights among blocks (20A, 20B, 65A, 65B) are likely caused by differences in physical composition of soils and soil moisture related to elevation. Significant differences in seasonal patterns across the years ($F_{(10)} = 10.3$, $p < 0.0001$) may be due to variable rainfall patterns. Bahiagrass heights in June 1997 were taller than in June 1998 and 1999 (Figure 2.1). Bahiagrass heights consistently fluctuated seasonally, with the least growth in spring (March) and the most in late summer (August), because the flowering stems or culms were produced at this time of year. In August 1999, the bahiagrass was the tallest recorded for the three-year period.

Compared with the 1997 and 1999 data, the mean height of bahiagrass was lowest in 1998 across all three treatments (Figure 2.1). The mean tallest height of vegetation was inconsistent for the three years of the study. In 1997 the tallest bahiagrass was in the single mow treatment; in 1998 tallest bahiagrass was in the mow three times treatment, and for 1999 the tallest recorded mean height for all three years was in the no mow treatment. However, seasonal effects were stronger than all treatment effects (Figure 2.1).

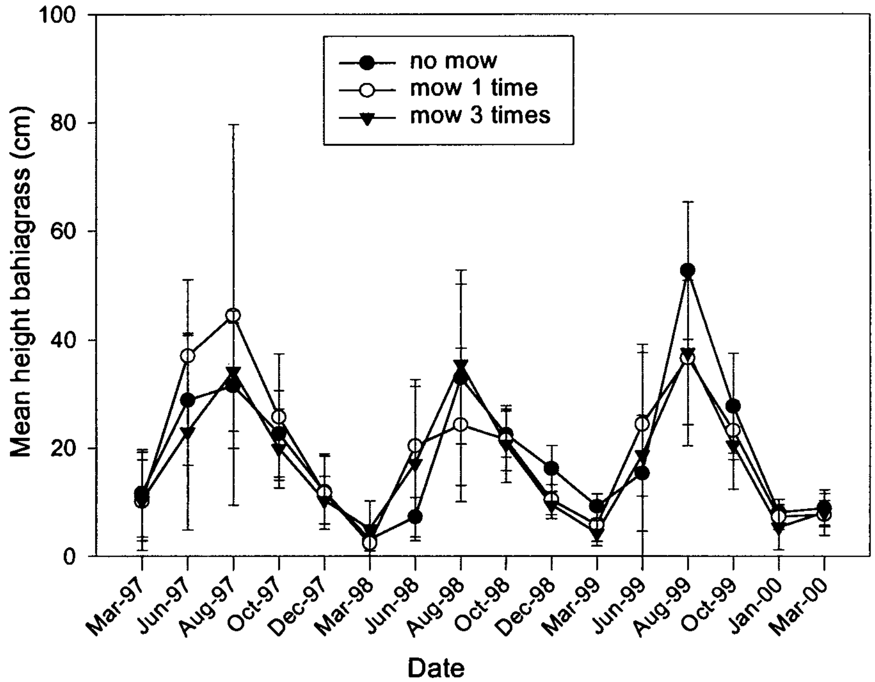

Figure 2.1. Mean (± 1 SD) height (cm) of bahiagrass on roadsides mown at one of three frequencies from March 1997 to March 2000. Sample sizes vary by date and treatment because of interference with the mowing frequency treatments.

Native Vegetation

Mowing frequency effects were more dramatic in the natives than in the bahiagrass, with vegetation in the no mow treatment often at least twice as tall as in either of the mown treatments ($F_{(12)} = 17.3$, $p < 0.0001$; Figure 2.2). We also found significant dependence on season ($F_{(4)} = 23.3$, $p < 0.0001$) and block ($F_{(5)} = 79.6$, $p < 0.001$). Again, the seasonal differences ($F_{(12)} = 23.5$, $p < 0.0001$) in native plant height and response to treatment ($F_{(39)} = 28.9$, $p < 0.0001$) varied by year of the study. Greater variability was seen in the native vegetation heights than in that of bahiagrass, likely because multiple species were included in the analysis. Year to year height variation was similar in 1997 and 1998 but changed in late summer 1999. Vegetation heights increased in the fall (October and December), as the grasses, including broomsedge (*Andropogon* spp.), produced flowering stalks. Particularly tall vegetation was recorded for October 1999 and January 2000 (Figure 2.2). Mean native vegetation heights generally fell in March, increased during the summer, and peaked in October.

Discussion

Season rather than the mowing treatment controlled bahiagrass height. Plants that were not mowed were no taller in the winter months than were plants mowed up to three times in the previous season. In the panhandle of Florida, mowing appears unnecessary in the winter (mean height consistently below six inches) and may not be necessary outside the clear zone (mean height below 20 inches in August). In the clear zone, if height is to be maintained below nine inches, mowing is necessary at higher frequency than the three times tested through the summer season.

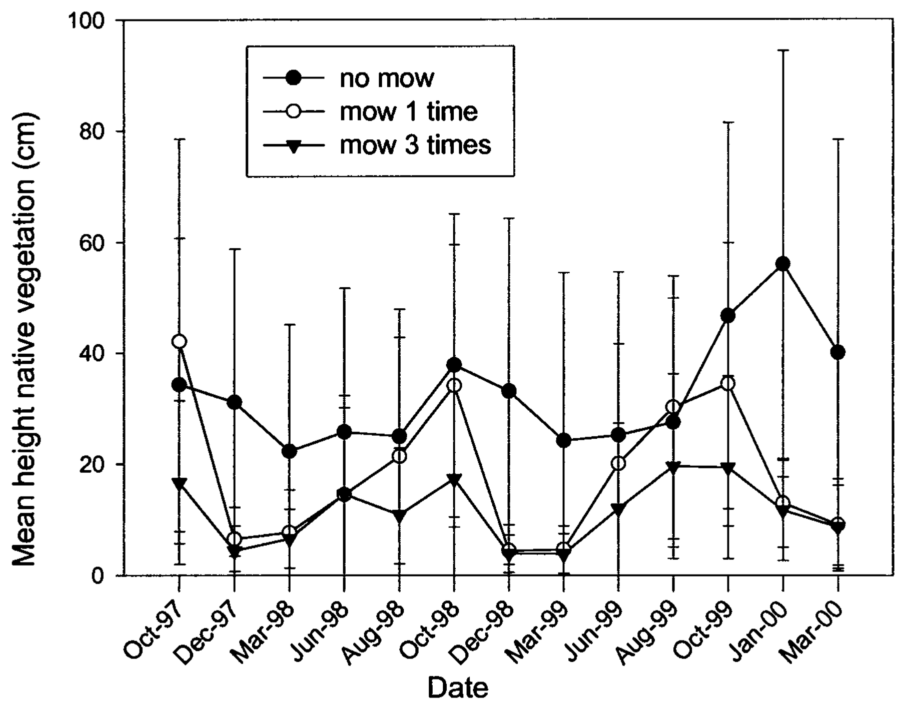

Figure 2.2. Mean (± 1 SD) height (cm) of native species on roadsides mown at one of three frequencies from March 1997 to March 2000. Sample sizes vary by date and treatment because of interference with the mowing frequency treatments.

Effects of the mowing frequency were more noticeable in the native vegetation than in the bahiagrass (Figure 2.2). The mean height of the no mow plots was tallest at every sampling period except October 1997 and August 1999. With the same two exceptions, the heights of the vegetation in the mowing once treatment ranked between those in the no mowing and the mowing three times treatment. Vegetation in the highest mowing frequency plots showed the lowest heights of the three treatments. However, if the goal of mowing native vegetation is for woody species control rather than for height of the herbs (beyond the clear zone, for example), mowing even once every three years appears to be more than sufficient, as heights remained below two feet in the unmown vegetation.

Management Implications

The cost of maintaining roadside rights-of-way through frequent mowing is considerable. Additionally, the necessity of frequent mowing outside of the clear zone is questionable. This work shows that native vegetation and nonnative vegetation achieve similar heights during the growing season although the growing (or flowering) season may be different for bahiagrass and native species. The results indicate that less frequent mowing outside the clear zone, once every three years or more, would accomplish equal results in maintaining vegetation below two feet in height compared to the more frequent mowing often practiced today. While the results may not be applicable to areas further south in Florida, reducing mowing in north Florida should still provide substantial savings for the state.

Experiment E: Compare the effects of prescribed fire to that of mowing in native vegetation along roadsides.

Introduction

FDOT owns vast acreages of land on rights-of-way. A percentage of this area transects natural areas where the native vegetation outside the clear zone is continuous with native vegetation on state, federal, or private property. FDOT attempts to manage the rights-of-way in a cooperative manner with the adjacent landowner. This may involve, though currently infrequently, the use of fire in certain circumstances where the public safety concerns can be ameliorated. However, the relative effects of fire versus the more common mowing management have not been compared.

We conducted this comparison along roadsides in the Apalachicola National Forest (ANF), where adjacent vegetation is managed with prescribed fire. We hypothesized the following: (1) the effects of prescribed fire are the same as those for mowing to maintain the native vegetation height along roadsides, (2) woody shrubs will remain low in stature when burned or mowed on an annual basis, and (3) woody stem density will be reduced equally as well by burning or mowing. Over a longer period than is possible for this experiment, we would anticipate that annual fire would reduce the density of woody vegetation. Because many herbaceous plant species produce flowers in response to burning (Menges and Kohfeldt 1995, Johnson and Abrahamson 1990, Platt et al. 1988), we also observed flowering responses to learn whether mowing stimulates the same types of responses as fire.

Methods

We worked with U.S. Forest Service staff in ANF, where two of the mowing blocks for Experiment C were already in place. Mike Dueitt, ANF Fire Management Officer of the Apalachicola District, informed us of the burning schedule during the 1999 growing season and conducted the burns. ANF staff agreed to use the roads as fire breaks in designated locations and to allow us to establish plots in native vegetation along the roadsides within the intended unit and adjacent to that unit. Bruce Harvey of the Wakulla District also assisted with this project; however, burning was postponed in that District because weather conditions prohibited burning during the summer 1999.

Experimental Design

Six roadside sites were selected within management compartments scheduled for burning during the summer of 1999. The 4 x 30 m (13 x 98 ft) plots were marked with wooden stakes and pin-flags. Plots paired for similar starting vegetation were randomly established in each compartment; one plot in each pair was burned, and the second plot was mowed within a week of burning. Pairing the timing as well as the location of plots was important because the phenological responses of the plants are temporally variable (Robbins and Myers 1992). All plots were located parallel to the roads, outside the mowed road edge above the swale.

To protect the plots to be mowed from fire when the compartments were burned, the vegetation around the plots was mowed and raked. The mowed plot in Compartment 71 was protected from fire with the assistance of a hot-shot fire crew who cleared a 3 ft wide fire line of vegetation, 10 ft from the plot. Liberty County Correction inmates prepared two additional plots in a similar manner to protect the plots from accidentally burning. Immediately before burning, the ANF fire crew also watered the cleared area around the mowed plots to assure that these plots were not burned.

Two plots in one burn compartment were burned by ANF staff on April 9, 1999. Mowed plots were established within one mile of these burned plots to serve as comparison plots. A third plot was burned on May 5. The last two plots were burned July 27 and 29. All burned and mowed plots were monitored in November 1999 and 2000.

Monitoring

Baseline conditions were measured in March and April 1999 (Figure 2.3). Herb height data were collected every meter along three randomly located transects within the 30 x 4 m (98 x 13 ft) plots. Shrub density and height measurements were determined in five 1 x 2 m (3.3 x 6.5 ft) randomly located sub-plots along the transects. Shrubs were defined as woody plant species with single or multiple stems that were between 0.4 m (1.3 ft) and 4 m (13 ft) in height. Some species considered as sub-shrubs were not included in this study; species in this category included *Vaccinium myrsinites* and *Licania michauxii.* The height of the tallest shrub was measured in sub-plots. Flowering species likely to be seen from automobiles were recorded. Photographs were taken of these plots during monitoring.

Data Analysis

Height and density data were analyzed using analysis of covariance. The mean height data from the plots in March 1999 were used as covariates in the analysis of the heights for November 1999 and 2000. Tukey HSD, a multiple comparison test, was used to determine the significant differences (at $p < 0.05$) between group means in the analyses. Data were transformed to stabilize variances where necessary.

<u>Results</u>

Mean height of herbaceous species was significantly higher in the burned (34.3 cm or 1.1 ft) than in the mowed treatments in November 1999 (29.5 cm or 0.9 ft; $F_{(1, 889)} = 175.5$, $p < 0.001$) and

November 2000 ($F_{(1, 889)} = 6.32$, $p < 0.01$). The mean height of the herbs in March 1999 was not a significant covariate in November1999, but was significant in November 2000. Site differences among compartments (blocks) contributed significantly to the differences in height as did the interaction between block and treatment.

Figure 2.3. Monitoring vegetation height in Apalachicola National Forest research plot before the prescribed fire.

Mean height of herbaceous vegetation recorded in November 2000 appears to be returning to March 1999 pre-treatment levels in both burned and mowed blocks (Figure 2.4). Although the mean height of vegetation was higher in November 1999 in all blocks (A-E) after burning, in blocks C, D, and E, mean heights in the mowed plots did not return to the March pre-treatment levels. Significant block differences may be due to soil differences: mean heights in block D (solid bars, Figure 2.4) were 10 cm (4 inches) higher than other blocks in pre-treatment monitoring. This block is located in Burn Compartment 71 (Figure 2.5), in a savanna area of Kennedy Creek drainage, and the soils generally have higher nutrient levels in this area.

Shrub heights were also significantly dependent on the treatment in 1999 ($F_{(1, 276)} = 6.86$, $p < 0.01$) and in 2000 ($F_{(1, 276)} = 8.58$, $p < 0.004$). Height was not changed by burning in 1999 but increased in all blocks in 2000 (Figure 2.6). Height decreased with mowing, especially in blocks C and E in 1999 (Figure 2.6 a, b), and remained low in block E in 2000 (Figure 2.6 c). This difference among the blocks was reflected directly in 1999 ($F_{(4, 276)} = 2.58$, $p < 0.004$) but was not significant in 2000. Unlike the herbs, blocks that had taller shrubs in March also had taller shrubs in November regardless of treatment ($F_{(1, 139)} = 4.50$, $p < 0.04$), except in block C where the shrubs in the mowing treatment did not return to pretreatment heights.

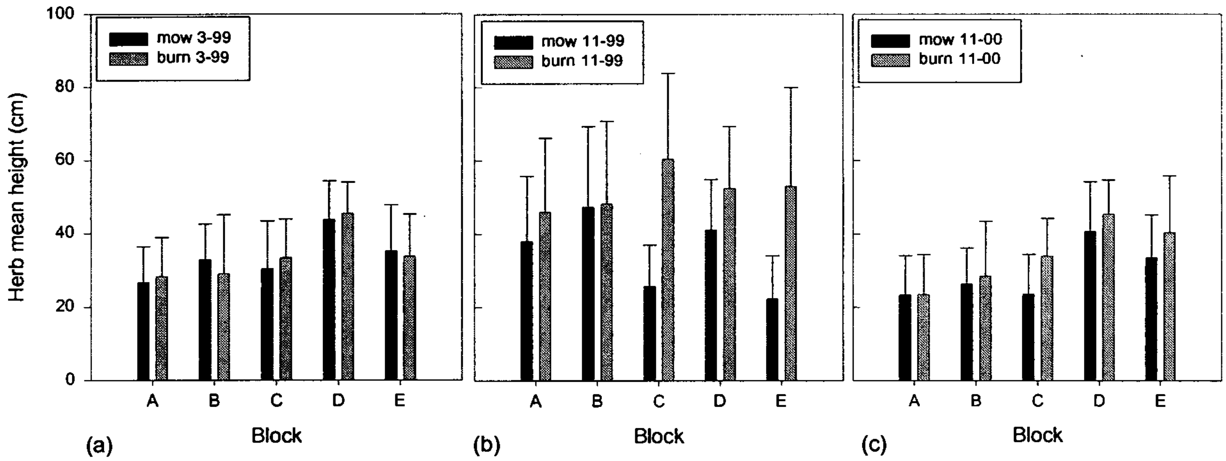

Figure 2.4. Mean height (+ 1 SD) of herbs in March 1999 before treatment (mow and burn), in November 1999 six months after treatment, and in November 2000, in five blocks of paired plots in the Apalachicola National Forest.

Mowing decreased shrub densities to a greater extent than did burning in 1999 ($F_{(2, 138)} = 5.00$, $p < 0.03$; Figure 2.7). Density in November was dependent on the pretreatment density in March ($F_{(1, 139)} = 7.49$, $p < 0.007$). Both treatments reduced the significantly higher shrub densities in block C (5.5 shrubs/ 2 m^2) to densities not distinguishable from those in the other blocks (roughly 1 per 2 m^2 or 21 ft^2 plot) in 1999. By November 2000, shrub densities in the burned blocks increased significantly from 1999 densities especially in Block D, where titi shrubs resprouted vigorously from fire (Figure 2.4 c).

Flowering species easily seen from automobiles traversing roadsides were noted in spring and fall (October and November) 1999 and 2000 during monitoring (Table 2.1). None of the species listed were observed in all plots, although the plants on the list are common species in several plant communities including pine flatwoods and sandhills.

Discussion

Differences in herbaceous vegetation heights in burn treatments may be associated with the rapid growth and flowering of wiregrass (*Aristida beyrichiana*). Wiregrass was at high densities in all the plots and responded rapidly to the growing season fires compared with a slower growth response to mowing. Our previous work (Gordon et al. 2000) showed that the mean number of flowering wiregrass stalks is significantly higher in burned than in mowed plots. The results of this study were consistent with the earlier work: wiregrass regrowth following mowing was significantly less vigorous than after burning.

Shrub height was less affected by burning than by mowing as native shrubs have adapted to the fire regime of the habitat in which they grow. Burning elicits rapid growth and stimulates sprouting in shrubs following fire, as near-ground competition has been reduced and fire recycles nutrients for growth (Christensen 1977). Mowed shrubs may not recover as quickly as burned shrubs because the woody tissue is frequently shredded, damaging shoot regeneration tissue and exposing damaged tissue to invasion by insects or disease. In addition, saw palmettos cut below the reclining stems may be killed by close mowing. However, under annual to biennial fire conditions, the hardwoods would likely be similarly suppressed (Glitzenstein et al. 1995).

Figure 2.5. Apalachicola National Forest Block D during the May 12, 1999 prescribed fire. The to-be-mowed plot in the foreground was protected by vegetation removal and watering before prescribed burn.

