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Responses to Prescribed Fire at Big Thicket National Preserve, Texas, USA

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Responses to Prescribed Fire at Big Thicket National Preserve, Texas, USA

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Abstract

US Federal land managers have utilized hand ignited prescribed fire at Big Thicket National Preserve in efforts to restore the structure and diversity of the longleaf pine (Pinus palustris) forest. A fire ecology study was initiated by Rice University in the early 1990's and the National Park Service has continued monitoring the plots. Ordination was applied to species abundance data to examine changes in vegetation communities from a variety of prescribed fire treatments and controls. The vegetation data was separated by size class to include overstory, small tree, large sapling and seedling data. Across the size classes and treatments, the sandhill and wetland savanna vegetation types remained less effected by fire treatments and only the upland pine responded to changes in the overstory. Upon reviewing fire return interval histories, it became evident that prescribed fire alone was not changing vegetation communities. Most of the plots did not have longleaf pine trees or seedlings present and only two plots that were mechanical treated showed distinction among other treatment regimes. Restoration treatments including the mechanical and chemical application and seedling plantings are necessary to ensure restoration of the longleaf pine forest structure and diverse understory vegetation.

Keywords: Longleaf pine; East Texas; Species diversity; Ordination

Introduction

Following Euro-American settlement, longleaf pine (*Pinus palustris* Mill.) forests were cleared faster than current rates of deforestation among temperate and tropical rainforests [1]. In the moist tropical rainforests of South America, Africa, and Asia, forty percent of the forests have been deforested: over the past four hundred years, ninety-seven percent of the longleaf pine ecosystem was cleared [2]. These longleaf pine forests once dominated the southeastern United States, with a range of 29-38 million hectares [2-5]. The most critical element in the longleaf pine ecosystem is the occurrence of fire which fosters a dense and diverse herbaceous layer with up to 300 species per hectare, many of which are currently rare or endangered [6,7].

Historically, lightning and Native Americans periodically set fires that formed the open, grassy, park-like forest structure of the longleaf community, and weather and topography regulated the boundaries of a fire [8]. Grassy herbaceous vegetation fueled low to medium intensity growing season surface fires, which occurred every two to ten years [6,9,10]. Studies in Louisiana of scars in remnant longleaf pines calculated a 2.2 year mean fire return interval from 1650-1905, with a range from 0.5-12 years [11]. In the early 1900's, fire exclusion changed the "common and unregulated" fire regime characteristic of the southeast for forest protection and pine regeneration and has been one of the factors in the decline of the ecosystem [2,12,13]. Without fire, other pines, hardwoods, and brush species occupy the mystery and out-compete native longleaf seedlings [14-16].

Fire intensity and behavior are most important factors that accounts for species composition in the longleaf pine ecosystem, rather than seasonality and frequency, while noted that higher intensity fires, such as wildfires, result in a higher mortality of invading pine and hardwoods. In these forests, fire alone may not alter the composition, since higher intensity fires have resulted in a greater density of brush resprouts than the pre-burn conditions. Therefore, managers will often use mechanical and chemical treatments to help reduce fuel loadings and brush density in forests with a history of fire suppression, as prescribed fires often lack the intensity to cause mortality to woody vegetation [12,17,18].

Fire frequency has a strong effect on ground cover vegetation with annual or biennial return intervals resulting in high species diversity. Furthermore, seasonality had a weaker influence on differences in fire effects [19]. Composites and some legumes responded better with August versus January burning, while dormant season fires have greater stem densities of hardwood resprouts compared to growing season fires, and found that summer fires maintain fire dependent grasslands without fostering regeneration of hardwoods, where winter fires regulated size but not the number of hardwoods, while also advocating annual prescribed fire to eliminate small hardwoods and develop a grassy herbaceous layer [12,18,20]. Pine litter and the herbaceous vegetation carry fire well. However, hardwood invasion due to fire suppression can lessen the intensity of subsequent fires and result in further proliferation of hardwoods and recommended high intensity summer fires to combat hardwood invasion, but concluded winter burns have similar benefits to summer burns depending on management objectives [21-23].

From 1989 to 1993, data was collected in east Texas to assess the effects of fire across a moisture gradient of vegetative communities and concluded intensity differences caused the decrease of fire effects from dry to wet vegetative types [24]. The Big Thicket National Preserve started a fire effects monitoring program in 2001 and continued measuring these plots to facilitate adaptive management by documenting the effects of prescribed burns on the vegetation and determining if the prescribed fire program is meeting burn objectives.

The objective of this study was to analyze fire effects data collected

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from the 1990's through 2012 to document changes in forest structure and species composition from successive prescribed fire treatments. Across a gradient of vegetation types, long-term species abundance data was analyzed to determine if prescribed fire treatments have affected the overstory tree composition over time and how vegetation types have responded to varying levels of prescribed fire treatment among different size classes of vegetation.

Methods

Study area

On October 11, 1974, the National Park Service established Big Thicket National Preserve, which covers over 40,000 hectares in southeast Texas, composed of nine different land units and six water corridors. Big Thicket is located 60-120 km north of the Gulf of Mexico, between the Trinity River to the west and the Neches River to the east. The region is within the West Gulf Coastal Plain, which has a subtropical humid climate with an even occurrence of precipitation throughout the year. The average annual temperature is 19.5°C with an average of 132 cm annual rainfall [24]. During the summer months, frequent thunderstorms and tropical storms occur. On September 24, 2005 hurricane Rita made landfall along the border between Texas and Louisiana with sustained wind speeds of 193 kph, and traveled 241 kilometers inland, tracking over Big Thicket. On September 13, 2008 hurricane Ike made landfall on the northern end of Galveston Island with sustained winds of 175 kph and tracked to the northeast affecting the Preserve. Various degrees of damage occurred from the hurricanes, which created gaps in the canopy and increased the amount of dead and down fuels.

In the oldest known east Texas longleaf stand, tree ring analysis from 1755-1995 indicated fires occurred at mean frequencies of 1.5 years [25]. Ordination analysis confirmed vegetative communities are highly related to soil texture in the Western Gulf Coastal Plain ecoregion, longleaf pine was an important part of the Big Thicket region in stands that were previously logged, which have succeeded into oak-hickory-pine stands. However, data also demonstrate oaks as a component of the forest prior to settlement [3].

Study design

This study followed methods developed by researchers from Rice University who collected data from 1989 to 1993 to determine the effects of fire management on vegetation. After 1993, the plots were not measured again until 2000, when Big Thicket National Preserve developed a fire effects monitoring program to support fire management. The vegetation types followed the classification of Jurney et al. [25], and examined sandhill pine-oak, upland pine, upperslope pine-oak, midslope oak-pine, lowerslope pine-hardwood, and wetland pine savanna. Across each vegetation type a baseline was established, from which plot transects were randomly placed. Along these plots transects, five, 10 m × 10 m plots were established at random distances and randomly selected as to which side of the transect the plot was located as shown in Figures 1 and 2. Plots were placed in both burn and control units of each vegetation type, and measured for tree, sapling, and woody seedling data (Table 1).

Plot measurements

Burned plots were measured each year following a fire and control plots every 4-5 years. Overstory trees, saplings, and understory woody seedlings were measured in each 10 m × 10 m plot. The protocol was:

(a) Trees greater than five centimeters in diameter at breast height (dbh, 1.4 meters above soil surface) were classified as overstory trees and identified, tagged and measured for dbh.

(b) Small trees between two to five centimeters in dbh were placed into three size classes (2- 3 cm, 3-4 cm, and 4-5 cm), identified but not tagged.

(c) Saplings were counted and identified in a 20 m^2 (2 m × 10 m) belt transect that measured 1-m along the central line of each plot. Saplings were categorized into large saplings (dbh 1-2 cm dbh) and small saplings (dbh 0-1 cm dbh). Single woody stems are counted as live individuals if living tissue is present above dbh.

(d) Woody seedlings were documented by height in two categories (below 0.5 meters and between 0.5 m and 1.4 m in height), counted and identified over a 10 m^2 area (1 m × 10 m) along the central line of each plot.

Plots were measured before a prescribed burn, immediately after a burn, one-year postburn, and 2 years postburn (Table 2). Documents of prescribed fire operations and fire effects monitoring were reviewed for each burn to reference seasonality, frequency, and intensity. The plots had a varying degree of prescribed fire treatment based on past management. However, the compiled reports from the history of burns help inform conclusions when reviewing data results.

Data analysis

To determine changes and trends of the burned and controlled

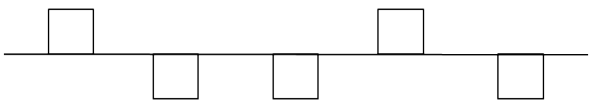

Figure 1: Plot design where each 10 × 10 meter subplot is located at random distances and random sides of a transect.

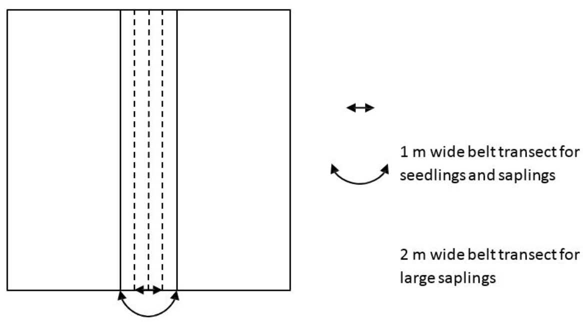

Figure 2: 10 × 10 m subplot diagram demonstrating nested belt transects.

Preserve Unit	Big Sandy		Turkey Creek		Lance Rosier	
	Burn	Control	Burn	Control	Burn	Control
Upland Pine	3	1	2	1	X	X
Upperslope Pine-Oak	4	4	2	2	X	X
Midslope Oak-Pine	3	3	1	1	1	1
Lowerslope Pine-Hardwood	2	2	1	1	X	X
Sandhill Pine-Oak	X	X	3	2	X	X
Wetland Pine Savanna	X	X	X	X	4	3
Total	12	10	9	7	5	4

Table 1: Number of plots within each vegetation type per Preserve unit. X=no plots.