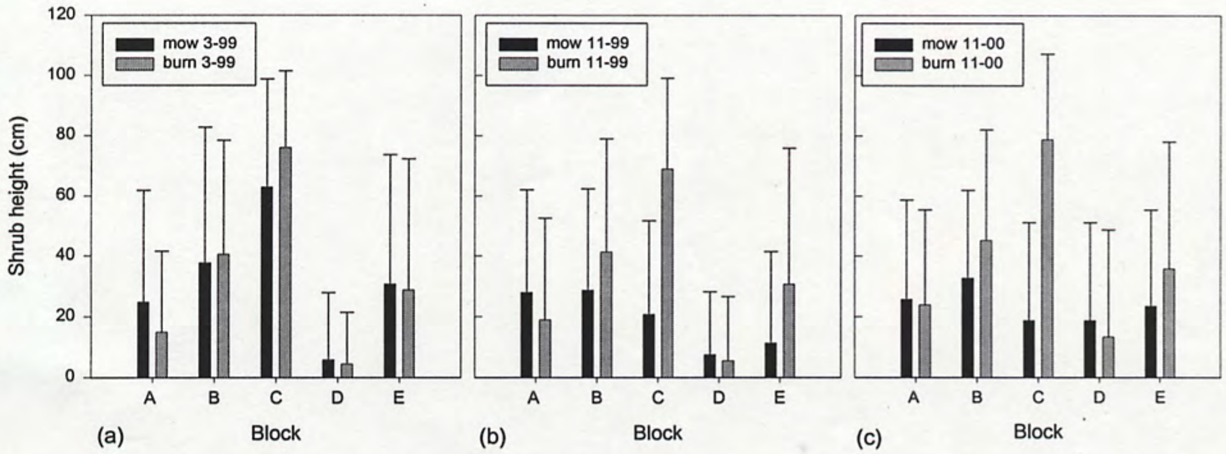

Figure 2.6. Mean height (+ 1 SD) of shrubs in March 1999 before treatment (mow and burn), in November 1999, six months after treatment, and in November 2000, in five blocks of paired plots in the Apalachicola National Forest.

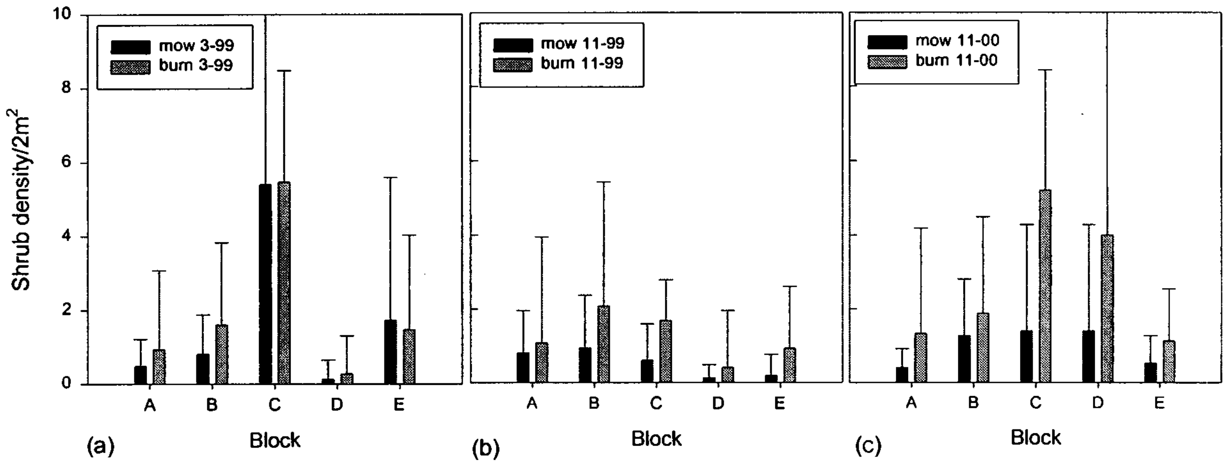

Figure 2.7. Mean density (+ 1 SD) of shrubs in March 1999 before treatment (mow and burn), in November six months after treatment, and in November 2000, in five blocks of paired plots in the Apalachicola National Forest.

Table 2.1. List of flowering plants in research blocks likely to be observed from roadsides in Apalachicola National Forest. The plants on this list were observed in blocks A-E in flower in the spring 1999, fall 1999 and fall 2000.

Scientific name	**Common name**	**A**	**B**	**C**	**D**	**E**
Agalinis divaricata	Agalinis			1		1
Aster concolor	Eastern silver aster	1	1			1
Aster tortifolius	White-topped aster		1	1		
Carphephorus odorissimus	Vanilla-leaf	1				
Coreopsis leavenworthii	Tickseed				1	1
Erigeron strigosus	Prairie fleabane				1	1
Eriocaulon sp.	Pipewort		1			
Eryngium aromaticum	Snakeroot			1		
Eupatorium mohrii	Mohr's eupatorium			1		
Euthamia minor	Flat goldenrod	1				
Haplopappus divericatus	Slender scratch-daisy			1		
Heterotheca subaxillaris	Camphorweed					1
Hypericum hypericoides	St. Andrews cross	1	1	1	1	
Liatris sp.	Gayfeather	1			1	1
Liatris tenuifolia	Short-leafed gayfeather		1	1		
Pityopsis graminifolia	Narrow-leaf silkgrass	1	1	1		1
Polygala cruciata	Drumheads			1	1	
Rhexia sp.	Meadow beauty		1			
Sabatia brevifolia	Short-leaf rose gentian	1	1	1		1
Seymeria pectinata	Peidmont black senna		1			
Viola septemloba	Early blue violet	1				
Xyris sp.	Yellow-eyed grass		1			

Management Implications

The natural process controlling vegetation composition and structure in most of the upland natural communities found within the southeastern United States is fire. Where permitted and feasible, fire is being used by prescribed burning practitioners to manage vegetation adjacent to roadways. This experiment shows that, outside of the immediate flowering season following a growing season burn, most of the vegetation heights are similar between burned and mowed plots. The exception is caused by the flower and seed stalks resulting from the growing season burns rather than by woody growth. The use of fire along certain roads, where the safety of drivers is not jeopardized by higher vegetation in the clear zone, would allow for adjacent landowners to manage the landscape without costly fireline preparations. Mowing the clear zone every three years (see above) to control woody growth may be less expensive than fireline maintenance. In addition, fire management on ROWs would allow for diversity of views, colors, and textures along public roads. This management would also result in vegetation most similar to the vegetation adjacent to the ROW where roads traverse natural areas.

Two additional advantages of incorporating fire management on rights-of-way through natural areas are the reduction of fuels important for wildfire control and reduction of costs to FDOT. Prescribed burning would likely be conducted by the adjacent land manager, who would then use the roadside as a fireline. FDOT would have reduced or no mowing costs in those areas. Clearly, however, this management could only occur along selected roads across the state where vehicle loads and speeds could accommodate smoke on occasion.

OBJECTIVE 3: Investigate the propagation of little bluestem (*Schizachyrium scoparium*) for turf development potential and use along roadsides.

Introduction

Little bluestem (*Schizachyrium scoparium*) is a common grass in the sandhill community of north Florida. It often forms a turf-like mat, reproducing vegetatively by producing rhizomes (horizontal underground stems), stolons (horizontal aboveground stems), and new shoots (tillers) from the base of the plant. Although little bluestem has been documented to have low seed viability and is reported to be difficult to germinate (Heath et al.1973), burning in springtime (March-June) increases flowering (Biswell and Lemon 1943) and may increase seed quality, quantity, and germination. This set of experiments focused on three reproductive aspects of little bluestem: (1) effects of fire on seed production and viability, (2) results of shadehouse propagation tests on seeds, and (3) establishment of transplanted plugs and seed germination and growth under field conditions.

Experiment F: Examine the effect of fire on seed production and viability in little bluestem.

Introduction

Little bluestem holds potential as a native turfgrass for roadside vegetation because it is a drought resistant native grass species that adapts to local environmental conditions (Barnes et al. 1995; Heath et al. 1973) and forms areas of continuous cover in sandhills. However, due to low seed quality and difficulty encountered in germination (Heath et al. 1973), it has received little attention. Earlier work did show that growing season (March-June) burning increases flowering (Biswell and Lemon 1943). Plants do produce seed without fire (pers. obs.), but little is known about viability of seed from burned versus unburned parent plants. Therefore, populations of little bluestem were burned at The Nature Conservancy's Apalachicola Bluffs and Ravines (ABRP; Figure 1.2) adjacent to unburned populations. We hypothesized that little bluestem plants that are burned would produce more flowers and viable seeds per flowering stalk than unburned plants. In addition, the flowering stem densities and the seed germination should be higher for burned than for unburned plants.

Methods

Experimental Design

In spring 1999, four natural stands of little bluestem were located in burn units at ABRP. We conducted prescribed burns within the four units in May and June 1999, leaving some of the little bluestem unburned in at least four areas in each unit (Figure 3.1).

Ten randomly located points within each burned and unburned area were marked in July 1999. In November, one flowering culm was cut from the plant closest to each flag and the flowers counted. To obtain the percentage of flowers with filled (mature) seeds, we extracted seeds from filled flowers under a dissecting microscope using Hamilton Bell #5 forceps. Seeds were carefully removed from the flowers as they were easily broken by rough treatment or by applying pressure to the flowers to determine whether they contained filled seeds.

Extracted seeds from Burn Units 1 and 6 were then used to determine viability through germination trials; too few seeds were collected from the other two burn units. Seed germination was tested by placing 20 flowers from each unburned and burned area in moist filter paper in plastic envelopes. Seed germination trials were continued for 10 weeks.

Flowering stem (culm) density was also determined for Burn Units 1 and 6 by counting the number of stems per 0.25 m^2 (2.7 ft^2). All culms within the square quadrat placed within one meter (3.3 ft) of each flag in all units were counted.

Figure 3.1. Unburned natural stand of *Schizachyrium scoparium* at Apalachicola Bluffs and Ravines Preserve with the burned portion of the stand in the background.

Data Analysis

We assessed the influence of fire on flower production and stem density using analysis of variance. Seed germination results from burned or unburned parent plants were compared using contingency table analysis.

Results

The only unit that showed a difference in the number of flowers in burned and unburned little bluestem was BU6, where more flowers were produced in the burned areas (Figure 3.2). As a result, we detected a significant site effect ($F_{(1, 72)} = 6.3$, $p < 0.001$), but no effect of fire. We counted an average of 210 flowers in BU6, significantly more than the 78 and 75 flowers in BU1.

Unlike the number of flowers, the percent of flowers with mature seeds was significantly higher for burned plots ($F_{(1, 20)} = 7.74$, $p < 0.01$), although there remained significant differences among the four burn units ($F_{(3,20)} = 14.01$, $p < 0.001$). As a result, the interaction term between treatment and site was also significant ($F_{(3, 20)} = 5.67$, $p < 0.005$): while filled seed production was always higher in burned than in unburned sites, the difference was striking only in BU1 (10.75% vs. 2%). BU1 burned plants also produced significantly more filled seed than either treatment in any of the other blocks (Figure 3.3).

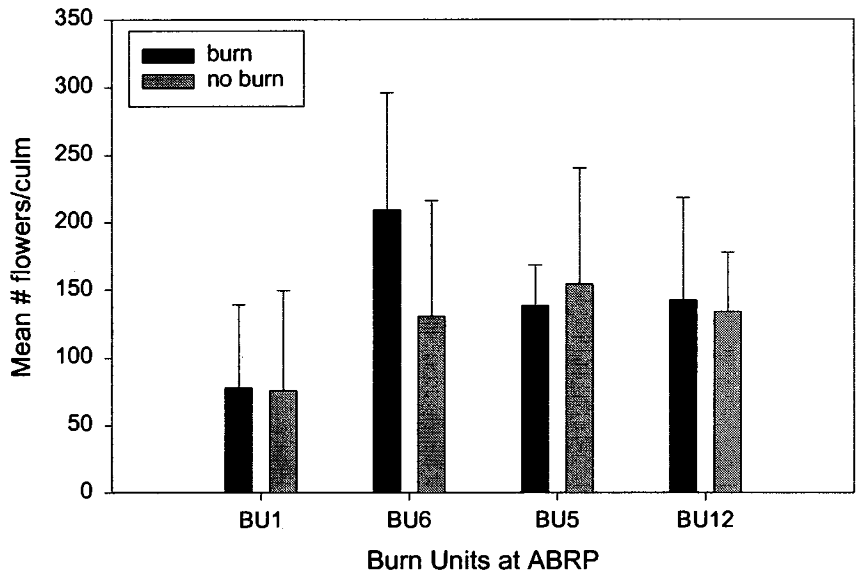

Figure 3.2. Mean (± 1 SD, n=10) number of flowers per flowering stem in four burned and unburned stands in native sandhill habitat at ABRP. Differences between burned and unburned stands were not significant.

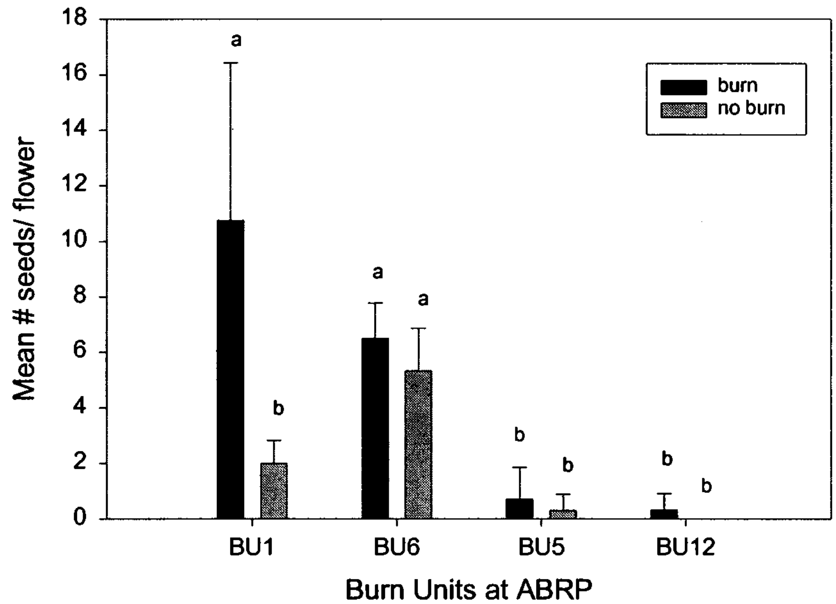

Figure 3.3. Mean (± 1 SD) number of filled seeds per 100 flowers collected from the four burned and unburned stands at ABRP. Means accompanied by the same letters are not significantly different from one another.

Seed germination tests were started on February 3, 2000 using mature seeds extracted from flowers from BU1 and BU6. Multi-way contingency table analysis showed significant differences for percent germination after 10 weeks between burned and unburned areas (X^2 = 6.76, df = 1, p = 0.009). Higher percentages of seeds germinated from plants that had been burned in BU1 (55.5%) and BU6 (81.7%) than from those that had not (both under 40%; Figure 3.4).

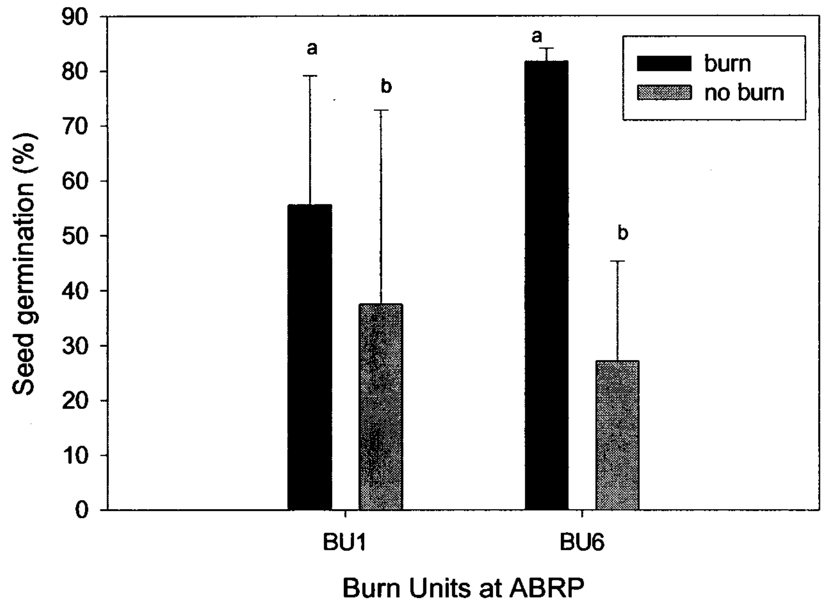

Figure 3.4. Percent germination of *Schizachyrium scoparium* seeds collected from BU1 and BU6. Means accompanied by the same letters are not significantly different from each other.

Flowering culm densities (0.5 m^2) were also significantly higher in burned areas of BU1 and BU6 than in the unburned areas in those blocks (all blocks: $F_{(1,72)}$ =63.78, p < 0.01). Those two units also had higher culm densities than did either the burned or unburned areas of BU5 and BU12 (Figure 3.5). Again, differences among burn units resulted in significant block ($F_{(3,72)}$ = 30.91, p < 0.001) and block by treatment interactions ($F_{(3, 72)}$ = 16.02, p < 0.001).

<u>Discussion</u>

While results from this experiment are not entirely consistent among blocks, the data do suggest that fire increases seed viability and may increase seed production in little bluestem. If this species is determined to be desirable for restoration, further work to clarify these results and differences among sites would be warranted. However, the results also demonstrate that fire is not necessary for viable seed production in this species. Therefore, assuring a consistent seed source even in years when fire is not feasible or prohibited may be possible. Examination of seed production under drought conditions would clarify the potential for consistent seed availability in little bluestem.

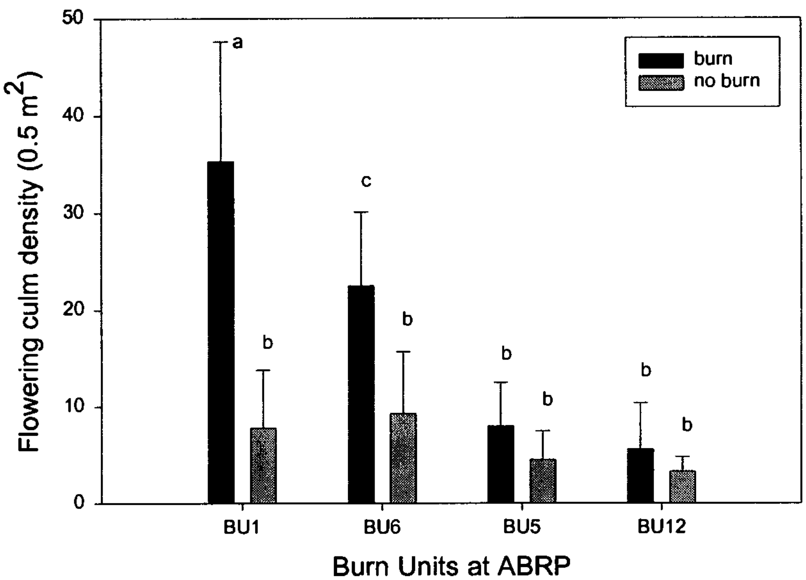

Figure 3.5. Mean (± 1 SD n=10) flowering culm density in plots within four burned and unburned stands at ABRP. Means accompanied by the same letters are not significantly different from each other.

Experiment G: Conduct shadehouse propagation tests of little bluestem from seeds and cuttings.

Introduction

Much work has been accomplished with native grasses to develop techniques for seed production, harvesting, and processing in some locations (Barnes et al. 1995). As mentioned previously, little work has been done with little bluestem. Shadehouse propagation tests were conducted at ABRP on transplanted plugs and sown seed to determine whether plugs would successfully transplant into a shadehouse and form continuous cover by producing rhizomes, stolons, and new shoots. Similarly, we looked for turf development from seeds sown in the shadehouse within the first growing season.