Bith Fire Effects Plot History																	
PLOT	**FMU**	**B/C**	**1990**	**1991**	**1992**	**1993**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
101-BSU-UP B	1606	Burn	i			1	0,3,4	1	2	4	1	2	3		4	1	2
103-BSU-UPO-B	1605	Burn	i			1	0,3,4	1	2	4	1	2	3		4	1	2
105-BSU-LOP-B	1605	Burn	i			1	0,3,4	1	2	4	1	2	3		4	1	2
107-BSU-MPO-B	1610	Burn	i				0,3					2	3		4	1	2
109-BSU-LOP-B	1610	Burn	i				0,3					2	3		4	1	2
111-BSU-UP B	1501	Burn		i	1	2	0		3	4	1	2		4	1	2	3
112-BSU-UP B	1501	Burn		i	n	C	0	C?		4	1	2		4	1	2	3
113-BSU-UPO-B	1501	Burn		i	1	2	0	3		3,4	1	2		4	1	2	3
115-BSU-UPO-B	1501	Burn		i		1	0	3		3,4		3		4	1	2	3
117-BSU-MPO-B	1501	Burn		i		1	0	3	2	3,4		3		4	1	2	3
119-BSU-UPO-B	1201	Burn	i	1	2	2	0,3,4	1	2	4	1	2	4,5,6	1	2	3	
121-BSU-MPO-B	1201	Burn	i	1	2	2	0,3,4	1		4	1	2	4,5,6	1	2	3	
102-BSU-UP-C	1607	Control	i			C	0				C		C		C		C
104-BSU-UPO-C	1605	Control	i			C	0				C		C		C		C
106-BSU-LOP-C	1605	Control	i			C	0				C		C		C		C
108-BSU-MPO-C	1610	Control	i				0			C			C		C/4	1	2
110-BSU-LOP-C	1610	Control	i				0			C			C		C		C
114-BSU-UPO-C	1501	Control		i		C	0			C				C	C		C
116-BSU-UPO-C	1501	Control		i		C	0			C				C	C		C
118-BSU-MPO-C	1501	Control		i		C	0			C				C	C		C
120-BSU-UPO-C	1301	Control	i		C		0			C				C		C	
122-BSU-MPO-C	1301	Control	i		C		0			C				C		C	
201-HCU-VWI-B	2101	Burn						i,5	6,1	4	1	2	3	4	1	4	1
202-HCU-VWI-B	2101	Burn							i,5	1(5)6	4	1	2	4	1	4	1
301-TCU-SH-B	3601	Burn		i	1	2	0	3	4	1	2	4	1	2	4		2
303-TCU-SH B	3601	Burn		i	1	2	0	3	4	1	2	4	1	2	4		2
305-TCU-UPO-B	3601	Burn		i	1	2	0	3	4	1	2	4	1	2	4		2
308-TCU-MPO-C	3601	Control		i		3	0	3	4	C			?	C	C		C
309-TCU-UP B	3701	Burn	i	1	2	2	0					5			3		
312-TCU-UPO-B	3701	Burn	i	1	2	2	0			3		5			3		
313-TCU-LOP-B	3701	Burn	i	1	2	2	0					5			3		
315-TCU-UP B	3701	Burn								1	2,3		1	2	3	4	1
316-TCU-SH-B		Burn								i,5,6	1	2	3	3	3		3
302-TCU-SH C	3601	Control		i		C	0	C					C		C		C
304-TCU-SH-C	3601	Control		i		C	0		C				C		C		C
306-TCU-UPO-C	3601	Control		i		C	0			C			C		C		C
307-TCU-MPO-C	3601	Control		i		C	0	C?		C		4	C		C		C
310-TCU-UP C	3701	Control	i		C		0			C			C		C		C
311-TCU-UPO-C	3702	Control	i		C		0			C			C		C		
314-TCU-LOP-C	3701	Control	i		C		0			C			C		C		C
501-LRU-WPS-B	5101	Burn			i		0										
503-LRU-MPO-B	5101	Burn			i		0										
505-LRU-WPS-B	5301	Burn	i	1	2	2	0,3	4	1	2	3	3	3	3	3	4	1
506-LRU-WPS-B	5401	Burn	i	1	2	2	0,3	4	1	2,4	1	2	3	3	3		
509-LRU-WPS-B	5401	Burn	i	1	2	2	0,3	4	1	2,4		3	3	3	3		
502-LRU-WPS-C	5101	Control			i		0	?									
504-LRU-MPO-C	5501	Control			i		0										
507-LRU-WPS-C	5401	Control	i		C		0			C			C		C		
508-LRU-WPS-C	5401	Control	i		C		0			C			C		C		

Vegetation/Monitoring Types			**Plot Work Types**	
	SH	Sandhill Pine Forest	i	Installation and initial readings
	UP	Upland Pine Forest	0	Re-establishment of old plots
	UPO	Upper Slope Pine Oak Forest	1	First year reading
	MPO	Mid Slope Pine Oak Forest	2	Second year reading
	LOP	Lower Slope Oak Pine Forest	3	Pre-Burn reading
	WPS	Wetland Pine Savannah	4	Post-Burn reading
Modified 09/2018	WUI	WLJI Fuels Reduction Project	5	Pre-treatment (mechanical/chem)
A. Rudriguez	B=Burn	C=Control	6	Post-treatment (mechanical/chem)

Table 2: Plot series list designating type of reading conducted for each year.

plant communities over time, data were analyzed with Canonical Correspondence Analysis (CCA), a multivariate technique that finds the maximal separation of niches, using plots or subplots with varying combinations of species and their abundance. CCA is primarily a graphical technique that projects data onto a set of gradients, usually chosen as the first two components that result from multivariate analysis. Plots can then be visualized on a two-dimensional projection according to their centroids to identify locations that have similar species compositions. CCA has been used to examine the temporal change in vegetation in relation to the prescribed burns in southeast Texas, including plots established at Big Thicket National Preserve [21]. Species abundance was used to compare differences in the vegetation communities. Ordination was preformed separately for each of four vegetation sizes representing different strata of the forest: trees (>5 cm DBH), small trees (2-5 cm in DBH), large saplings (0-2 cm in DBH), and seedlings (less than 1.4 m tall). Following by Marks and Harcombe [24], data was analyzed to determine how vegetation communities have responded to fire management at Big Thicket National Preserve in R using the vegan library.

Results

Temporal changes were addressed in ordination plots that separated the first species abundance data taken from the most recent measurement. Graphs were stratified by treatment versus control as well as vegetation size classes: overstory, small trees, large saplings, and seedlings (Figures 3a-6d). This was followed by a second set of ordinations that combined the earliest and latest observations to assess if there was a statically significant difference in vegetation gradients due to time, treatment versus control, and the number of burns (Figures 7-10). The species abundance data for each of the vegetation types is encompassed in a hull identified by a dashed line.

Figures 3a-3d represent the basic ordination plots for the overstory data, with separate graphs for initial and last measurements, treatment and control. The labels for the species centroids in the two-dimensional projects were omitted to allow for a clear visual of the convex hulls with labels corresponding to the vegetation types: Sandhill (SH), Upland Pine (UP), Upperslope Pine Oak (UPO), Midslope Pine Oak (MPO), Lowerslope Pine Oak (LPO), and Wetland Pine Savanna (WPS). Before prescribed burn treatments most of the vegetation types had convergence of species abundance, except for the midslope vegetation type; however, in Figure 3b only the wetland pine savanna showed distinction as a vegetation type (Figure 3a).

Figure 3c shows the first measurements on the control subplots and reveals more separation, especially for the Wetland Pine Savanna and Sandhill vegetation types, while Figure 3d shows the most recent measurements for the control group and the vegetation types with increased overlap compared to the initial measurements; Sandhill and Wetland Pine Savanna continue to be apart from the concentration of the other vegetation types. Figures 4a-6d show the remaining three strata with overlap between vegetation types common, but the tendency for uniqueness of Wetland Pine Savanna and Sandhill appears throughout.

Figures 7-10 present subsequent CCA's that addressed the questions of treatment levels (i.e., number of prescribed burns) nor the statistical significance of time, treatment levels, and treatment versus controls as linear constraints. The blue convex hulls encompass the treatment versus control subplots. The red convex hulls encompass subplots that have experienced one, two, three, four, six, or seven burns. The labels represent the centroids of the convex hulls. The dots represent subplot observations.

Figure 7 displays the overstory data. The treatment and control centroids separate from each other, and there is separation of the convex hulls for the different treatment levels, especially those plots with two or six burns. There is not a significant difference between the treatment and controls. Instead, the most significant separator of subplots was the number of burns ($p<0.001$) (Table 3). The comparison of pre versus post plot measurements was also significant ($p<0.030$). The individual circles represent individual subplots all within the same vegetation type. Figures 8-10 are for the other strata. All of the linear constraints are significant, meaning the differences in treatment level and burn or control all contributed to subplot separation.

Discussion

Treatment histories of the plots had varying degrees of fire frequency, seasonality, and fire intensity. Several major natural disturbances occurred, including two major hurricanes, flooding events, and a long-term drought, all representing the complicated ecological history behind the long-term data collection. Changes occurred over time, and the number of burns had an effect on vegetation, and with the exception of overstory observations, burning led to clear differentiations over time.

Overstory

Before prescribed treatments were initiated, tree abundance did not produce distinct vegetation patterns with only the midslope vegetation type and some of the wetland savanna types distinct from the other community types. After two decades, the sandhill abundance, demonstrating changes due to fire management in the more xeric communities and a trend of fire stimulated succession. The wetland savanna also showed more divergence as a distinctive vegetation type, as the overstory responded to fire management over time, even with a limited number of prescribed burns. The midslope type represents a transitional ecotone where fire management also had an effect over time as the midslope type demonstrated a convergence with upperslope and lowerslope forests. Fire management shifted the boundaries between upperslope, midslope, and lowerslope communities, with most change in the midslope type.

The overstory control plots initially showed distinction between the sandhill, wetland savanna, and some of the midslope communities. The sandhill and wetland savanna continued to appear distinct but there was some convergence with other communities, indicating encroachment by species due to the lack of fire effects despite the xeric and wet edaphic conditions that also regulated these communities. The midslope type also showed less distinction over time, demonstrating successional effects and community responses to other natural disturbances not related to prescribed fire; therefore, it is also likely change by the burned midslope communities can be attributed to succession and other environmental disturbances over time, rather than just the effects of fire and upland pine vegetation types show more convergence and similarities in species.

Small trees, saplings and seedlings

In the reference of Liu et al. [21], treatments reduced small tree densities immediately post burn, with minimal effects in the wetter vegetation types of midslope, lowerslope, and wetland savanna. Small tree data initially showed distinction among the wetland savanna