Methods

Our earlier work with this species suggests that clumps can successfully be transplanted and that seeds germinate within the first season. From both burned and unburned areas in Burn Unit 6, we hand-collected seeds (Figure 3.6) in mid-November to mid-December 1999 for the shadehouse and field (Experiment G below). Liberty County inmates collected little bluestem plugs on February 25 for the shadehouse. The plugs were cut using 2.5 inch bulb cutters, pushing the cutter below the root system. The plugs and associated soil were placed in 3-inch pots and transported to the shadehouse.

Seeds

Seeds were stored until mid-February when freezing weather was less threatening. Filled seeds were sown in shadehouse soil mixture at a rate of 10.4 lbs per acre, taking into consideration the percent of flowers with filled seeds from the burned (6.5%) and unburned (5.3%) areas from BU6. Ten 25 x 50 x 7 cm (9.6 x 19 x 2.4 in.) flats were sown in the shadehouse at ABRP on March 2, 2000. Flowers plus seed weighed 2.25 g (0.07 oz) per flat from burned areas and 2.74 g (0.09 oz) per flat from unburned areas. Seeds were spread evenly by hand and covered with 1 cm (0.03 in) of soil.

Plugs

Schizachyrium scoparium plugs were removed from field populations and planted in shadehouse flats on March 2, 2000. Plants with at least one sprouting rhizome (sprig) were separated from the plugs and 18 sprigs were planted in each of ten 25 x 50 x 10 cm (9.6 x 19 x 2.4 in.) flats filled with soil mix. This mixture, consisting of 65% crushed pine bark, 25% 6B gravel, and 10% sand, with Osmocote®, Micromax®, and phosphorus fertilizer, has been used successfully at the preserve for propagation of other sandhill species (G. Seamon, pers. obs.).

Flats containing sprigs and seeds were watered by hand until seedlings became established; then the flats were watered from overhead sprinklers. Flats were rotated periodically on the shadehouse benches to assure that location of the flat relative to the overhead sprinkler did not affect the water quantity available. Initially, daily watering soaked the flats and watering was scheduled every other day. Sprinklers were turned off on days receiving at least 0.1 inch of rain.

Monitoring

Seedlings were counted in May 2000 for an intermediate germination count. All seedlings were counted (including the dead ones) to determine if germination rates differed between seeds collected from burned and unburned parent plants.

Data Analysis

Seedling produced from seeds from burned and unburned parent plants were analyzed using analysis of variance. No data analysis of the plugs was necessary because of high mortality (see below).

<u>Results</u>

Three months after sowing, significantly higher numbers of seeds from the burned area germinated in the flats than did those from the unburned area (Figure 3.7; $F_{(1, 36)} = 7.36$, p =

0.01). Seedling survival was independent of the burn treatment, with significantly more seedlings surviving than dying ($F_{(1, 36)} = 17.09$, $p < 0.001$). Most seedlings died from root rot because the flats received too much water. We stopped watering daily, increased the number of drainage holes in the flats, and started using the overhead sprinkler. These steps resolved the over-watering problem. Sprinklers were turned off the end of June. After a week of no rain, seeds and plugs showed signs of drought stress. Sprinklers were turned back on, but the plants still showed signs of stress. By the end of August, insufficient seedlings or plugs remained alive for analysis.

Figure 3.6. Hand collection of *Schizachyrium scoparium* seeds in November 1999 by a student from Northwestern University on winter break. These stands were burned in spring 1999.

<u>Discussion</u>

The preliminary results from Experiment F that little bluestem seed from burned parent plants may have greater germinability than those from unburned parents were confirmed in this experiment. Although seeds germinated under shadehouse conditions, the establishment and survival of little bluestem were more sensitive to the irrigation level and substrate than were wiregrass seedlings and other sandhill species (G. Seamon, pers. obs.). We saw no indication that seedlings from seeds of burned parents were more robust to root rot than were seedlings from unburned parents. More rapidly draining medium like sand may be more successful for propagating *Schizachyrium scoparium*. Plugs produced tillers and stolons but also showed signs of over-watering and insufficient watering. Additional research is needed for shadehouse propagation of little bluestem. However, again these results suggest that prescribed fire may result in higher seed production and germinability.

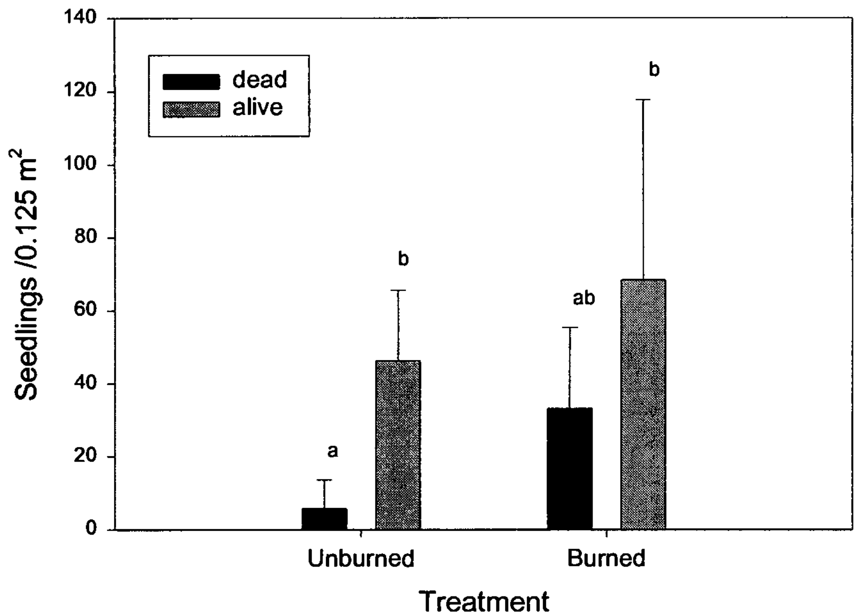

Figure 3.7. Mean number (± 1 SD) of *Schizachyrium scoparium* seedlings germinating in the shadehouse by status of the parent plants from which seeds were collected (burned and unburned). Means accompanied by the same letters are not significantly different from each other.

Experiment H: Conduct field trials of little bluestem establishment.

Introduction

To be of greater use for restoration and roadside management, little bluestem should have the ability to establish and form dense stands in the field. Ideally, such stands would develop from direct seeding or planting of sprigs or plugs. As a result, we conducted field trials at ABRP to determine the success of transplanting little bluestem plugs from native habitat into field plots and to observe cover development from rhizomes, stolons, and new shoots. We also sowed little bluestem seeds at a rate of 10 lbs per acre in field plots, and followed germination and density of seedlings during the first growing season. We hypothesized that both propagule sources would result in dense stands of little bluestem, but that stands would form more rapidly in plots of plugs than seeds. We also hypothesized that seedling establishment and growth would increase with early irrigation. However, the 2000 drought interfered with the test of this hypothesis.

Methods

Experimental Design

Field trials of little bluestem using direct seeding and plugs were established in 1 m^2 (10.8 ft^2)

plots located near the larger (15 x 15 m) plots for Experiment A. All plots were located approximately 2 m (6.6 ft) inward from the corner and 3 m (9.8 ft) outside existing plots. In the irrigated plots, sprinklers were 5 m (16.4 ft) from the plots and were adjusted to deliver water only to the 1 m^2 plots outside the larger plots. Propagule type (seeds or plugs) and irrigation treatment (water or none) were factorially combined to produce four treatments in a split-plot design. Irrigation was the main plot treatment, with the propagule type as the sub-plot treatment. Planting sites were burned in December 1998. Ten blocks of each treatment combination were established (n=40). Pin flags were placed in the corners of each plot.

Seeds

On February 5, 2000, all existing vegetation was removed from the plots, and the surface soil was gently disturbed by raking to prepare for sowing. Seeds were sown at a rate of 10.4 lbs of viable seed per acre, or 18 g / m^2. A 6.5% viable seed content calculated by flower weight was used to determine sowing rate as in Experiment G. Seeds were hand-sown evenly into the raked soil and covered with approximately 1 cm (0.03 in) of clean pine needles (no weeds or other vegetation; Figure 3.8). The surface soil, seeds, and pine needles were rolled, using a 5-gallon water drum filled with sand, weighing 60 lbs The modified roller was pushed over the entire plot first in one direction then at a 90° angle.

Plugs

Two plug transplanting efforts were attempted in this experiment. The first plants were transplanted on December 16, 1999. This effort failed because subsequent cold weather killed the plants. We then examined plants in the natural stands weekly by digging up one or two and inspecting for tiller or stolon formation. By the end of February, plants were actively reproducing vegetatively. On February 25, 2000, a second set of 320 plugs was transplanted from the burned area of BU6, the unit that had the highest number of flowers per stalk and the highest percent germination in the burned portion. Plugs were removed using 2.25-inch diameter bulb planters and placed into 2.5 inch nursery pots for transplanting to the experimental sites near the larger 15 x 15 m (4.9 x 4.9 ft) burned research plots for Experiment A. A total of 16 plugs was planted in a grid pattern on 25 x 25 cm (9.8 in) centers within the 1 x 1 m (3.3 x 3.3 ft) plots (Figure 3.9). All plugs were watered initially and received irrigation twice weekly for the first two weeks. Subsequently, only those plots in the irrigation treatment were watered.

Irrigated plots received the same watering schedules as irrigated plots in Experiments A and B above, using the average daily rainfall for March through June by month for the 10% of months with the highest precipitation recorded from 1968-1997 (Table 1.2). While our initial intent was to discontinue irrigation in May, watering was continued until August because of low rainfall in spring and into summer.

Because of the drought conditions, we assessed seed germination and establishment in June (to serve as an intermediate sampling period before the September monitoring). We used a 0.5 x 1 m (1.6 x 3.2 ft) sampling quadrat divided into 50- 10 x 10 cm (4 x 4 in) grid cells to count every seedling in 12 randomly selected 100 cm^2 cells. This sampling allowed us to estimate seedling establishment. In both plugged and sown plots, we measured total percent cover of little bluestem in September 2000. In addition, for the plug plots, we estimated the change in distance between plugs from the planting point to assess the rate of spread from plugs. Dependence of growth on irrigation was assessed using analysis of variance.

Figure 3.8. *Schizachyrium scoparium* seeds rolled into soil with pinestraw.

Results

Seed germination and seedling establishment were noted within three weeks in both the irrigated and un-irrigated plots in the field. However, from March through May, less than 0.1 inch of rain fell, according to the ABRP weather station. Germination without irrigation was minimal: 0.13 (± 0.79) in irrigated plots versus 8.63 (± 6.64) in un-irrigated plots. Not surprisingly, we found significantly higher ($F_{(1)} = 199.6$, $p < 0.001$) mean numbers of seedlings establishing in the irrigated plots (8.63 plants / 100 cm^2) than in the un-irrigated plots (0.13 plants / 100 cm^2). We expected more seeds to germinate and become established if the usual summer weather pattern returned, however the drought continued throughout the summer.

A comparison of plugs and seedlings in September 2000, six months after planting, showed a significant increase in cover in the irrigated ($F_{(1,36)} = 483.6$, $p < 0.001$) plots compared to the un-irrigated plots (Figures 3.10, 3.11). Seedling cover was higher in the irrigated plots, while plug cover was higher in the unirrigated plots resulting in a significant interaction between irrigation treatment and plant form (seedling or plug) ($F_{(1, 36)} = 9.45$, $p < 0.004$). Seedlings in the irrigated plots formed a dense cover, however few seedlings survived in the un-irrigated plots because of the summer drought. Little bluestem plugs responded to the irrigation through rhizome development and produced new shoots. As a result, the distance plugs when planted and in September decreased from 23.5 cm to 13.5 (± 4.7) cm, a distance of almost 10 cm. This decrease was only marginally significant ($F_{(9,90)} = 1.79$, $p<0.08$) despite the overall trend. Few plugs in the un-irrigated plots survived to the end of summer (Figures 3.12 and 3.13).

Figure 3.9. *Schizachyrium scoparium* plugs planted in field plots on 25 cm (9.8 in) centers.

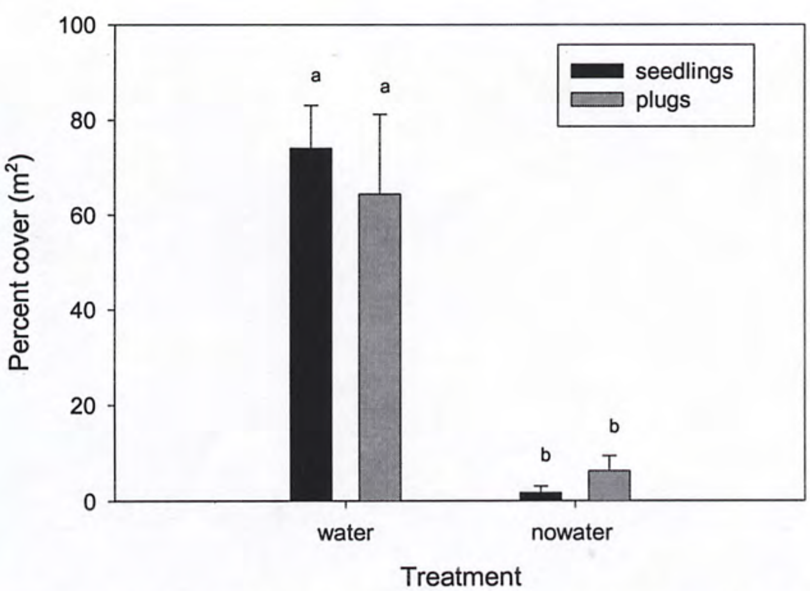

Figure 3.10. Mean (± 1 SD) *Schizachyrium scoparium* seedling germination in the irrigated and un-irrigated field plots at Apalachicola Bluffs and Ravines Preserve in June 2000.

Figure 3.11. *Schizachyrium scoparium* seedlings in the irrigated plots at Apalachicola Bluffs and Ravines Preserve in June 2000.

Discussion

Certainly in drought years, seed germination in field conditions is dependent on water availability. Seeds started germinating within the first two weeks in both irrigated and un-irrigated plots, as we provided initial water to both sets of plots and rain fell during the first month after planting in February. Most seedlings in the un-irrigated plots died as a result of the spring drought (April-June) and few seeds germinated during the dry summer months. By June, seedlings in the irrigated plots were well established and covered most of the plot. By extrapolating the mean number of stems to the whole plot, there would be 860 plants in each square meter in the irrigated plots. By comparison only 13 plants per m^2 would be in the un-irrigated plots.

Plugs were similarly dependent on the irrigation treatment. Unlike in the shadehouse study, no root rot related mortality was seen; any excess water drained rapidly. By the end of six months, little bluestem plants produced sprouts from rhizomes as well as tillers, initiating turf formation in the sandhill experimental plots with irrigation. The distance between plugs was decreasing as new shoots were developing, thus adding to the percentage of vegetation cover. However, cover was significantly lower than in the direct seeded plots.

Figure 3.12. *Schizachyrium scoparium* plugs being weeded in irrigated plots in June 2000.

Management Implications

Little bluestem (*Schizachyrium scoparium*) appears to be suitable as a native turfgrass for roadside vegetation, but it appears that direct seeding is the method of choice. Clean seeds are not necessary as flowers with filled seeds germinate quite well under field and shadehouse conditions. Because of low seed fill, we recommend that seed be collected from native habitats burned the spring before seed collection and investigate the percent of filled seeds prior to establishing the sowing amount.

During critical periods of development, the amount of water limits establishment of seedlings and plugs. More work needs to be done to assess the required watering duration for seedling establishment and to determine whether little bluestem could be planted in summertime when rainfall is more predictable. Transplanting plugs directly into the field is limited by the amount of water needed for establishment. It may be that transplanting on roadsides could be conducted during more predictable rainfall months. Once plants are established, plants adapt to the local weather conditions. During the spring drought in 2000, observations of native little bluestem patches showed dry plants, but some leaves remained green and plants produced new shoots once the rains started.

Shadehouse studies are inconclusive for both seeds and plugs as water quantity was a major factor in establishment. Because little bluestem is adapted to deep, xeric soils, we suspect that the soil mix used was not suitable. Additional research on propagation methods may result in more successful ways to grow little bluestem in the shadehouse setting. However, we are optimistic that this species will develop continuous cover if sufficient precipitation or irrigation is available.

Figure 3.13. *Schizachyrium scoparium* plugs in unwatered plots following drought conditions in June 2000.

<u>OBJECTIVE 4</u>: Continue assessment of experiments on native revegetation and on roadside vegetation management (Contract BA-523).

The Florida Department of Transportation funded a study on the Establishment and Management of Upland Native Plants on Florida Roadsides (State Study No. 785, WPI 0510785, State Job No. 99700-3352-919, Contract No. BA523) from November 1996 through February 2000. Results of this work can be found in the report by Gordon et al. (2000). Three tasks within that project were continued in this contract to gain better insight into the methods tested for using native seeds in roadside revegetation. These experiments worked with native seed harvest and mechanical sowing in three different settings: windrows bulldozed in 1997 at the Apalachicola Bluffs and Ravines Preserve (ABRP), upland pasture restoration at the Disney Wilderness Preserve (DWP), and islands in an access road leading to the visitors center at DWP (Figure 1.2).

BA 523 Experiment A1. Mechanical harvest and sowing of native seed at Apalachicola Bluffs and Ravines Preserve.

<u>Introduction</u>

Native species were successfully established using direct seeding techniques applied to bulldozed windrows in a disturbed sandhill at ABRP. In addition to the seed spread through direct seeding, other species apparently naturally colonized the sites. Native species from adjacent areas and from existing seed banks contributed to the species richness on the site (Gordon et al. 2000). Because wiregrass (*Aristida beyrichiana*) was once a dominant understory component in these systems, establishment of this species is critical for the restoration of sandhills. Results from the first three years of the study show that wiregrass densities exceeded the three to five plants per m^2 (10.8 ft^2) reported in natural longleaf pine communities (Clewell 1989). In May 2000, all the research plots were burned. We expected to see few differences in native species composition within the first year after burning. While some opportunistic, or early successional species, sometimes colonize sites post-fire, they usually do not persist after the first year. While the initial effect of fire is to reduce species cover, we hypothesized that cover would be restored by the time of monitoring in September 2000. Following fire, cover of bare ground would increase, while litter cover would decrease. We hypothesized that wiregrass density would remain the same as before burning but the plants would flower and set seed, thereby increasing the density of wiregrass in the second and third years post-burn.

Methods

Experimental Design

In early 1997, six windrows were leveled using a bulldozer. The windrows, linear rows of soil and vegetation, were formed in the late 1950s to clear the land for planting slash pine (*Pinus elliottii*). The windrows supported a mixture of hardwoods, shrubs and groundcover. The site was divided into 48- 15 x 30 m (49 x 98 ft) plots, nine in each of the six leveled windrows (6 blocks). Nine treatments were randomly assigned to the plots within each block, resulting in a randomized complete block design. Treatments included combinations of species and management methods: (1) native; (2) native augmented with an annual cover crop; (3) native rolled with a soil aerator; (4) native augmented with an annual cover crop and rolled; (5) native and watered; (6) native augmented with an annual cover crop and irrigated; (7) native rolled and irrigated; (8) native augmented with an annual cover crop, rolled, and watered; and (9) no seeded control. Methods and analysis are described in the previous contract Gordon et al. (2000). The seed used were a mix of native groundcover seed that was mechanically and hand collected at the Preserve.

On May 12, 2000, the ABRP prescribed fire team burned the experimental plots. The fire was ignited along the length of the bulldozed windrows starting with the eastern most block (F) and burning each block in succession. All plots, including the unsown controls, were burned completely, and plot corners were flagged.

Monitoring

Quantitative monitoring was conducted in September and October 1999, and October 2000. Percent cover of native vegetation, nonnative vegetation, bare ground, and litter (dead plant material disconnected from a living plant) was determined by ocular estimation in 0.5 x 1.0 m

(1.6 x 3.3 ft) quadrats using the Daubenmire cover classes (Bonham 1989). Quadrats were located every five meters on transects randomly located through a restricted randomization of one transect in each of three five meter sections. This resulted in nine cover, wiregrass density, and species frequency sampling units per treatment plot. The reference plots were monitored in October 2000 using the same methodology as the experimental plots in Objective 1 above.

Data Analysis

Differences among treatments were analyzed using ANOVA as described in Gordon et al. 2000. Community similarity between the treatment plots and reference plots was also assessed as described above for Experiments A and B. The same reference plot data were used as for the earlier analysis.

Results

Species Richness

Thirty more species were identified in the totals across the blocks in 1999 than in 1997 and 1998. However, this increase was not reflected by an increase in the average number of species per plot. Of the 131 species, six were present in all plots: four grasses (*Andropogon virginicus, Aristida beyrichiana, A. purpurescens,* and *Schizachyrium scoparium*); an herb (dogfennel: *Eupatorium compositifolium*), and a vine, (greenbriar: *Smilax auriculata*). Forty-three (32%) of the plant species occurred in half (25/51) of the plots and 34 (26%) of the plants were observed in three or fewer plots.

Five months after the prescribed burn in May 2000, significantly lower species richness was observed in the research plots. Total plant species decreased from 131 in 1999 to 123 in 2000 (Figure 4.1). The species richness per plot averaged 40 to 49 species per 225 m^2 (2422 ft^2) in 2000, compared to 49 to 53 species per plot during the first year of the study in 1997 (Appendix D). A repeated measures analysis from 1997 to 2000 shows significant decreases in the number of species over time (Wilk's lambda = 0.43, $F_{(3,126)} = 9.37$, $p = 0.001$; Figure 4.1). This decrease started prior to the prescribed fires, with a decrease from 1997 to 1998, no change from 1998 to 1999, but again a decrease after the fires in 2000. Increases in richness some blocks over that period resulted in a significant interaction between year and block ($F_{(3,15)} = 2.25$. $p = 0.01$). As reported earlier (Gordon et al. 2000), the unsown plots (controls) had equivalent species richness as the treatment plots, suggesting significant input from dispersal or the soil seedbank.

Wiregrass Density

Wiregrass was definitely introduced into the treatment plots by our sowing, as all treatment plots contained significantly higher density of this species than did the controls in all years ($F_{(3, 1350)} = 376.7$, $p < 0.001$). We found no significant differences in wiregrass density among the other treatments, though the trends suggest higher establishment in plots that were rolled (Figure 4.2). Density also significantly decreased between 1997 and each of the subsequent years of study

($F_{(2, 1350)} = 6.75$, $p = 0.001$), with no significant interaction between treatment and year. The decrease in density could be attributed to several factors, including a decline in the actual number of plants or an increase in the difficulty of distinguishing individual plants as they mature and form clumps. Clewell (1989) found wiregrass densities of 5.3 clumps per m^2 (10.8 ft^2) in undisturbed sandhill. The densities we found per 0.5 m^2 equaled or exceeded those found by Clewell (1989), except in the unsown controls (cntrl).

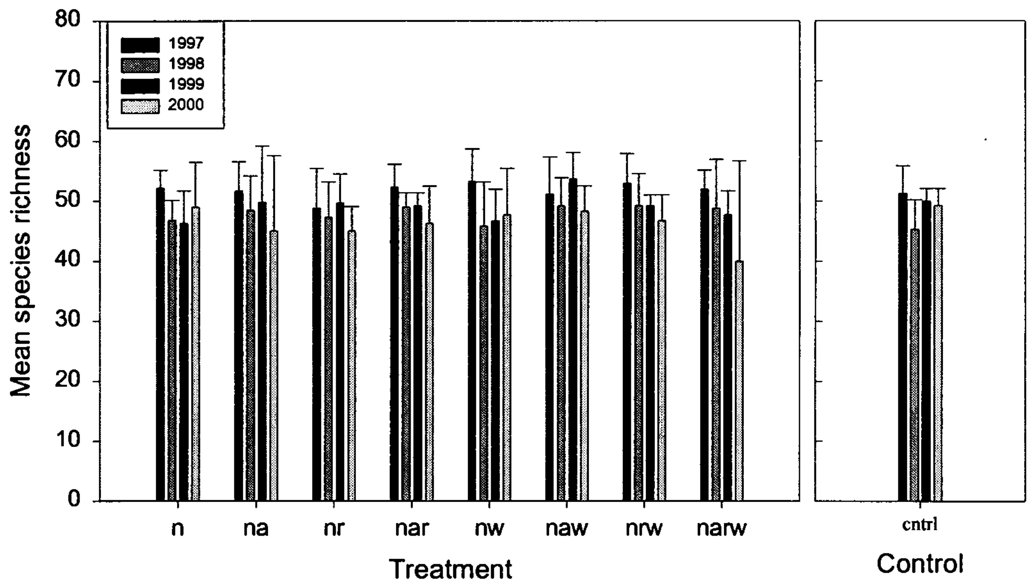

Figure 4.1. Mean (± 1 SD) species richness / 225 m^2 (2322 ft^2) by treatment at Apalachicola Bluffs and Ravines Preserve (n = 6; n = native seed mixture, a = annual cover crop, r = rolling, w = watering; n = 3 for cntrl = unsown control). The unsown control data to the right of the treatment plots was not included in the data analysis.

Percent Cover

Mean percent cover of native plant species also significantly changed over the four year period ($F_{(3,1350)} = 384.9$, $p < 0.001$). Cover of native species increased for the first three years and across all treatments ($F_{(8, 1350)} = 2.37$, $p = 0.02$). Differences in the response of native cover in 2000 following the prescribed fire resulted in a nearly significant interaction between year and treatment ($F_{(3,1350)} = 1.51$, $p < 0.06$; Figure 4.3). Native vegetation cover was 21.75% in 1997, 29.8% in 1998, and 63.3% in 1999, but decreased to 46.1% in 2000. The average percent vegetation cover in the untreated controls increased to 56.85% in 1999, almost as high as that in the sown plots even without the wiregrass. After the prescribed fires, cover in all the plots decreased comparably.

Nonnative vegetation cover responses were the opposite of that of the native species ($F_{(3, 1350)} = 14.2$, $p = 0.001$; Figure 4.4). For the first three years nonnative cover decreased; in 2000, after prescribed burning, the cover increased. In 1997, crabgrass (*Digitaria* sp.) was the only nonnative species observed. Crabgrass was partially removed from the plots in 1997, was not observed in 1998 (Gordon et al. 2000), but returned in 1999. After burning in 2000, crabgrass flowered and was present in seven of the eight treatment plots as in 1997, but at much reduced percent cover (all < 0.5 %). Another nonnative species, centipede grass (*Eremochloa ophiuroides*), was present in low abundance (0.28%), mainly in the narw treatment plots, resulting in a significant difference among the treatments in nonnative cover in 1999 ($F_{(2, 1350)}$ = 3.9, $p < 0.001$; Figure 4.4). Changing trends in cover across the treatments in different years also resulted in a significant year by treatment interaction term ($F_{(3, 15)} = 2.16$, $p < 0.002$).

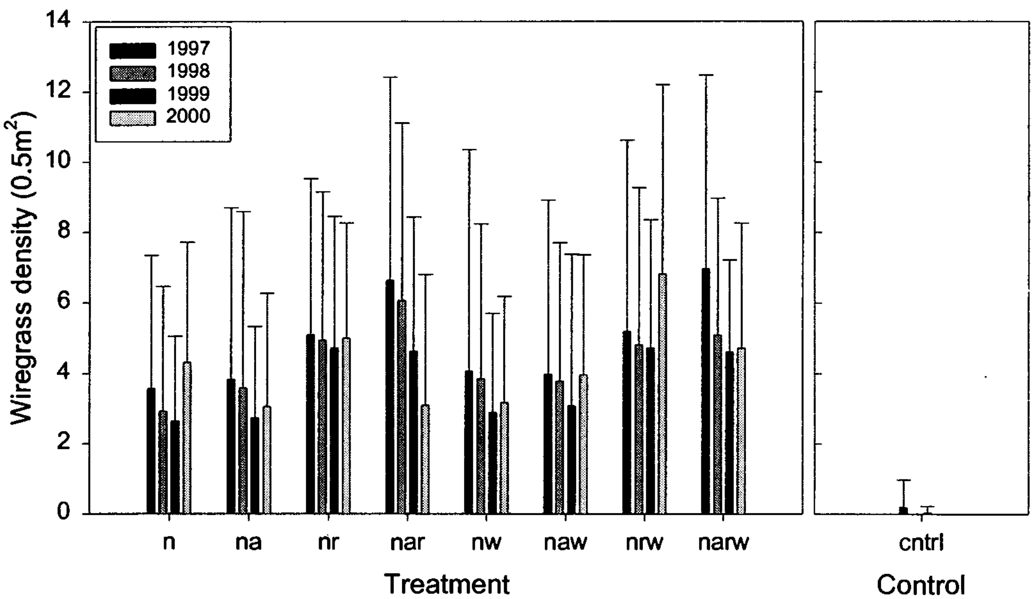

Figure 4.2. Mean (± 1 SD) wiregrass density (0.5 m^2) by treatment at ABRP in fall 1997, 1998, 1999, and 2000 (n = native seed mixture, a = annual cover crop, r = rolling, w = watering, cntrl = no treatment). N = 6 for all treatments except n = 3 for the no treatment plots.

Not surprisingly, as the vegetation cover increased, mean percent of bare ground decreased. Repeated measures analysis for the four years from 1997 to 2000 showed significant differences among years ($F_{(3, 1350)} = 678.4$, $p < 0.001$; Figure 4.5) and blocks ($F_{(2, 1350)} = 678.4$, $p < 0.001$). Again following differences in vegetation, bare ground also varied significantly among treatments ($F_{(8, 1350)} = 2.99$, $p < 0.002$). By 2000, treatment differences were consistent across the years so we saw no significant interaction between years and treatments, but did see a significant interaction between year and block. Percent bare ground ranged from 76.8% to 81.5% in all plots in 1997. By 1999, mean bare ground across all plots was 27%, with the highest percent of bare ground in the controls (33.2%). Following the prescribed burn in spring 2000,bare ground in all treatments increased, ranging from 37% in the native rolled plots to 52% in the native and watered plots (Figure 4.5).

Percent litter cover varied significantly among years ($F_{(3, 1350)} = 138.4$, $p < 0.001$) but not among treatments (Figure 4.6). Particularly because of different responses in litter cover between 1998 and 1999, we found a significant interaction between year and block ($F_{(15, 1350)} = 2.35$, $p < 0.003$).

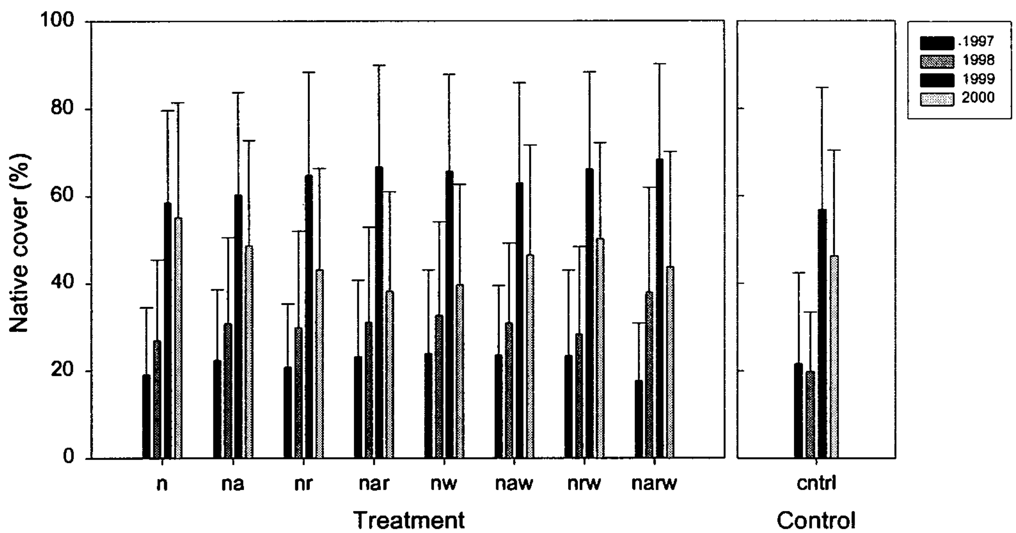

Figure 4.3. Mean (+ 1 SD) percent cover of native vegetation by treatment at ABRP in fall 1997, 1998, 1999, and 2000 (n = native seed mixture, a = annual cover crop, r = rolling, w = watering, cntrl = no treatment). N=6 for all treatments except n=3 for the no treatment plots.

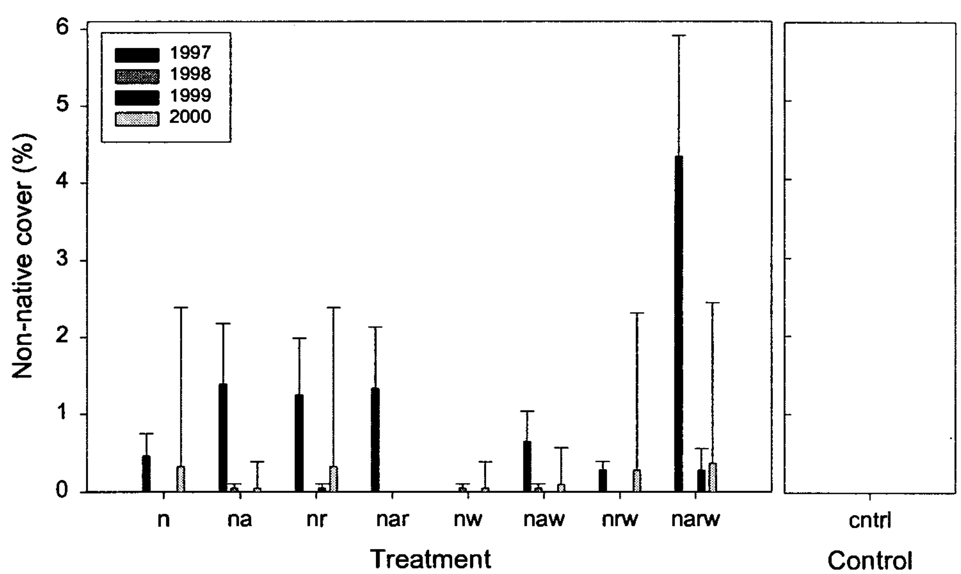

Figure 4.4. Mean (± 1 SD) percent cover for nonnative species by treatment at ABRP in fall 1997, 1998, and 1999 (n = native seed mixture, a = annual cover crop, r = rolling, w = watering, cntrl = no treatment). N = 6 for all treatments except n = 3 for the no treatment plots. Means accompanied by the same letter (above the bar) are not significantly different from one another.

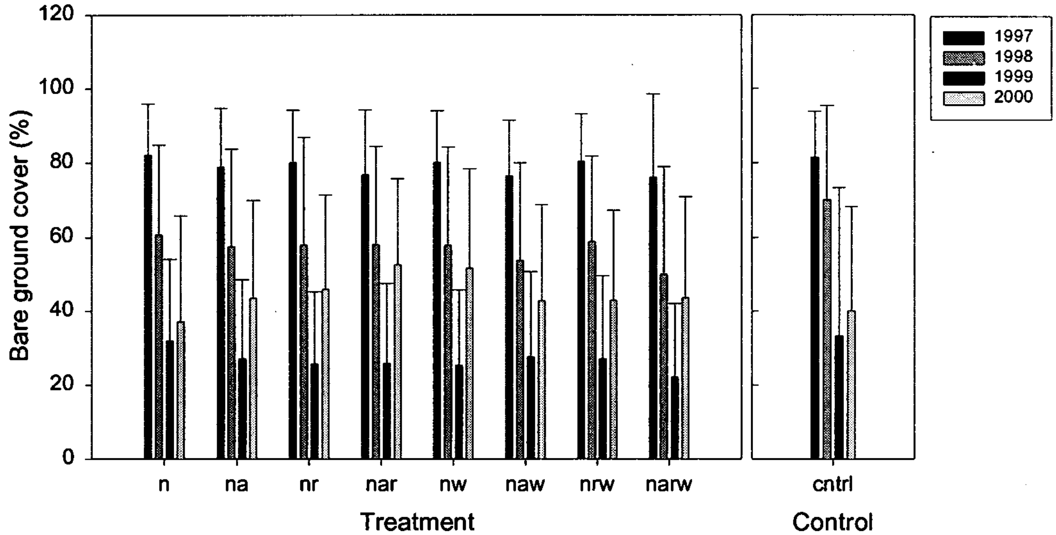

Figure 4.5. Mean (± 1 SE) percent cover of bare ground by treatment at ABRP in fall 1997, 1998, and 1999 (n = native seed mixture, a = annual cover crop, r = rolling, w = watering, cntrl = no treatment). N = 6 for all treatments except n = 3 for the no treatment plots.

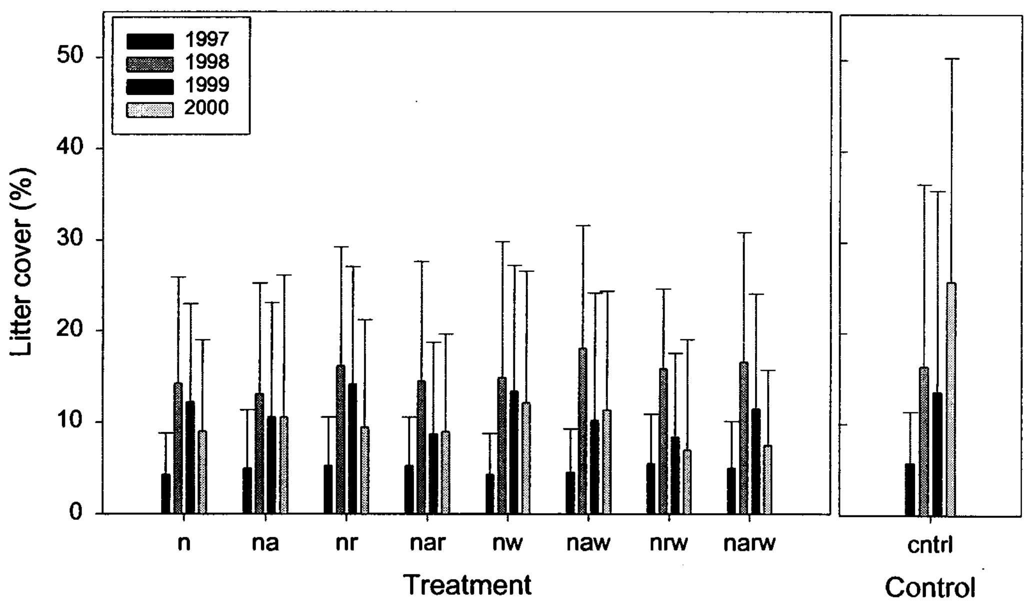

Figure 4.6. Mean (± 1 SD) percent cover of litter by treatment at ABRP in fall 1997, 1998, and 1999 (n = native seed mixture, a = annual cover crop, r = rolling, w = watering, cntrl = no treatment). N = 6 for all treatments except n = 3 for the no treatment plots.