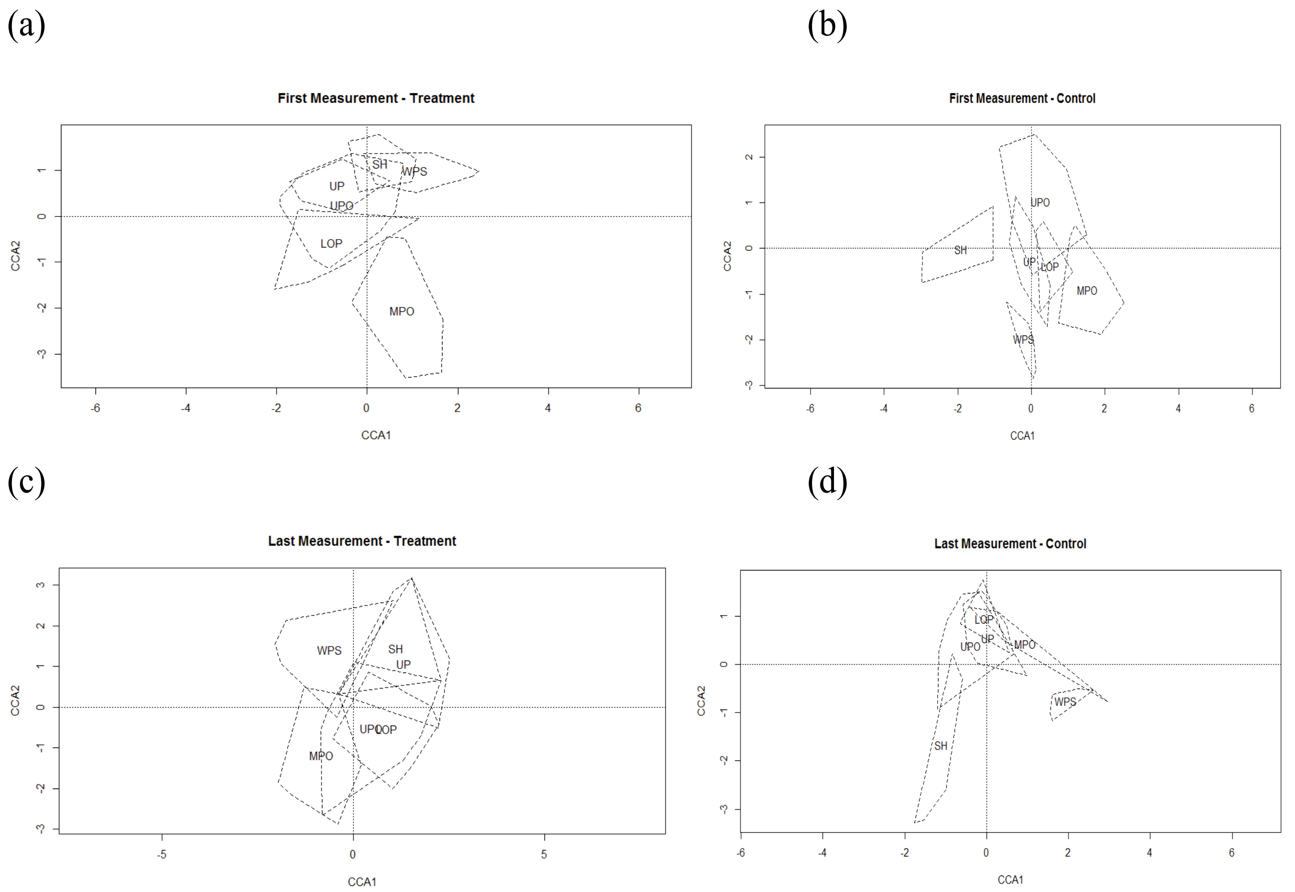

Figure 3: (a) Overstory: Treatment at First Measurement. Convex hull separates species by Sandhill (SH), Upland (UP), Upland Pine Oak (UPO), Midslope Pine Oak (MPO), and Lowerslope Pine Oak (LPO) vegetation types.(b) Overstory - Treatment at Last Measurement Convex hull separates species by Sandhill (SH), Upland (UP), Upland Pine Oak (UPO), Midslope Pine Oak (MPO), and Lowerslope Pine Oak (LPO) vegetation types. (c) Overstory - Control at First Measurement. Convex hull separates species by Sandhill (SH), Upland (UP), Upland Pine Oak (UPO), Midslope Pine Oak (MPO), and Lowerslope Pine Oak (LPO) vegetation types. (d) Overstory - Control at Last Measurement. Convex hull separates species by Sandhill (SH), Upland (UP), Upland Pine Oak (UPO), Midslope Pine Oak (MPO), and Lowerslope Pine Oak (LPO) vegetation types.

and sandhill types, with the other types overlapping; over time the upperslope and midslope types became more distinct. The wetland savanna type showed more convergence with the other vegetation types, demonstrating tree encroachment despite burning. The sandhill type showed increased distinction as fire affected small trees. However, a similar effect was not observed in the upland type. Over time, the upperslope and midslope pine oak types diverged from the other vegetation types, further demonstrating fire effects on these types.

Small trees in the control plots did not demonstrate much change over time. Although fire did not previously cause change in the small tree strata for the midslope and wetland savanna types, results revealed change over time for these communities, demonstrating plant community release [21]. Compared with smaller and larger sizes classes, one would predict more movement in the small trees size class; the lack of change in vegetation structure indicates that the prescribed burning was not intense enough to evoke change in the small trees. Finally, the effects of edaphic conditions in the sandhill and wetland savanna types are displayed as those communities remain distinct overtime, and when compared to overstory trees, there is less change overtime.

Liu et al. [21] showed changes between burn and control plots; however, no clear pattern of convergence or divergence was evident. Some of the burned stands showed species compositions returning to pre-fire conditions as species readily re-sprouted. In our study, only the upperslope vegetation type appeared to demonstrate change with fire treatments, while the sandhill community remained distinct, retaining vegetation composition. The wetland savanna type converged with the other vegetation types, similar to the response of the small tree data, which could demonstrate encroachment over time. Overall, little change was exhibited in the large sapling data as most of the vegetation types remained converged, with the sandhill and wetland savanna types as distinct communities. This demonstrates the resiliency of plant species to fire by aggressive resprouting when fire intensities do not cause mortality to large saplings, and a reduced frequency of burning does not reduce species abundance over time.

While Liu et al. [21] did not reveal identifiable patterns of change in the seedling strata for the vegetation types. A comparison of the data over time reveals similar trends as most of the vegetation types treated with fire increased overlap over time, while the wetland savanna and sandhill communities remained as distinct communities. It is harder to detect patterns over time as the seedling vegetation can be reset rapidly after a disturbance to pre-fire conditions.