Mean percent litter increased across all treatments and the untreated controls from 5% in 1997 to 15.5% in 1998, but decreased to 11.3% in 1999 and to 10.5 in 2000 following burning.

Interestingly, litter levels increased in the control plots between 1999 and 20000 despite the prescribed fires (Figure 4.6).

Prior to establishment of woody species, these experimental units should provide excellent seed collection sites for further restoration efforts. The progress of plants on this site has been encouraging for revegetation efforts. Wiregrass seed production was high this fall after the spring 2000 burn, and seed has been collected and sown in further restoration efforts.

Community Similarity

Species frequency was equally dissimilar across all six blocks with no block or restoration treatments effects. However, when the unsown control plots were included in the analysis (reducing n to 3), BC showed that the controls were significantly more similar to the reference plots than were any of the experimental plots ($F_{(2,16)} = 8.17$, $p < 0.001$; Figure 4.7). This analysis also showed a significant block effect ($F_{(8,16)} = 3.62$, $p < 0.05$). No significant differences were detected in by the PS index. As seen for Experiments A and B in BB 937 (above), species frequency was generally low in similarity to the reference condition (<0.34).

For all the treatments combined, 15 species were shown to contribute most to the patterns of similarity in sandhill at ABRP (Table 4.1). The similarity values for PS and 1-BC for these 15 species were calculated from 103 species that occurred in both the treatment and reference plots. The 103 species represent 84% (103/123) of the total number of species documented in the treatment plots in 2000. Correlation coefficients for two of the 15 species, wiregrass (*Aristida beyrichiana*) and thin bluestem (*Aristida purpurescens*) contributed significantly to both indices, indicating strong contributions to the sandhill patterns. In the species frequency analysis, wiregrass showed the highest correlation (PS=0.601; 1-BC= 0.729); all other species had similarity values less than 0.5 (Table 4.1). Seven of these species, three grasses, two herbs, one shrub, and one tree, were also listed as indicator species in Experiment A.

Cover analyses for the restoration and control plots showed higher similarity values than did frequency, ranging from 0.68 to 0.72 (Figure 4.7). This, too, is consistent with the results seen in Experiments A and B in BB 937 (above). As seen for species frequency, similarity in cover of the restoration plots without the unsown control plots (n=6) showed no significant treatment or block effects. However, when the unsown control plots were included in the analysis (n=3), the controls and the native watered and rolled plots (narw) were significantly more similar to the reference condition than were the other treatments using PS ($F_{(2,16)} = 4.34$, $p < 0.006$). This trend was similar but not signficant for the BC index.

In the cover analysis for all treatments combined, all cover variables except that for wiregrass contributed heavily to the BC similarity index, while only bare soil and litter contributed to PS (Table 4.2). The relative contributions to each index also varied. A negative correlation was shown for wiregrass by the PS index only. Wiregrass densities per 0.5 m^2 in the experimental plots were as high or higher than densities found in other sandhill habitats (Clewell 1989) including the reference plots, thus accounting for the negative correlation.

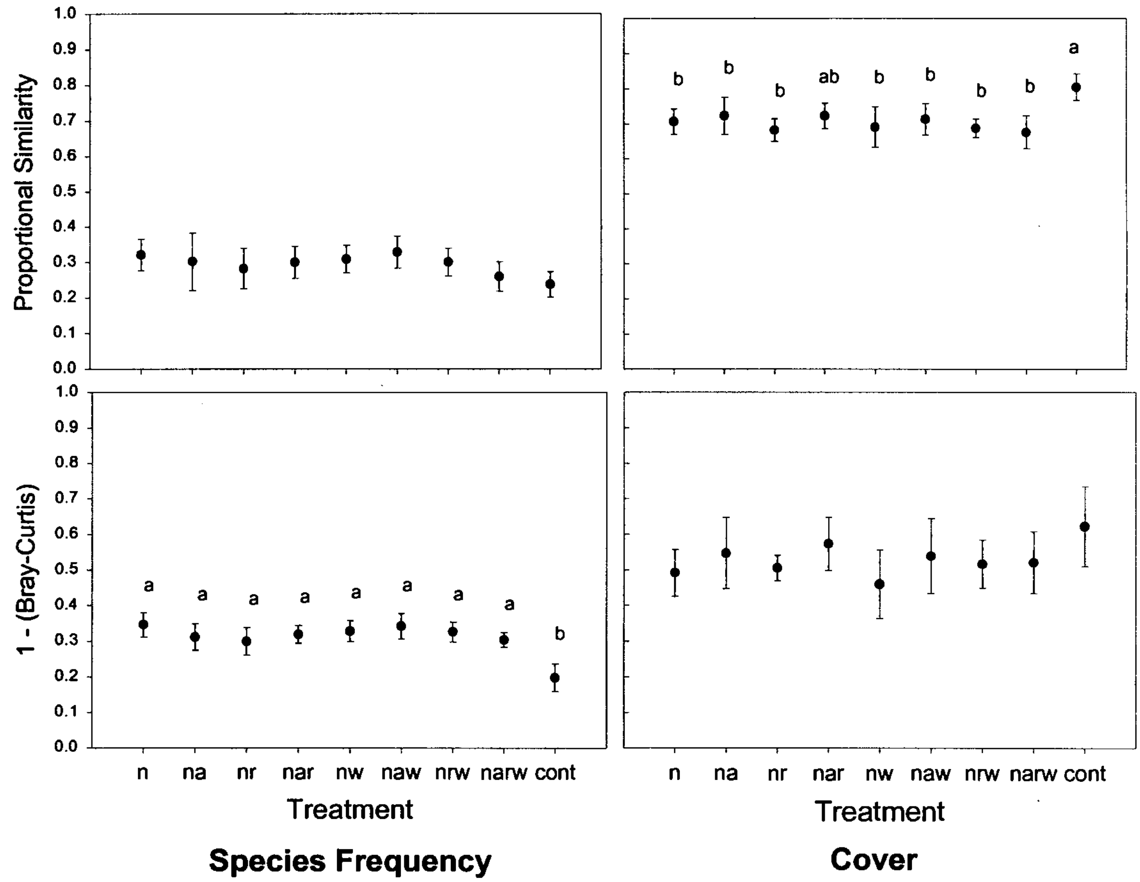

Figure 4.7. Comparisons of two indices (Proportional Similarity and 1 - Bray-Curtis) for measuring the similarity of herbaceous ground cover species frequency and cover. Index values approach 1.0 as restoration treatments (n = 6; n = native seed mixture, a = annual cover crop, r = rolling, w = watering; n = 3 for cntrl = unsown control) increase in similarity with the reference plots. Means accompanied by the same letters are not significantly different from one another.

Discussion

Three years after direct sowing of native seed onto disturbed sandhill soil we saw high percent cover of native species, negligible nonnative species cover, and decreasing bare ground. The unsown controls demonstrate that the primary species added through the direct seeding was wiregrass, despite the other seed included. However, the stands are species rich, and wiregrass was established in sufficiently high densities to carry fire (Figure 4.8). As response of restored wiregrass and other species to fire has not been investigated (Figure 4.9), the seed production and regrowth after the May 2000 prescribed fire should provide important information for the restoration process.

Table 4.1. Similarity and cover coefficients for frequency similarity measures. Correlation coefficients for PS = proportional similarity and BC = 1 - Bray-Curtis. Coefficients for species contributing disproportionately to similarity are bolded.

		Correlation coefficient	
Species	**life form**	**PS**	**BC**
Aristida beyrichiana	grass	**0.601**	**0.729**
Aristida purpurescens	grass	0.373	
Paspalum setaceum	grass	0.281	
Schizachyrium scoparium (green)	grass	0.296	
Schizachyrium tenerum	grass	0.333	0.308
Bulbostylis ciliatifolia	sedge	0.440	
Liatris chapmanii	herb	0.323	
Solidago odora	herb	0.433	
Stylosanthes biflora	herb	0.359	
Tragia urticifolia	herb	0.317	
Licania michauxii	shrub	0.291	
Vaccinium arboreum	shrub	0.278	
Quercus hemisphaerica	tree	0.329	
Quercus laevigata	tree	0.298	
Smilax auriculata	vine	0.457	

Table 4.2. Similarity and cover coefficients for frequency similarity measures. Correlation coefficients for PS = proportional similarity and BC = 1 - Bray-Curtis. Coefficients for species contributing disproportionately to similarity are bolded.

COVER (percent)	**Correlation coefficients**	
	PS	**BC**
Wiregrass	-0.378	
Native	0.493	**0.813**
Baresoil	**0.533**	**0.709**
Litter	**0.874**	**0.632**

The similarity analysis shows that the species present in these disturbed sites are not terribly similar to those in the high quality reference sites at ABRP, as all treatments show values below 0.5 for both indicies. The lack of wiregrass in the unsown control plots resulted in significantly lower similarity as indicated by the Bray-Curtis index. However, cover in these restoration sites is fairly similar to that in the reference plots, even without wiregrass. Clearly this revegetation effort has increased the similarity of the disturbed sandhills to higher quality sites, but has not yet restored the structure and composition of the vegetation.

Figure 4.8. Direct seeded plot three years after sowing in 1996. Plot received native seed only as the sowing treatment. Wiregrass clumps are seen in the foreground.

Figure 4.9. Direct seeded plot one week after a controlled burn in May 2000. Fire burned vegetation to mineral soil, but plants will resprout and colonize the area within several weeks.

Management Implications

The understory vegetation of disturbed sandhill sites that have been cleared can be revegetated using direct seeding methods with seed mix collected from nearby higher quality habitats. Wiregrass can clearly be successfully re-seeded, given appropriate soil conditions. The subsequent richness of the site will depend on both adjacent seed sources and whether the upper soil layer and resident seedbank remains present. Our research suggests that hayblowing sandhill seed mix is the most efficient method for direct seeding, particularly since seed cleaning methods have not been sufficiently successful to allow use of other mechanical sowing equipment (Gordon et al. 2000). Compressing the seed into the soil with one or more passes of a roller allows the seed more contact with the soil and promotes higher germination of wiregrass. However, care must be taken to avoid transport of nonnative propagules to the restoration site on equipment. Additionally, if nonnative species are already present, they can preclude establishment of the natives if not properly treated prior to sowing (see below).

Spring burning stimulates flowering in the fall for many sandhill plant species, especially wiregrass and other grass species. Burning may also improve the quantity and quality of seeds for better germination. Fall seed collected from habitats burned the previous spring may result in high species richness and increased percent cover of native vegetation.

BA 523 Experiment A2. Mechanical harvest and sowing of native seed at Disney Wilderness Preserve.

Introduction

As much of the area prioritized for restoration has not only been disturbed, like the above area, but has nonnative species present, we also addressed methods for revegetating this type of area with native understory species. This work was conducted in improved pastures at DWP, in areas that once were flatwoods rather than sandhills. We tested the site preparation treatments of single and multiple herbicide (3% glyphosate) application or disking or a combination of herbicide application and disking to remove the nonnative bahiagrass (*Paspalum notatum*) prior to sowing the native seed mix with or without an annual cover crop. All plots were rolled following sowing, and none was irrigated.

As described in greater detail in Gordon et al. (2000), we hypothesized that: (1) repeated treatments of either disking or herbicide or both would be necessary to virtually eliminate bahiagrass pasture; (2) sowing with an annual cover crop would benefit establishing native seedlings as expected in the sandhill experiment as well); (3) hydrology of the site would interact with the treatments to influence the success of the restoration effort and the species that establish; and (4) the numbers of nonnative species establishing in the restoration plots would be higher in the improved pasture site because of the more extensive disturbance, propagule availability, and activity in the site than in the silviculturally altered sandhill at ABRP.

After two years, we concluded that the bahiagrass was best removed with multiple treatments of herbicide or disking followed by herbiciding multiple times. Over the two years, the cover of bahiagrass continued to decrease and that of the natives to increase. Species richness was high, especially in the wetter pastures, where the native community was more successfully established. Like in the sandhills, our sowing primarily added wiregrass to an already rich system. However, differences in site hydrology influenced the results and the cover of other nonnative species. Within the current contract we added an additional year of data to evaluate longer-term results of the treatments. Much of this work was conduced by Krisann Kosel, Stewardship Project Coordinator at the Disney Wilderness Preserve.

Methods

This experiment has six blocks (pastures) in which a split-plot design was applied. The main plot is bahiagrass removal treatment: disking, herbiciding, disk and herbiciding, multiple disking, and multiple herbiciding. Each of these treatments was randomly applied to one 30 x 30 m (98 x 98 ft) plot in each block. The split is on addition of winter rye to half of each plot (15 x 30 m or 49 x 98 ft). However, because the annual rye split-plot treatment did not significantly influence species cover or richness in any year, plots with rye were excluded from the 1999 analysis presented. The methods for seed collection, plot size, sowing (all plots rolled), and response measurement are as described for ABRP above. Data were arcsin square root transformed to increase consistency with repeated measures analysis of variance model assumptions. A Bonferroni correction (making alpha = 0.007) for the cover data was used as several likely correlated variables were measured in the same plots.

Results

Cover

As in other years, we found that the bahiagrass removal treatment and pasture (block) ($p < 0.0001$ for all variables) significantly affected all measures of cover, and those relationships changed over time. Graphs of the 1997 and 1998 data are in Gordon et al. (2000). Significant differences among treatments in bahiagrass cover were the same in 1999 as in 1998. From lowest to highest bahiagrass cover were: multiple herbicide < multiple disk = disk and herbicide = single herbicide < single disk ($F_{(8)} = 16.7$, $p < 0.0001$; Figure 4.10 a). For other nonnative species, multiple disk, single disk, and multiple herbicide had significantly lower cover than did the other treatments ($F_{(8)} = 2.01$, p=0,04; Figure 4.10 b), a slight change from the 1998 data. Native species cover increased significantly from: single disk < single herbicide < disk herbicide = multiple disk < multiple herbicide ($F_{(8)} = 8.53$, $p < 0.0001$; Figure 4.10 c). The wettest pasture had the greatest native cover, composed of the least weedy native species ($F_{(10)} = 12.8$, $p < 0.0001$). As in previous years, an increasing proportion of the native species cover class was composed of species characteristic of pine flatwoods communities rather than weedy natives.

Percent cover of litter was lowest in the multiple herbicide plots, and lower in the single and disk plus herbicide plots than in the single disk plots. Multiple disk plots had equivalent cover of litter with all three of those latter treatments ($F_{(8)} = 67.2$, $p < 0.0001$; Figure 4.10 d). Finally, bare ground cover followed roughly the same pattern as seen for litter ($F_{(8)} = 13.9$, $p < 0.0001$; Figure 4.10 e).

Species richness

Mean species richness ranged from 30 to 45 species per 450 m^2 (4841 ft^2) in fall 1999. These numbers are lower than in 1998: mean richness per plot across all treatments was 37 species in 1997, 46 species in 1998, and 39 species in 1999 (Gordon et al. 2000). After the three years, species richness was significantly highest in the multiple herbicide treatment plots and lowest in the single disk ones ($F_{(40)} = 2.39$, $p = 0.0012$; Figure 4.11). As seen for the cover data on natives, richness increased with pasture moisture ($F_{(10)} = 11.09$, $p < 0.0001$).

Discussion

We concluded from the 1997 and 1998 data that the treatments most effective at reducing the bahiagrass and increasing the natives were multiple herbicide and disk and herbicide, while the single disk was least effective (Gordon et al. 2000). Adding a third year of data suggests that the multiple herbicide treatment was significantly more effective than the disk and herbicide treatment. The single disk treatment remains the least effective. These patterns exist for both cover and richness data.

Other conclusions from the first two years of data are not contradicted by this third year: despite no significant difference in initial cover of bahiagrass in the pasture blocks, we consistently see differences in response among the pastures. As a result, hydrological and perhaps other factors will influence the success of this type of restoration effort. Persistence and spread of other nonnative species once the bahiagrass was reduced could also potentially present a significant problem to establishing natives, depending on the starting condition of the sites to be restored. While the cover of those species seems to be decreasing over time, this effect will be dependent on initial conditions and availability of propagules from adjacent sites. Extensive site preparation efforts to reduce the nonnative component may be necessary.

Overall, however, the prognosis for pasture restoration of flatwoods appears good. These pasture sites, like the less disturbed sandhill sites described above, seem to have maintained a rich soil seedbank. More mesic sites may be easier to restore than xeric ones, but in all cases, direct seeding followed by rolling to increase seed contact with soil appears to allow germination of wiregrass and other species. For the others, perhaps simply removal of the bahiagrass allows release from the seedbank. Soil disturbance is not required, since high germination occurred in the multiple herbicide plots, where such effects were minimal compared to the disked plots. Understanding whether the mechanism for seedbank suppression is physical, or competition for light or water would require further research.

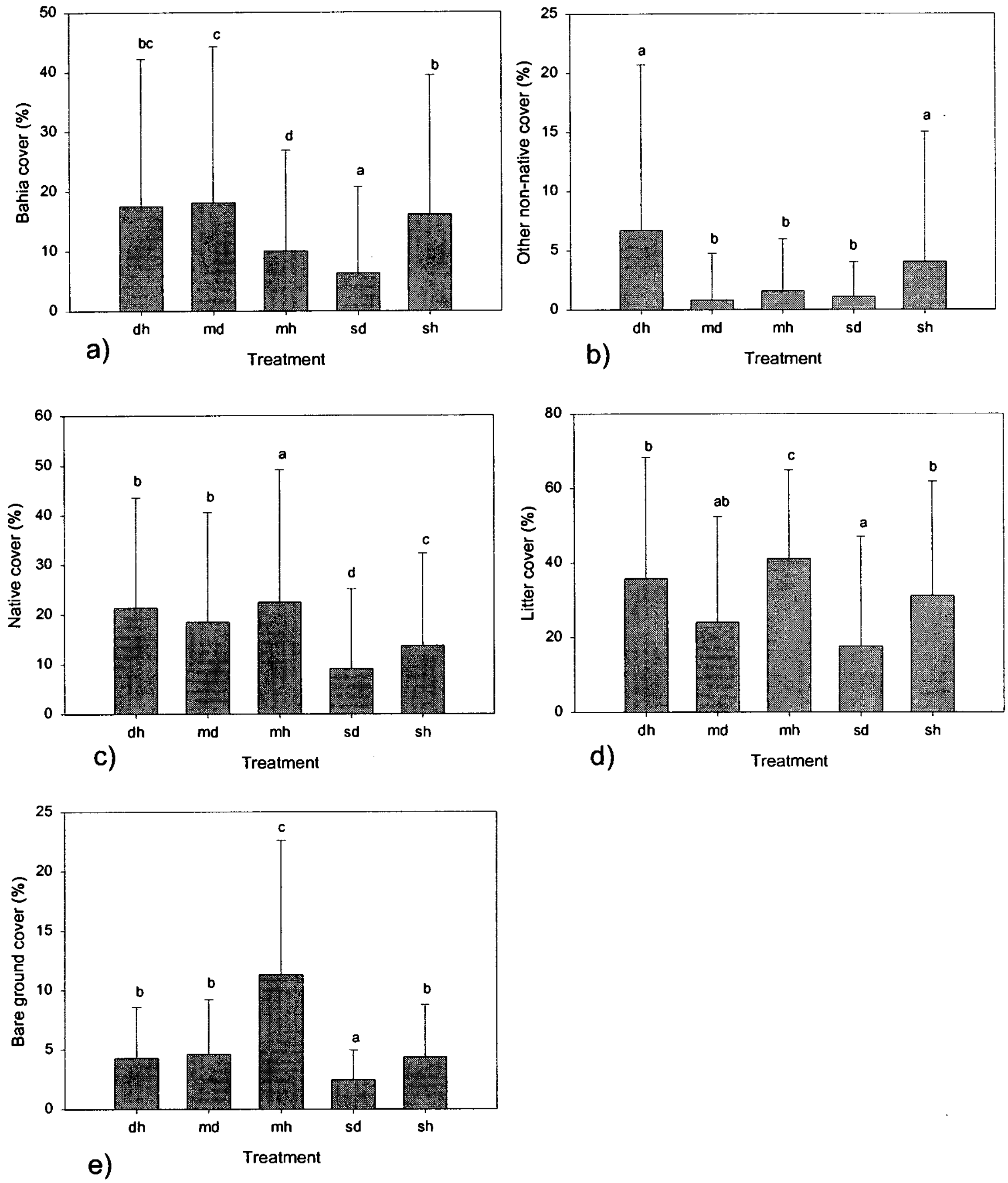

Figure 4.10. Fall 1999 mean (+ 1 SD) percent cover of (a) bahiagrass, (b) other nonnative, (c) native, (d) litter, and (e) bare ground by bahia removal treatment at DWP (n=6); dh = disk and herbicide, md = multiple disk, mh = multiple herbicide, sd = single disk, sh = single herbicide. Means accompanied by the same letter (above the bar) are not significantly different from one another.