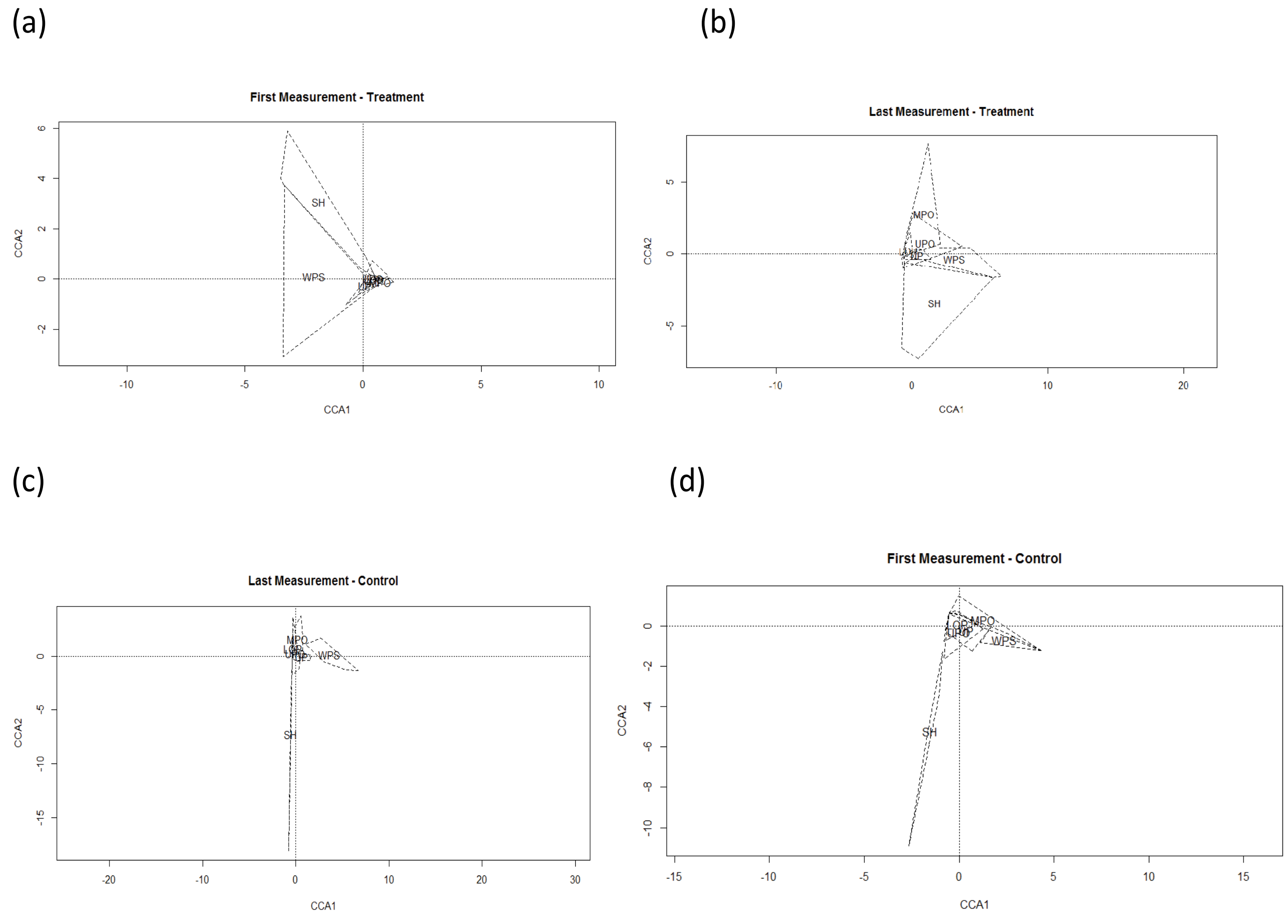

Figure 4: (a) Small Trees - Treatment at first measurement Convex hull separates species by Sandhill (SH), Upland (UP), Upland Pine Oak (UPO), Midslope Pine Oak (MPO), and Lowerslope Pine Oak (LPO) vegetation types. (b) Small Trees - Treatment at last measurement. Convex hull separates species by Sandhill (SH), Upland (UP), Upland Pine Oak (UPO), Midslope Pine Oak (MPO), and Lowerslope Pine Oak (LPO) vegetation types. (c) Small Trees - Control at first measurement. Convex hull separates species by Sandhill (SH), Upland (UP), Upland Pine Oak (UPO), Midslope Pine Oak (MPO), and Lowerslope Pine Oak (LPO) vegetation types. (d) Small Trees - Control at last measurement. Convex hull separates species by Sandhill (SH), Upland (UP), Upland Pine Oak (UPO), Midslope Pine Oak (MPO), and Lowerslope Pine Oak (LPO) vegetation types.

	Overstory	Small Trees	Large Saplings	Seedlings
Number of Burns	<0.001	<0.001	<0.001	<0.001
Pre versus Post	0.03	<0.001	<0.001	<0.001
Treatment	0.12	<0.001	<0.001	<0.001

Table 3: P-values from Permutation Tests.

Permutation tests

When Liu et al. [21] analyzed their data, no significant pattern of change was detected between burn and control or changes between vegetation types for the overstory, large sapling, and seedling data. The ordination of the small tree abundance suggested change mainly for the drier vegetation types. In comparison, our analysis showed significant changes before and after treatments among the vegetation types, and among different frequencies of burn treatments for all of the size classes. When comparing changes from burning treatment, all of the sizes showed significant differences except within the overstory size class. This is similar as a reference of Marks and Harcombe [24], as there was not a significant change detected in the overstory tree data, indicating that fire treatments did not have an effect on the overstory vegetation after decades of treatment.