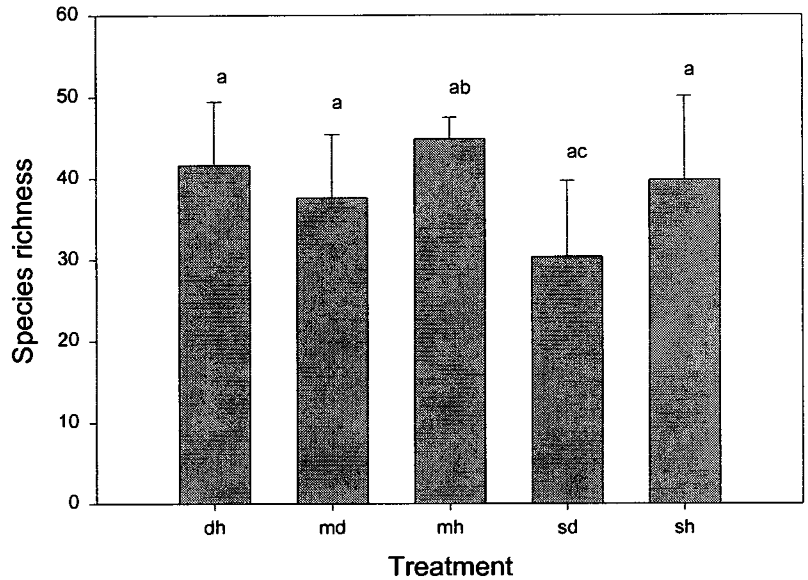

Figure 4.11. Mean (+ 1 SD) species richness / 450 m^2 (4841 ft^2) by treatment at DWP in 1999 (n=6); dh = disk and herbicide, md = multiple disk, mh = multiple herbicide, sd = single disk, sh = single herbicide. Means accompanied by the same letter are not significantly different from one another.

Management Implications

In a recent meeting on upland restoration held by The Nature Conservancy at DWP (DWP 2000), several messages consistent with these results were apparent. Initial conditions and site factors (hydrology, soils) will influence the amount of seed necessary and the success of the revegetation effort. Because of the benefit of effectively controlling bahiagrass and other nonnative and weedy native species, the group recommended that site preparation of improved pastures or heavily disturbed sites be conducted for at least a year prior to any planting. One approach that will be tested at DWP is to treat a 100 ac pasture twice with glyphosate herbicide and then disk monthly for a year. The only risk here is that this prolonged site preparation will diminish the native species in the seedbank as effectively as the nonnative seedbank is reduced. Another approach being used by Beth Wertchnig at CF Industries is to apply herbicide in March or April, disk starting about three weeks later as seedlings emerge and continuing on a monthly basis until October, use a turn-plow to bury any remaining seed, roll, and treat any emerging seedlings with glyphosate in November prior to sowing native seed (DWP 2000). Residual effects of the herbicide in suppressing native seedlings have not been investigated, though we have found that such effects are likely and will require some attention (Gordon et al. 2000a).

BA 523 Experiment B. Roadside sowing trials at the Disney Wilderness Preserve.

Introduction

Since the restoration experiments suggest that revegetation with native sandhill species is possible along rights-of-way beyond the clear zone, we are further testing the methods in a roadside situation. This work is similar to that conducted on the Blountstown Bridge (Experiment C above), though the soils and elevations have not been altered to the extent of that highly disturbed site. Instead, this test is along the access road to the new DWP Visitor Center. The road was constructed in 1998, with demonstration plots sown with either native flatwoods seed mix or native wildflowers in traffic islands. The demonstration plots included four islands (84 x 23 ft) and two bus pullouts (104 x 10 ft), all elliptically shaped.

While some of the native wildflowers did well (Figure 4.12) little vegetation established in most of these plots (Gordon et al. 2000). High winds immediately after sowing in 1998 were seen to remove most of the mulch and, presumably, the seed. Plots were re-monitored in June 1999, confirming the earlier results. This experiment was then discontinued. However, to understand whether or not flatwoods seed could be stored for a year and remain viable, one traffic island was re-seeded in December 2000 with pine flatwoods mix that had initially been collected and used in 1998. Amy Miller, Biological Scientist on FDOT contract BC-354, conducted much of this work.

Figure 4.12 Sown *Coreopsis leavenworthii* blooming in a bus pullout at the Disney Wilderness Preserve in June 1999.

Methods

We applied Plateau® herbicide in July 1999 to remove nonnative invaders. Glyphosate herbicide was applied in October prior to adding five inches of mulch. Spot treatment of any vegetation that survived that application occurred two weeks later. Because of concerns that glyphosate remaining on the site in organic matter would have pre-emergent effects on the native seed (J. Norcini, pers. comm., Gordon et al. 2000a), we mowed and then raked away the dead material.

Sowing occurred on December 9, 1999, on one of the islands near the Visitor Center. Mulch was removed, and the area was rolled to smooth and compact the soil before sowing. Seven pounds of flatwood mix were sown by hand as evenly as possible over the raked and rolled soil. The seed had been collected in November 1998, and stored in paper bags in an air-conditioned facility. A flat roller filled with water (weight about 150-lbs) was used to improve seed contact with the soil. Pine straw was spread approximately 0.75 in thick over the seed to prevent the seed from washing off (N. Bissett, pers. comm.). The plots were rolled again to compact the straw (Figure 4.13). To keep seed and pine straw in place, thin plastic netting was spread over the plot and stapled into the soil with 6" nursery cloth staples. The netting was removed when the pine straw settled into the soil.

Monitoring

We gathered three types of data: species richness; percent cover in five categories: wiregrass (*Aristida beyrichiana*), other native species, exotic species, bare ground or litter, and *Cyperus* spp.; and wiregrass density. The oval-shaped island was 22.9 and 6.4 m (75 and 21 ft) at its widest diameters, forming an area of 0.028 acres. A rectangle was placed within the oval that measured 19.2 x 3.0 m (63 x 10 ft) for the sampling. The rectangle was further divided lengthwise into five sampling sections each measuring 19.2 x 0.6 m (63 x 2 ft) so that a restricted randomized sampling design could be used for density.

Seedlings that could not be identified to species were labeled by genus. The species found were separated into native and exotic categories. Percent cover was estimated for each of the five cover categories using the point intercept method. Along each of the 19.2 m sides of the five sections, a point was dropped every 20 cm (5.5 inches) and one of the categories was recorded. *Cyperus* spp. was measured separately because it was the dominant species in the island and we could not determine whether it was native or exotic because most of it was immature. Wiregrass density was determined within belt transects measuring 19.2 x 0.20 m (63 x 0.6 ft). The transects were randomly located within each of the five sections of the rectangle.

Results

Of the 29 species recorded in the plot, six (21%) were nonnative (Appendix E). Although the other 23 species were natives, several of those are considered to be early colonizers. Many of these species should decrease as the native flatwood grasses become more established. Desirable plant species included in the plot are wiregrass, golden aster, tickseed, toothache grass, and love grass.

Percent cover of the island was dominated by bare soil and litter (Figure 4.14). Cover of wiregrass, other natives, and nonnatives were not different, averaging at or below 10% each. The *Cyperus* spp. averaged double that cover, while the nonvegetated cover was over 50%. Wiregrass density averaged 52.8 seedlings per 3.84 m^2 (41 ft^2), or 13.7 per m^2.

Figure 4.13. Seed mix rolled in with pine straw in road island at the Disney Wilderness Preserve.

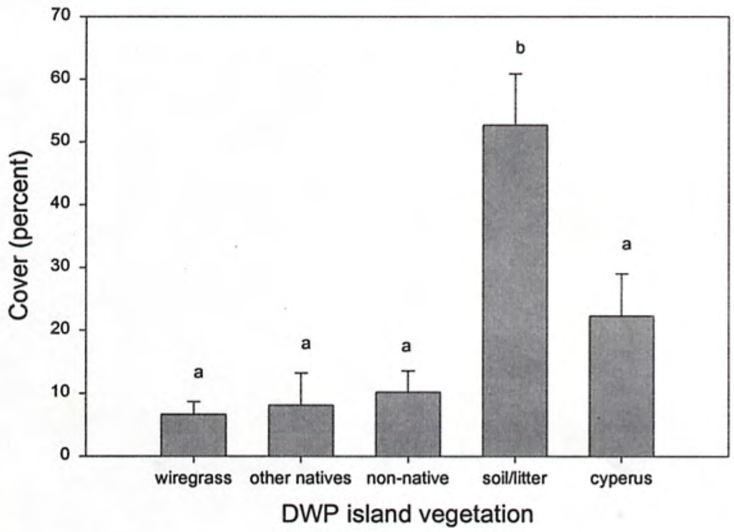

Figure 4.14. Percent cover (mean ± 1 SD) of the five vegetation categories on the traffic island at the Disney Wilderness Preserve following sowing with two year old native seed mix.

Discussion

While the island had low vegetation cover using the two year old flatwoods mix, we did learn that wiregrass and other native seed can be stored for at least two years and maintain some seed germinability. This result had been suggested by earlier work (Seamon 1998) but had not been explicitly tested in the field. As the planting area is surrounded by bahiagrass pasture, the wiregrass seed could not have naturally dispersed into the island. If any seed remained from the experiment in the previous year, it would also be two years old. The same is true for most of the natives seen, though seeds of *Cyperus* spp. and others may have been present in the roadside soil. As the other islands were mulched, we cannot extrapolate which species would have been present without our sowing efforts. However, higher density of germinable seed would have been necessary to attain the levels of cover seen in the sandhill or flatwoods plots discussed above. While these results are more favorable than those from the Blountstown Bridge (Experiment C), further investigation is necessary to clarify the seed and soil conditions most likely to permit denser establishment of native species.

Management Implications

These results suggest that storing seed of wiregrass and potentially other native species for more than one year can yield viable seed. As a result, seedling establishment might accrue over time for some of these species, as seeds not germinating in the year of sowing may germinate over time before the establishing plants produce seed (e.g., Seamon 1998). Because sources of native seed are limited and because seed production in some years is precluded if drought conditions result in prohibition of prescribed fires, successful seed storage is critical. However, further work is necessary to document how long seed storage is possible and any correlated decreases in viability with duration of storage.

OBJECTIVE 5: Refine recommendations for the use and management of native plants along roadsides.

While the majority of recommendations for revegetation and management of native plant species presented in our first report (Gordon et al. 2000) still appear valid, we have some modifications and some new recommendations as a result of this project. These recommendations may be further modified in the final report, as additional data will be available.

Modifications to conclusions in Gordon et al. (2000)

- While we continue to refine the methods for successfully revegetating with native sandhill understory species, our two roadside trials were somewhat discouraging. On the Blountstown Bridge site we had two primary difficulties that may not be uncommon on FDOT rights-of-way. First, the soil present, though intended to be from stockpiled topsoil, is clearly sub-surface substrate that formed a concrete-like surface. Re-surfacing with native surface soils without construction debris will be important for establishment of native species. Soil type, texture, and nutrient availability significantly influence the vegetation that can be supported. The small amount of native soil that we added to one plot, intended only to provide some mycorrhizal inoculation, was insufficient to ameliorate the poor soil conditions. Further, sub-surface soil will not contain the seedbanks of many native species that would otherwise be present to facilitate the revegetation process. Secondly, the area was sown with bahiagrass and an annual cover crop despite our prior arrangements to avoid having to both remove nonnative species and revegetate with natives. The growing conditions were not optimal for these species either, as evidenced by low cover of these nonnatives, but they did provide a source of contamination with nonnatives that was clear in our pilot plots. Under these conditions, which may prevail on FDOT sites, native species were unable to establish. Seed availability and soil quality on rights-of-way may be the largest impediments to revegetation with natives.

Additionally, on our first trial of establishing native flatwood seed mix in the bus pullouts along the DWP Visitor Center road, we apparently lost much of the seed sown immediately because of high winds. Roadsides often are windy areas, both because they are corridors and because the vehicles generate wind. As a result, in potentially windy areas we recommend an approach like the one taken in this contract: adding a thin layer of pine straw (without nonnative contaminants like the *Lygodium japonicum* we found) above the seed, and securing the straw with plastic netting until it has settled.

- Whereas we had concluded after two years that the most effective methods for removing bahiagrass and replacing the native longleaf pine system species were disking followed by multiple applications of glyphosate herbicide or multiple applications of glyphosate alone, the third year of data suggests that the second approach is significantly more effective. Further, results from this project and others indicated that removal of the nonnative bahiagrass should be initiated and continued for at least a year prior to sowing native species seed. While this approach may not be possible on most roadsides, where erosion and aesthetic concerns would preclude lengthy exposure of bare soil, it may be feasible on mitigation or other FDOT projects.

- While we had been concerned that cover of bare ground remained high in the sandhill restoration plots at ABRP (50-61%) after two years, cover of native vegetation had significantly increased by year three. Percent cover of bare ground was reduced across all treatments to about 30%, at the high end of the natural range of bare ground cover in undisturbed sandhills at ABRP. While the timing and trajectory of cover development appears satisfactory for restoration purposes, FDOT may require more rapid and extensive vegetation cover development on many rights-of-way.

- The frequency with which native vegetation requires mowing beyond the clear zone is less than once every three years in north Florida. This mowing frequency will maintain the height of woody species below two feet, providing clear visibility for drivers while substantially reducing mowing or herbicide application costs. Further no mowing is necessary during most of the winter months, even in the clear zone. Bahiagrass returned to relatively the same height of well below six inches every winter despite substantially different weather years during each of the four years of this study.

New recommendations

- Comparison of equipment used for sowing seed revealed that the fertilizer spreader was the most difficult to use but resulted in the highest density of wiregrass established. The advantage of the spreader was not evident for the other variables of cover and species richness. While we would still recommend the hayblower as the easiest and most efficient for sowing, we suggest further investigation to refine methods to incorporate some of the advantages of the fertilizer spreader.

Figure 5.1. Lightly chopped sandhill plot in October 1999, nine months after sowing.

- Where substantial native vegetation remains on the site, using fire as the site preparation treatment is advantageous if irrigation is possible. Species richness increases somewhat with chopping, but both fire and chopping stimulate re-sprouting of native species so that cover recovers equivalently. Colonization by seed is clearly enhanced by the irrigation; if irrigation is not possible, light roller chopping prior to sowing seed allows more seedling establishment than does fire alone (Figure 5.1).

- Although we found that mowing was more effective in controlling regrowth of woody vegetation than was burning, we caution that this result is only after one year of study. If burning were conducted at fairly high frequency – every one to two years (analogous to the "clean-up" mowing sometimes conducted annually outside the clear zone) – these results would likely change. We encourage FDOT to continue to allow rights-of-way to be used as firelines in specified natural areas and to continue to examine whether fire might be a possible replacement for mowing in additional areas.

- We found that storage of native understory seed for two years is possible. We had wiregrass and potentially other seed germinate along the road after such storage. While the effects of storage on geminability require further research, we suggest that if donor sites are available and have been managed such that seeds are produced (e.g., growing season fire for stimulation of wiregrass seed production), seed should be collected and stored if necessary. Availability of native seed continues to lag behind demand at this point.

- Little bluestem (*Schizachyrium scoparium*) appears to be a useful species for native revegetation efforts. We recommend that FDOT continue exploration of this species as one that might form fairly continuous cover. We will better understand whether seed or plugs will be more successful for propagation after data collection this fall. Like wiregrass, this species appears sensitive to early spring precipitation levels. However, the 2000 drought confounds our ability to assess growth of this species in a "normal" year.

Technology transfer

Presentations

"Roadside Management of Native Plants" was presented by Doria Gordon at the FDOT Environmental Management Workshop in Tallahassee, FL. October 1998.

Upland restoration results funded by FDOT were presented by Doria Gordon at the annual meeting of the Southeastern Coastal Plain Chapter of the Society for Ecological Restoration in Lakeland, FL. February 1999.

Sandhill restoration results funded by FDOT were presented by Anne Cox at the Nineteenth Annual Conference of the Florida Native Plant Society in St. Augustine, FL. May 8, 1999.

"How invasive is bahiagrass?" was presented by Doria Gordon at the annual meeting of the Florida Exotic Pest Plant Council in Palm Beach, FL. May 25, 1999.

"Groundcover research: Sandhill research for roadside plots" was presented by Anne Cox at Florida Natural Areas Inventory. Tallahassee, FL. October 1999.

"Development of direct seeding techniques to restore native groundcover in a sandhill ecosystem" was presented by Greg Seamon at the Second Annual Eastern Native Grass Symposium in Baltimore, MD. November 1999.

Doria Gordon participated in a presentation and discussion of the slide presentation on "Landscape design, construction, and maintenance of native plant species on rights-of-way" to FDOT landscape architects.

"Groundcover species richness in sandhill restoration in northwest Florida" was presented by Anne Cox at the Twentieth Annual Conference of the Florida Native Plant Society in Miami, FL. May 2000.

Greg Seamon and Krisann Kosel presented results from this work at the Upland Restoration Workshop held at the Disney Wilderness Preserve by The Nature Conservancy, Kissimmee, FL. May 2000 (see DWP 2000 in the literature cited section).

"Native species for use along rights-of-way" will be presented by Doria Gordon at the FDOT 2000 Environmental Management Workshop in St. Petersberg, FL. September 2000.

Tours

Listed below are the tours and the dates with the names of participants and numbers in parentheses and type of tour presented.