Two-dimensional representations show the interactions of first to last measurements, treatment type burn versus control, and burn frequency (Figures 7-10). For the overstory data, the treatment and control centroids separate from each other, and the convex hulls for the different treatment levels, especially those plots with two or six burns, also show separation. The distinction of the plots with six burns is attributed to not only a higher number of burns but also a mechanical treatment where brush and small trees were mulched by a rotating grinding head in 2007. The plots that were burned only in 1992 and 2009 were midslope and lowerslope pine oak forest vegetation and are distinctive due to the wetter vegetation type. Since it is harder to burn in these fuels under prescribed conditions and the low frequency of burns. However, there was no significant difference between the overstory treatment and controls; the most significant separator of subplots was the number of burns (p<0.001) (Table 3). The comparison of pre versus post was also significant (p<0.030), indicating a change in species abundance data over time. For the other strata all of the linear constraints are significant, so the differences in treatment assignment and treatment level all contribute to separating the subplots (Figures 8-10). Although these show distinctions of the hulls in regard to

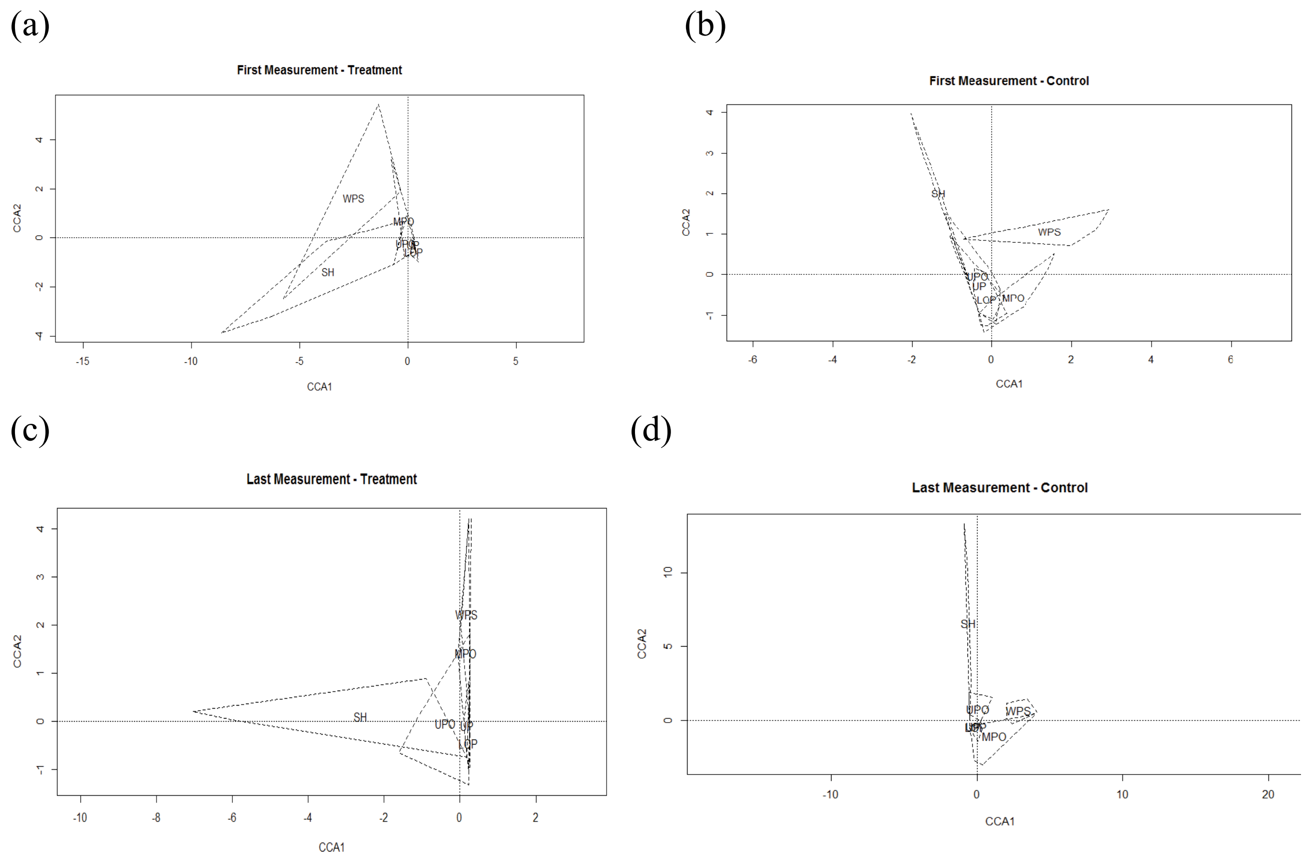

Figure 5: (a) Large saplings - Treatment at first measurement. Convex hull separates species by Sandhill (SH), Upland (UP), Upland Pine Oak (UPO), Midslope Pine Oak (MPO), and Lowerslope Pine Oak (LPO) vegetation types. (b) Large saplings - Treatment at last measurement. Convex hull separates species by Sandhill (SH), Upland (UP), Upland Pine Oak (UPO), Midslope Pine Oak (MPO), and Lowerslope Pine Oak (LPO) vegetation types. (c) Large saplings - Control at first measurement. Convex hull separates species by Sandhill (SH), Upland (UP), Upland Pine Oak (UPO), Midslope Pine Oak (MPO), and Lowerslope Pine Oak (LPO) vegetation types. (d) Large saplings - Control at last measurement. Convex hull separates species by Sandhill (SH), Upland (UP), Upland Pine Oak (UPO), Midslope Pine Oak (MPO), and Lowerslope Pine Oak (LPO) vegetation types.

differences in number of prescribed burn treatments, there is a great deal of convergence making it more challenging to see a difference among the plots based by number of treatments alone, especially since those groupings may include plots of different vegetation types.