From September 25, 1998 to August June 26. FDOT personnel Shirley Shiver (Permitting Field Inspector), Ralph Carter (District Vegetation Specialist), and Preston Toole (District Permits Engineer). Summer 1999. (3).

Ann Blount, Ph.D. (IFAS Forage Breeder), Anne Barkdoll, Ph.D. (Environmental Consultant), and Harriet Soffes, (TNC Member). Summer 1999. (3).

Walter Kingsley Taylor, Ph.D. (UCF Professor and Author), Karen Taylor, Angus Gholson (Botanist). Summer 1999. (3).

ABRP Northwest Florida Program hosted a Groundcover Restoration Field Trip for agencies and partners. The field trip included demonstrations of various techniques and methodologies used for groundcover restoration and site inspections of the two FDOT research projects. Visitors represented the Florida Department of Transportation, Florida Division of Forestry, Florida Fish and Wildlife Conservation Commission, Joseph W. Jones Ecological Center, Tall Timbers Research Station, University of Florida, US Forest Service, US Fish and Wildlife Service, and private individuals. January 25, 2000, (85).

Anne Cox presented a summary of the FDOT projects for Craig Hedman and Fred Haynes from International Paper Company, and John Cox and Cody Laird from TNC Georgia Chapter. Jon Blanchard, Northwest Florida Program Director for TNC, accompanied by Rick Studenmund, gave a tour of the ABRP research plots. May 11, 2000. (4)

May 21, 2000 - Anne Cox and Greg Seamon gave a field tour of the FDOT research plots for Annie Blount of the IFAS Forage Breeding and Management Unit and Roger Gates, Research Agronomist, USDA-ARS, Crop Genetics & Breeding Research Unit, Coastal Plain Experiment Station, Tifton FL. (2)

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Appendix A. Plant species frequency in Experiment A and B plots in October 1999.

- 1 indicates rooted stem(s) of one or more plants of the species in a plot.
- **%** = Percent of plots with species present across all the treatments.
- Treatment codes are as follows: **ccu** = chop, cultipack; **cfe** = chop, fertilizer spreader; **cha** = chop, hayblower; **chy** = chop, hydroseeder; **fhai** = fire, hayblower, irrigate; **fcu** = fire, cultipack; **ffe** = fire, fertilizer spreader; **fha** = fire, hayblower; **fhac** = fire, hayblower, chop; **fhy** = fire, hydroseeder; **cno**= chop, no seed; **fno** = fire, no seed; **nno** = no fire, chop, or seed.

NOTE: all treatments have six replicates except the chop, no seed (cno), which had three replicates because of space limitations for plot location.

SPECIES		ccu	cfe	cha	chy	cno	fcu	ffe	fha	fhac	fhai	fhy	fno	natv	All %
Andropogon gyrans	grass	50	33	33	17	0	17	17	0	0	17	33	0	0	16.7
Andropogon sp.	grass	67	33	33	50	33	50	67	33	67	50	67	33	67	50.0
Andropogon sp. 1 (very hairy)	grass	83	100	100	100	100	100	100	100	83	100	100	100	83	96.2
Andropogon ternarius	grass	67	100	67	67	67	83	67	67	83	67	50	83	67	71.8
Andropogon virginicus	grass	33	50	33	50	33	33	67	33	33	50	33	50	100	46.2
Andropogon virginicus var. *glauca*	grass	67	50	67	67	100	67	50	50	33	33	83	100	33	61.5
Aristida beyrichiana	grass	83	100	67	67	0	17	100	50	100	100	33	17	17	57.7
Aristida purpurescens	grass	67	67	67	50	67	83	67	50	50	50	50	100	83	65.4
Dichanthelium aciculare	grass	100	100	100	100	100	100	100	100	100	100	100	100	100	100.0
Dichanthelium sp. 1	grass	67	67	83	67	67	33	33	17	67	50	50	67	33	53.8
Dichanthelium sp. 2	grass	67	100	83	83	100	83	67	83	67	100	83	67	100	83.3
Digitaria ciliaris	grass	33	0	17	17	33	0	0	0	0	0	0	0	0	7.7
Eragrostis spectabilis	grass	0	0	0	0	0	0	0	0	0	17	0	0	0	1.3
Eremochloa ophiuroides	grass	0	17	0	0	0	0	0	0	0	0	0	0	0	1.3
Leptoloma cognatum	grass	0	33	0	17	33	0	33	0	17	0	0	17	83	17.9
Paspalum notatum	grass	0	0	17	17	0	0	0	0	0	0	0	0	0	2.6
Paspalum setaceum	grass	100	83	100	100	100	83	100	83	83	83	100	100	100	93.6
Paspalum sp.	grass	33	0	0	0	0	17	0	0	17	0	0	0	0	5.1
Schizachyrium hirtiflorum	grass	17	33	17	33	67	33	17	17	50	33	17	50	33	32.1
Schizachyrium scoparium 1	grass	83	50	50	50	33	50	50	67	83	67	50	17	33	52.6
Schizachyrium scoparium 2	grass	100	100	100	100	100	100	100	100	83	100	83	100	100	97.4
Schizachyrium tenerum	grass	83	100	50	67	33	83	83	100	33	67	67	100	50	70.5

SPECIES		ccu	cfe	cha	chy	cno	fcu	ffe	fha	fhac	fhai	fhy	fno	natv	%
Schizachyrium tenerum	grass	83	100	50	67	33	83	83	100	33	67	67	100	50	70.5
Sorghastrum secundum	grass	0	0	0	0	0	0	0	0	0	0	0	17	0	1.3
Triplasis americana	grass	33	67	17	33	33	0	0	17	17	50	0	17	67	26.9
Acalypha gracilens	herb	0	0	17	17	0	0	0	0	0	17	0	0	0	3.8
Aeschynomene viscidula	herb	0	0	0	17	0	0	0	0	0	0	0	0	0	1.3
Agalinis sp.	herb	0	0	0	0	0	0	0	0	0	17	0	0	0	1.3
Ambrosia artemisiifolia	herb	17	0	17	0	0	0	0	0	0	17	0	0	0	3.8
Asclepias sp.	herb	0	0	0	0	0	0	0	0	0	0	0	0	17	1.3
Balduina angustifolia	herb	50	100	100	50	33	50	83	83	83	100	50	100	67	73.1
Calamintha dentata	herb	100	100	100	100	100	100	100	100	100	100	100	100	100	100.0
Centrosema virginiana	herb	17	0	0	0	33	0	0	0	0	0	0	17	0	5.1
Chamaecrista fasiculata	herb	100	83	83	100	100	100	100	83	83	83	83	50	83	87.2
Chaptalia tomentosa	herb	0	0	0	0	0	0	0	0	0	0	0	17	0	1.3
Chenopodium sp.	herb	0	0	0	0	33	0	0	0	0	0	0	0	0	2.6
Chrysopsis gossypina	herb	0	0	0	0	0	0	0	0	0	17	17	17	0	3.8
Cnidoscolus stimulosus	herb	0	0	33	0	0	17	17	0	17	17	0	0	17	9.0
Commelina erecta	herb	100	100	100	100	100	100	100	100	100	100	100	100	100	100.0
Composite 2	herb	17	0	0	0	0	0	0	0	17	33	0	0	0	5.1
Conclinum coelestinum	herb	50	33	33	0	33	33	0	0	0	83	0	0	17	21.8
Conyza canadensis	herb	0	0	0	0	0	0	17	0	50	17	0	0	0	6.4
Crotalaria rotundifolia	herb	67	50	33	33	67	33	17	17	17	83	0	17	50	37.2
Croton argyranthemus	herb	100	100	100	100	100	100	100	100	100	100	100	100	100	100.0
Dalea pinnata	herb	100	83	100	83	100	100	100	100	100	83	100	100	83	94.9
Diodia teres	herb	100	67	83	83	67	17	17	50	33	67	67	17	33	53.8
Erechtites hieracifolia	herb	0	0	0	0	33	0	0	0	17	0	0	0	0	3.8
Erigeron sp.	herb	33	17	33	33	0	0	0	0	0	0	0	0	17	10.3
Erigeron strigosus	herb	17	0	0	0	0	0	0	0	0	0	0	0	0	1.3
Eriogonum tomentosum	herb	67	33	33	17	0	17	17	50	67	50	33	50	0	33.3
Eupatorium capillifolium	herb	17	0	0	0	0	17	0	17	0	0	17	0	17	6.4
Eupatorium compositifolium	herb	100	100	100	100	100	100	100	100	100	100	100	100	67	97.4
Eupatorium linearifolium	herb	17	0	17	33	0	17	17	0	0	17	0	17	0	10.3
Eupatorium mohrii	herb	17	0	17	0	0	0	0	0	0	0	0	17	0	3.8
Euphorbia exserta	herb	67	67	100	67	67	50	67	83	83	67	100	100	50	74.4
Euphorbia floridana	herb	83	100	67	83	0	100	100	83	67	83	100	67	100	79.5
Euthamia minor	herb	0	0	17	0	0	17	0	0	0	17	17	0	0	5.1
Froelichia floridana	herb	0	0	17	17	0	17	0	0	0	33	0	0	0	6.4

SPECIES		ccu	cfe	cha	chy	cno	fcu	ffe	fha	fhac	fhai	fhy	fno	natv	%
Galactia sp.	herb	33	0	33	67	0	50	17	50	33	33	33	33	33	32.1
Galactia volubilis	herb	83	67	83	100	67	67	50	83	83	67	100	50	33	71.8
Gaura angustifolia	herb	17	0	0	0	0	0	0	0	0	0	0	0	0	1.3
Gnapthalium falcatum	herb	0	50	17	17	67	0	0	0	0	67	0	0	33	19.2
Hediotis procumbens	herb	0	17	17	0	0	0	17	17	17	0	0	0	0	6.4
Hieracium gronovii	herb	33	0	33	0	33	0	0	0	17	17	0	0	33	12.8
Hypericum gentianoides	herb	100	100	100	100	100	100	100	100	100	100	100	100	83	98.7
Hypericum hypericoides	herb	50	17	50	33	0	17	33	33	17	0	67	33	50	30.8
Lechea minor	herb	100	83	83	67	33	67	50	67	0	33	67	83	83	62.8
Lespedeza hirta	herb	0	0	0	0	33	17	17	0	17	17	33	17	50	15.4
Lespedeza repens	herb	67	17	17	33	33	17	0	33	67	33	50	33	17	32.1
Liatris chapmanii	herb	67	50	50	50	0	0	33	0	33	17	0	17	0	24.4
Liatris garberi	herb	17	17	17	0	0	0	0	0	0	0	0	33	0	6.4
Liatris gracilis	herb	50	83	50	33	33	0	33	17	33	50	17	33	0	33.3
Liatris laevigata	herb	0	33	0	0	0	0	17	0	17	0	0	0	0	5.1
Liatris tenuifolia	herb	100	83	83	100	67	67	67	83	50	67	67	50	17	69.2
Opuntia humifusa	herb	50	100	83	67	100	67	100	83	100	100	100	100	67	85.9
Paronychia patula	herb	100	100	100	100	100	100	83	100	100	100	83	100	83	96.2
Phoebanthus tenuifolia	herb	0	0	0	0	0	0	0	17	0	0	0	0	0	1.3
Physalis sp.	herb	0	0	17	0	0	0	0	0	0	0	0	0	0	1.3
Physalis viscosa	herb	17	0	0	0	33	0	0	0	0	0	0	0	0	3.8
Phytolacca americana	herb	0	0	0	0	0	0	0	0	17	0	0	0	0	1.3
Pityopsis graminifolia	herb	17	17	0	17	33	0	17	0	33	0	17	0	0	11.5
Polanisia tenuifolia	herb	33	67	50	50	33	33	50	17	50	50	50	50	33	43.6
Polygonella gracilis	herb	100	100	100	100	100	100	100	100	100	100	100	100	100	100.0
Polypremum procumbens	herb	0	0	0	0	0	0	0	17	0	17	0	0	0	2.6
Rhynchosia cytisoides	herb	100	100	100	100	100	100	100	100	83	100	100	100	100	98.7
Rhynchosia reneformis	herb	100	50	67	67	100	0	17	83	17	33	33	17	67	50.0
Richardia scabra	herb	0	0	0	0	0	0	0	0	17	0	0	0	0	1.3
Ruellia caroliniensis	herb	50	17	0	0	0	17	0	0	0	0	17	17	0	9.0
Schrankia microphylla	herb	0	0	17	0	0	0	0	0	0	0	0	0	0	1.3
Seymeria pectinata	herb	17	17	50	17	33	17	50	67	0	50	33	17	17	29.5
Solanum carolinense	herb	0	0	0	0	33	0	0	0	0	0	0	0	0	2.6
Solidago odora	herb	100	100	100	100	100	83	100	83	100	83	100	100	83	94.9
Solidago sp.	herb	0	17	0	0	0	0	0	0	0	0	0	0	0	1.3
Stipulicida setacea	herb	17	83	50	0	33	50	33	50	33	83	100	67	33	48.7

SPECIES		ccu	cfe	cha	chy	cno	fcu	ffe	fha	fhac	fhai	fhy	fno	natv	%
Stylisma patens	herb	83	67	83	50	33	50	67	67	67	50	83	50	50	61.5
Stylosanthes biflora	herb	100	83	100	100	67	67	67	83	67	83	67	83	67	79.5
Tephrosia chrysophylla	herb	67	33	50	33	67	83	50	50	33	33	67	67	17	50.0
Tephrosia florida	herb	0	17	0	17	33	0	0	0	0	17	0	0	0	6.4
Tephrosia sp.	herb	0	17	17	0	33	0	0	0	0	0	0	17	0	6.4
Toxicodendron radicans	herb	67	100	83	67	100	33	33	17	33	83	50	17	67	57.7
Tradescantia sp.	herb	33	0	0	0	0	0	0	0	0	17	0	0	0	3.8
Tragia urens	herb	83	83	67	83	100	83	67	67	33	67	83	83	100	76.9
Tragia urticifolia	herb	50	17	33	17	0	0	0	17	50	50	0	17	0	19.2
Trichostema setaceum	herb	83	83	100	83	100	67	100	83	100	100	100	83	83	89.7
Unknown herb 1	herb	17	0	17	0	0	0	0	0	0	0	0	0	0	2.6
Unknown herb 6	herb	0	0	17	0	0	17	0	0	0	0	0	0	0	2.6
Unknown herb 8	herb	0	0	0	0	0	0	0	0	0	0	0	17	0	1.3
Unknown herb 9	herb	0	0	17	0	0	0	0	0	0	17	0	0	0	2.6
unknown herb 10	herb	0	0	0	0	0	0	0	0	0	0	0	0	17	1.3
Vernonia angustifolia	herb	0	0	0	17	0	0	0	0	0	0	0	0	0	1.3
Wahlenbergia marginata	herb	0	0	0	0	0	0	0	0	0	33	0	0	0	2.6
Warea cuneifolia	herb	17	0	17	17	33	0	0	0	17	0	17	17	33	12.8
Warea sessilifolia	herb	0	17	0	0	0	0	0	0	0	0	0	0	0	1.3
Bulbostylis ciliatifolia	sedge	83	100	100	100	100	100	100	100	83	100	83	100	100	96.2
Bulbostylis ciliatifolia var. *coarctata*	sedge	17	0	0	0	0	33	17	17	0	33	0	0	33	11.5
Carex tenax	sedge	33	33	33	67	67	17	17	67	17	50	17	50	33	38.5
Cyperus filiculmis	sedge	67	33	0	17	33	33	33	17	33	17	33	17	50	29.5
Cyperus globulosus	sedge	100	67	50	83	67	50	83	83	17	83	67	83	83	70.5
Cyperus retrofractus	sedge	17	0	0	0	33	0	0	0	0	17	0	17	17	7.7
Cyperus retrorsus	sedge	100	50	83	83	100	100	33	50	33	67	67	50	83	69.2
Cyperus sp.	sedge	17	0	0	17	0	17	0	0	0	17	0	0	0	5.1
Rhynchospora grayi	sedge	0	50	17	50	33	67	67	100	33	100	50	83	67	55.1
Bumelia lanuginosa	shrub	0	0	17	0	0	0	0	0	0	0	0	0	0	1.3
Callicarpa americana	shrub	33	33	33	67	67	50	50	50	67	67	83	50	100	57.7
Campsis radicans	shrub	0	0	0	0	0	0	0	0	0	0	0	17	0	1.3
Ilex vomitoria	shrub	0	0	0	0	67	17	0	0	0	0	0	0	0	6.4
Licania michauxii	shrub	33	33	50	33	67	0	17	17	33	50	17	50	0	30.8
Rhus copallina	shrub	67	67	83	33	67	33	50	33	50	83	33	0	100	53.8
Rubus cuneifolius	shrub	100	100	100	100	100	100	100	100	100	100	100	100	100	100.0
Vaccinium arboreum	shrub	100	67	83	50	67	83	83	67	83	83	83	67	83	76.9

SPECIES		ccu	cfe	cha	chy	cno	fcu	ffe	fha	fhac	fhai	fhy	fno	natv	%
Vaccinium corymbosum	shrub	0	0	17	17	0	17	17	17	33	17	50	0	17	15.4
Vaccinium darrowii	shrub	17	0	0	0	0	0	0	0	0	0	0	0	0	1.3
Vaccinium myrsinites	shrub	17	0	0	0	0	0	0	17	0	17	0	0	0	3.8
Vaccinium stamineum	shrub	50	50	83	67	100	83	67	83	50	100	67	83	83	74.4
Yucca flaccida	shrub	17	33	33	50	67	50	33	33	50	67	33	17	17	38.5
Carya sp.	tree	0	0	0	0	0	0	0	0	0	0	0	0	17	1.3
Carya tomentosa	tree	0	0	17	0	0	0	0	0	0	0	0	17	0	2.6
Crategus sp.	tree	0	0	0	0	33	17	0	0	0	0	0	17	17	6.4
Diospyros virginiana	tree	50	67	33	33	67	50	100	33	33	17	50	50	67	50.0
Liquidambar styraciflua	tree	17	17	17	0	0	0	17	0	0	33	17	17	17	11.5
Osmanthus americanus	tree	17	0	17	0	67	17	17	17	33	17	0	0	0	15.4
Pinus elliottii var. *elliottii*	tree	67	83	83	83	0	50	50	50	33	67	83	67	83	61.5
Pinus palustris	tree	17	17	50	50	33	100	100	67	33	100	100	83	100	65.4
Pinus taeda	tree	17	17	0	0	0	0	0	0	0	0	0	0	0	2.6
Prunus alabamensis	tree	17	0	17	0	0	0	0	0	0	0	17	0	0	3.8
Prunus angustifolia	tree	0	0	0	0	33	17	0	0	0	0	17	17	0	6.4
Prunus serotina	tree	0	0	0	33	0	0	33	0	0	0	0	17	50	10.3
Prunus umbellata	tree	0	0	0	0	0	0	0	0	0	0	0	0	33	2.6
Quercus geminata	tree	50	50	67	67	67	17	33	50	17	50	67	67	67	51.3
Quercus hemispherica	tree	100	83	100	100	100	83	100	100	83	83	100	100	100	94.9
Quercus incana	tree	33	33	17	0	33	17	17	33	33	17	0	17	17	20.5
Quercus laevis	tree	100	83	83	83	100	83	83	83	83	100	100	83	83	88.5
Quercus margaretta	tree	33	33	17	17	67	33	50	33	0	17	33	17	83	33.3
Quercus sp.	tree	0	17	17	0	0	0	17	0	0	17	0	0	0	5.1
Sassafras albidum	tree	0	0	0	0	0	0	0	0	0	0	0	17	17	2.6
Gelsemium sempervirens	vine	50	50	67	50	100	83	67	100	50	50	100	100	67	71.8
Ipomoea pandurata	vine	0	0	0	0	0	0	0	0	0	0	0	17	0	1.3
Ipomoea sagittata ??	vine	0	0	0	17	0	0	0	0	0	0	0	17	0	2.6
Passiflora incarnata	vine	17	0	0	0	0	0	0	0	0	0	0	0	0	1.3
Smilax auriculata	vine	67	33	83	100	0	50	17	50	50	83	33	50	83	53.8
Smilax bona-nox	vine	50	33	83	67	100	33	33	67	33	67	67	83	83	61.5
Smilax pumila	vine	0	17	0	0	0	0	0	33	17	50	17	0	0	10.3
Vitis aestivalis	vine	0	0	0	17	0	0	0	0	0	17	0	0	17	3.8
Vitis rotundifolia	vine	17	0	17	17	33	0	50	17	33	17	17	17	33	20.5

Appendix B. Total species richness and randomly blocked locations for Experiments A and B plots.

- Treatment codes are as follows: **ccu** = chop, cultipack; **cfe** = chop, fertilizer spreader; **cha** = chop, hayblower; **chy** = chop, hydroseeder; **fhai** = fire, hayblower, irrigate; **fcu** = fire, cultipack; **ffe** = fire, fertilizer spreader; **fha** = fire, hayblower; **fcha** = fire, hayblower, chop; **fhy** = fire, hydroseeder; **cno**= chop, no seed; **fno** = fire, no seed; **natv** = no fire, chop, or seed.

	Treatment												
Block	**ccu**	**cfe**	**cha**	**chy**	**fhai**	**fcu**	**ffe**	**fha**	**fcha**	**fhy**	**cno***	**fno**	**natv**
A	70	47	53	44	62	46	46	51	41	52	54	56	53
B	49	64	52	57	58	49	47	49	42	47	--	65	62
C	62	51	62	46	56	44	53	46	46	44	--	55	48
D	63	58	56	63	63	51	55	57	52	58	--	54	44
E	58	63	58	57	65	53	52	55	51	58	55	48	55
F	58	63	58	57	65	53	52	55	59	61	64	44	60

A1. Species richness September 1999.

	Treatment												
Block	**ccu**	**cfe**	**cha**	**chy**	**fhai**	**fcu**	**ffe**	**fha**	**fhac**	**fhy**	**cno***	**fno**	**natv**
A	68	58	58	59	56	61	59	54	53	60	63	53	67
B	66	67	65	63	61	57	58	51	57	64	--	67	60
C	66	60	67	55	56	43	56	52	55	50	--	53	61
D	62	63	62	67	62	51	61	62	52	57	--	54	71
E	70	56	80	56	59	56	58	61	63	58	61	51	51
F	56	57	58	58	65	57	57	60	53	61	75	50	63

A2. Species richness for September 2000.

*All treatments have six replicates except the chop, no seed (cno), which has three replicates because of space limitations for plot location.

Appendix C. Plant species located within plots on the Blountstown Bridge

			May 1999		Oct 1999		May 2000	
Scientific name	**Common name**	*	No soil	Soil	No soil	Soil	No soil	Soil
Acalypha gracilens	Three-seeded Mercury	N			1			
Ambrosia artemisiifolia	Ragweed	R	1	1	1	1	1	1
Aristida beyrichiana	Wiregrass	N	1	1				
Aristida purpurescence	Arrowfeather	N			1			
Bidens pilosa	Shepherd's needle	R		1		1		1
Callicarpa americana	Beauty Berry	N						1
Cassia obtusifolia	Sicklepod	E	1	1	1	1		
Cenchrus sp.	Sand bur	R			1	1	1	
Centrosema virginianum	Butterfly pea	N					1	
Crotalaria rotundifolia	Rabbit bells	N			1	1		
Crotalaria sp.	Rattlebox	R			1	1		1
Cyperus retrorsus	Pinebarren flat-sedge	N	1	1				
Dactyloctenium aegyptium	Crowfoot grass	E			1	1		
Digitaria ciliaris	Crabgrass	E	1	1	1	1	1	1
Diodia teres	Poorjoe	R	1	1	1	1		1
Eupatorium capillifolium	Dog fennel	R		1			1	1
Euphorbia sp.	Spurge	N			1	1		
Froelichia floridana	Cottonweed	N		1	1	1		1
Galactia sp.	Milkpea	N						1
Gnapthaliun sp.	Cudweed	R						1
Indigofera sp.	Hairy Indigo	E					1	
Ipomoea sp.	Morning-glory	N		1	1	1		
Lepidium virginicum	Peppergrass	R		1			1	1
Lolium perene	Rye grass	C	1	1	1			
Medicago sp.	Black Medic	E					1	
Paspalum notatum	Bahiagrass	C	1	1	1	1	1	1
Pinus sp.	Pine seedling	N	1	1				
Richardia scabra	Richardia	R	1	1	1	1	1	1
Schizachyrium scoparium	Little bluestem	N	1	1	1	1	1	1
Sida rhombifolia.	Sida	R	1	1		1	1	
Spermacoce sp.	Spermacoce	E			1	1	1	1
Stylosanthes biflora	Pencil flower	N					1	1
Tribulus terrestris	Puncture vine	E			1	1		
Unknown herb					1	1		
Unknown legume 1				1				
Unknown legume 2					1	1		
	TOTALS		12	18	21	20	14	16

* Letters designate the following categories

C = Cultivated

E = Exotic or Nonnative species

N = Native species

R = Ruderal

Appendix D. ABRP October 2000 species list and frequencies (%) by sowing or cultural treatment plots (Contract BA-523).

SPECIES	Lifeform	n	na	nr	nar	nw	naw	nrw	narw	cnt
Pteridium aquilinum	fern	33	50	0	50	17	17	17	33	0
Andropogon gyrans	grass	0	33	17	33	33	50	17	50	0
Andropogon longiberbis	grass	50	33	0	0	33	17	17	33	0
Andropogon ternarius	grass	33	33	33	17	33	33	0	67	1
Andropogon virginicus	grass	100	67	50	50	50	67	50	33	1
Andropogon virginicus var.*glaucus*	grass	83	67	33	67	33	50	67	67	1
Aristida beyrichiana	grass	100	100	100	100	100	100	100	100	1
Aristida purpurescens	grass	100	100	100	83	100	100	100	83	1
Dichanthelium aciculare	grass	83	83	83	100	100	83	83	83	1
Dichanthelium sp. 1	grass	67	50	83	17	33	100	100	33	1
Dichanthelium sp. 2	grass	100	67	100	67	100	100	67	83	1
Digitaria ciliaris	grass	67	50	33	67	50	67	33	17	0
Eragrostis refracta	grass	83	83	33	50	83	50	67	50	1
Leptoloma cognatum	grass	67	67	33	33	67	50	83	67	1
Panicum virgatum	grass	17	0	0	0	0	17	17	17	0
Paspalum notatum	grass	0	0	0	0	0	0	0	0	0
Paspalum setaceum	grass	67	67	67	33	67	83	67	50	1
Schizachyrium hirtiflorum	grass	33	17	17	0	0	0	0	17	0
Schizachyrium scoparium 1	grass	67	100	100	83	50	83	83	83	1
Schizachyrium scoparium 2	grass	100	100	100	100	100	83	83	100	1
Schizachyrium tenerum	grass	67	83	50	83	67	33	33	83	0
Sorghastrum secundum	grass	0	17	0	50	17	17	0	17	0
Sporobolus junceus	grass	67	67	100	50	83	83	83	67	0
Triplasis americana	grass	83	100	100	100	100	100	83	100	1
Bulbostylis ciliatifolia	sedge	100	100	100	100	100	100	100	83	1
Cyperus filiculmis	sedge	83	67	67	50	100	67	100	50	1
Cyperus globulosus	sedge	33	17	33	50	50	50	50	0	1
Cyperus retrofractus	sedge	0	17	17	0	17	0	0	0	0
Cyperus retrorsus	sedge	0	50	67	0	17	67	17	33	0
Cyperus sp.	sedge	0	0	0	33	0	17	0	17	0
Rhynchospora grayi	sedge	0	33	0	0	0	0	17	0	0
Scleria ciliata var. *ciliata*	sedge	17	17	33	17	17	33	17	50	1
Unknown sedge	sedge	0	0	0	0	0	0	17	0	0
Angelica dentata	herb	0	0	0	0	0	0	17	0	0
Asclepias humistrata	herb	0	17	0	0	0	0	17	0	0
Asclepias tuberosa	herb	0	0	17	0	0	17	17	0	0
Aster concolor	herb	0	17	0	17	0	50	17	33	0
Baptisia lanceolata	herb	33	0	17	17	17	33	50	17	0
Berlandiera pumila	herb	0	0	0	0	17	0	0	0	1
Calamintha dentata	herb	0	17	0	0	17	0	0	0	1
Chamaecrista fasiculata	herb	0	0	0	33	33	0	17	0	0
Chaptalia tomentosa	herb	0	0	0	17	0	0	0	0	0
Chrysoma pauciflosculosa	herb	0	0	0	0	17	0	0	0	0
Chrysopsis gossypina	herb	0	0	33	0	17	0	0	17	0
Cnidoscolus stimulosus	herb	100	67	100	100	100	67	83	83	1
Commelina erecta	herb	83	83	100	83	67	83	83	67	1

SPECIES	Lifeform	n	na	nr	nar	nw	naw	nrw	narw	cnt
Crotalaria rotundifolia	herb	33	0	0	0	0	17	0	17	0
Croton argyranthemus	herb	100	83	100	83	100	100	83	67	1
Croton glandulosus	herb	33	17	0	0	0	0	0	0	0
Dalea pinnata	herb	83	67	83	67	83	67	50	83	1
Diodia teres	herb	100	100	100	100	83	83	100	83	1
Erigeron sp.	herb	0	0	0	0	17	0	0	0	0
Eriogonum tomentosum	herb	17	33	83	50	67	33	67	67	0
Eupatorium capillifolium	herb	17	17	0	0	0	17	0	0	0
Eupatorium compositifolium	herb	100	83	83	100	100	83	100	83	1
Euphorbia exserta	herb	67	33	33	67	67	67	83	33	1
Euphorbia floridana	herb	83	83	100	100	83	67	83	67	0
Euthamia minor	herb	100	83	100	67	67	83	83	67	1
Froelichia floridana	herb	0	17	0	0	0	17	17	17	0
Galactia floridana	herb	33	17	0	17	17	17	0	0	0
Galactia volubilis	herb	50	33	33	33	83	17	67	17	1
Hypericum gentianoides	herb	0	0	0	0	0	0	0	0	0
Lechea minor	herb	17	33	0	17	50	33	33	67	0
Lespedeza hirta	herb	0	0	0	0	0	33	0	0	0
Liatris chapmanii	herb	100	83	100	100	100	83	100	83	1
Liatris gracilis	herb	50	50	50	50	50	50	83	33	0
Liatris tenuifolia	herb	83	83	100	100	100	67	100	83	1
Liatris unnamed	herb	0	0	0	0	0	17	0	17	0
Lupinus diffusa	herb	0	0	0	0	0	17	0	0	0
Opuntia humifusa	herb	100	83	100	83	83	100	83	83	1
Phoebanthus tenuifolia	herb	83	83	83	83	83	83	100	50	1
Physalis arenicola	herb	0	0	0	17	0	0	0	17	0
Pityopsis adenolepis	herb	67	67	83	100	83	100	100	67	1
Polanisia tenuifolia	herb	0	17	0	0	0	0	0	0	0
Polygonella gracilis	herb	17	33	0	0	17	33	0	0	1
Polypremum procumbens	herb	0	0	0	0	0	17	0	0	0
Rhynchosia cytisoides	herb	100	100	100	100	100	100	100	83	1
Ruellia caroliniensis	herb	50	0	17	17	33	17	17	17	0
Schrankia microphylla	herb	17	0	33	0	17	33	33	0	0
Solanum carolinense	herb	0	17	33	0	0	0	0	0	0
Solidago odora	herb	100	83	83	100	100	100	100	100	1
Stylisma patens	herb	100	83	100	100	100	83	83	67	1
Stylosanthes biflora	herb	33	0	0	33	17	17	50	0	0
Tephrosia chrysophylla	herb	50	83	67	83	83	50	83	67	1
Toxicodendron radicans	herb	83	67	83	100	67	83	67	83	1
Tragia urens	herb	67	33	33	50	83	33	33	17	0
Tragia urticifolia	herb	67	50	33	67	83	50	33	67	0
Unknown 1	herb	0	0	0	0	17	0	0	0	0
Unknown 2	herb	0	17	0	0	0	0	0	0	0
Unknown 3	herb	0	0	0	0	0	17	17	0	0
Unknown 4	herb	0	0	0	0	0	0	0	17	0
Unknown 5	herb	0	0	0	0	0	17	0	0	0
Unknown 8	herb	17	0	0	0	0	0	0	0	0
Unknown Aster	herb	17	0	0	0	17	0	0	0	0
Vernonia angustifolia	herb	17	17	0	0	0	50	0	17	0
Asimina longifolia	shrub	0	17	0	0	0	0	17	0	0
Bumelia lanuginosa	shrub	0	0	0	0	0	33	0	0	0
Callicarpa americana	shrub	83	83	50	83	67	67	100	50	1

SPECIES	**Lifeform**	**n**	**na**	**nr**	**nar**	**nw**	**naw**	**nrw**	**narw**	**cnt**
Licania michauxii	shrub	83	67	83	100	100	50	67	83	1
Rhus copallina	shrub	33	67	50	50	17	33	50	50	0
Rubus cuneifolius	shrub	67	33	17	0	0	33	33	17	0
Serenoa repens	shrub	17	0	0	17	33	33	0	17	0
Vaccinium arboreum	shrub	50	33	67	50	17	50	50	17	0
Vaccinium darrowii	shrub	67	50	50	33	50	50	17	0	0
Vaccinium stamineum	shrub	17	33	17	33	0	17	33	17	0
Diospyros virginiana	tree	67	83	83	100	50	83	50	67	1
Persea borbonia	tree	0	17	0	0	0	0	0	0	0
Prunus serotina var.*serotina*	tree	0	0	0	0	0	0	0	0	0
Prunus umbellata	tree	0	0	17	0	17	0	0	0	0
Quercus geminata	tree	33	0	17	33	33	17	17	0	1
Quercus hemisphaerica	tree	17	33	17	17	33	17	33	17	0
Quercus incana	tree	83	83	100	100	100	83	67	50	1
Quercus laevis	tree	83	67	100	83	83	83	83	50	1
Quercus margaretta	tree	17	17	0	50	0	17	17	0	0
Quercus pumila	tree	17	0	17	17	0	0	0	17	0
Gelsemium sempervirens	vine	0	0	0	17	0	17	0	0	0
Ipomoea sp.	vine	0	0	0	0	0	17	17	0	0
Passiflora incarnata	vine	0	0	0	17	0	0	0	0	0
Smilax auriculata	vine	100	100	100	100	100	100	100	100	1
Smilax bona-nox	vine	50	0	0	0	17	33	0	0	0
Smilax pumila	vine	33	0	33	17	33	17	33	0	0
Vitis aestivalis	vine	0	0	33	33	17	33	17	0	0
Vitis rotundifolia	vine	17	33	17	50	50	33	50	33	0

Appendix E. Plant list for entrance road islands and bus pullouts at DWP. Islands 1-4 and Bus turnarounds B1 and B2 were monitored in summer of 1999. Island 5 was planted in 2000. Plants with astericks * are nonnative or cultivated species.

Scientific name	Common name	Islands (1-4)				Bus		Island
		1	2	3	4	B1	B2	5
Ambrosia artemisiifolia	Ragweed					1	1	1
Ariastida beyrichiana	Wiregrass							1
Axonopus affinis	Carpetgrass					1		1
Carex sp.	Sedge	1	1					
Cassia obtusifolia	Sicklepod	1						
Chamaecrista nictitans	Sensitive pea	1				1		1
Chamaesycs sp.	Spurge							1
Chenopodium ambrosioides *	Goatsfoot							1
Chrysopsis scabrella	Golden aster							1
Conyza canadensis *	Horseweed	1	1			1		
Coreopsis leavenworthii	Common tickseed					1		1
Crotalaria sagittalis	Rattlebox						1	
Ctenium aromaticum	Toothache grass							
Cynodon dactylon *	Bermudagrass							1
Cyperus compressus	Small flat sedge	1	1	1	1	1	1	
Cyperus esculentus	Yellow nutsedge	1	1	1	1	1	1	
Cyperus globulosus	Globe sedge			1	1	1		1
Cyperus retrorsus	Cylindric sedge	1	1	1	1	1		1
Cyperus rotundus	Purple nutsedge					1		
Dactyloctenium aegyptium *	Crowfoot graee							1
Desmodium triflorum	Beggarweed					1		
Dichanthelium sp.	Dichanthelium					1		
Digitaria ciliaris *	Crabgrass 1	1	1	1		1	1	1
Digitaria serotina	Crabgrass 2	1		1		1		1
Diodia teres	Poorjoe					1		
Elephantopus alatus	Elephantsfoot							1
Erichtites hieracifolia	Fireweed					1		1
Erigrostis refracta	Love grass					1		1
Eupatorium capifollium	Dog fennel		1			1		1
Eupatorium compositifolium	Dog fennel							1
Galium sp.	Bedstraw							1
Gnapthalium falcatum	Cudweed		1			1		
Hedyotis corymbosa	Innocence							1
Hydrocotyl umbellata	Pennywort			1		1		
Lepidium virginicum	Peppergrass					1		
Lespedeza striata	Lespedeza					1		
Linaria canadensis	Toadflax							1
Lolium perenne *	English ryegrass	1	1			1		
Ludwigia maritima	Slender seedbox	1				1		
Macroptilium lathyroides	Phasey bean					1		
Murdannia nudiflora	Doveweed						1	
Oxalis stricta	Yellow woodsorrel		1			1		

Scientific name	Common name	Islands (1-4)				Bus		Island
		1	2	3	4	B1	B2	5
Panicum spp.	Panicum				1			1
Paspalum dilatatum	Dallisgrass	1						
Paspalum notatum *	Bahiagrass	1	1	1	1	1	1	1
Paspalum setaceum	Thin paspalum							1
Pluchea sp.	Camphorweed							1
Polypremum procumbens	Rustweed	1						
Portulaca amilis	Pink purslane	1	1	1				
Rhexia nashii	Meadow beauty					1		
Rhynchospora sp.	Beakrush					1		
Richardia brasiliensis *	Richardia	1		1		1		1
Scoparia dulcis	Goatweed	1	1			1		1
Sida spinosa	Prickly sida	1				1		
Solanum americanum	Nightshade							1
Solanum viarum	Soda Apple		1					
Sorghastrum secundum	Indian grass					1		
Trifolium repens	White clover					1		
Unidentified Aster						1		
Unknown dry plant		1	1			1		
Urochloa piligera	Signal grass					1		
Urochloa ramosa	Signal grass			1		1		
	Total species	19	15	11	6	38	7	29