Conclusion

We found that changes have occurred over time, the number of burns had an effect, and with the exception of the overstory, burning has led to clear differences. The distinction of the sandhill and wetland savanna types, representing the most xeric and wet vegetation types at Big Thicket, suggest that edaphic conditions play the primary role in determining species abundance. However, these communities depend on fire but with a reduced role. Upland pine vegetation exhibited the most change from fire treatments, aligning with similar species abundance to sandhill vegetation. The midslope vegetation became less distinct overtime, indicating shifts towards the lowerslope and upperslope pine oak vegetation types. This effect was also seen in the control plots, demonstrating succession of hardwood species and increased brush densities in the absence of fire. However, the only test that did not have significance was the relationship between the overstory burn versus control vegetation, indicating fire did not have a significant effect on species abundance for overstory trees over this timespan.

Most of the plots did not have a presence of either longleaf seedlings, indicating that fire alone will not achieve these objectives with a maintenance burning regime. The burns of every 3-5 years have not affected forest structure, particularly under prescribed burn conditions, which do not occur during dry and windy conditions when wildfires would burn. Furthermore, when examining the prescribed burn history, many burn units were not treated on a 3-5-year rotation but had much longer intervals between burns. After reviewing the maps from the early burn reports, the use of perimeter fire ignition did not effectively carry into the interior of the burn units. Some of the burn units experienced better fire coverage once interior strip firing was applied. However, hand ignition continued to create a mosaic pattern across the burn units.

Furthermore, breaks in vegetation from disturbance such as wind events or past fires, also cause challenges for carrying a fire when fine fuels are absent. The Big Thicket National Preserve has never used helicopter ignitions, which would help ensure fire treatment is effective, particularly in burn units 200-600 hectares in size and with diverse vegetation types.

Although the past effects of fire management have been limited, fire managers at the Preserve have implemented additional restoration treatments to restore forest conditions by grinding midstory brush and

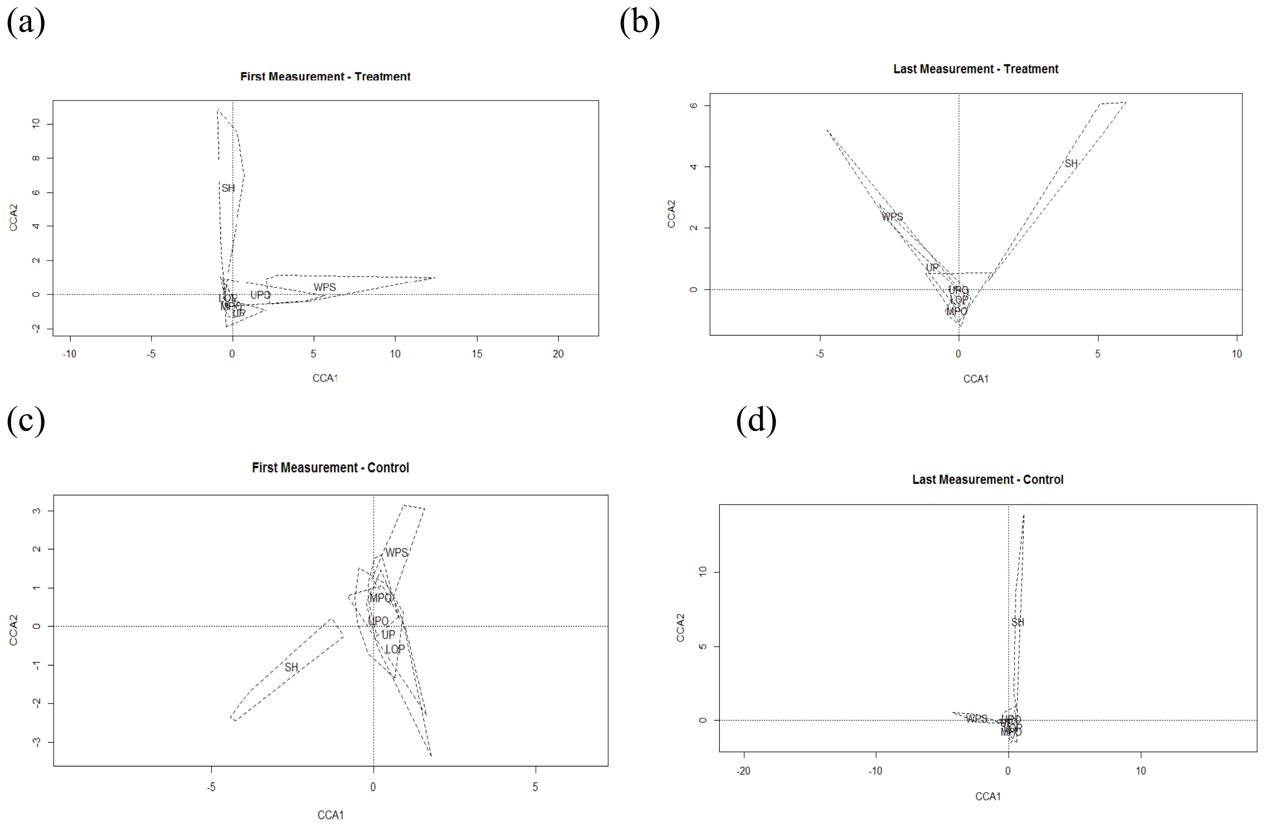

Figure 6: (a) Seedlings - Treatment at First Measurement. Convex hull separates species by Sandhill (SH), Upland (UP), Upland Pine Oak (UPO), Midslope Pine Oak (MPO), and Lowerslope Pine Oak (LPO) vegetation types. (b) Seedlings - Treatment at Last Measurement. Convex hull separates species by Sandhill (SH), Upland (UP), Upland Pine Oak (UPO), Midslope Pine Oak (MPO), and Lowerslope Pine Oak (LPO) vegetation types. (c) Seedlings - Control at First Measurement. Convex hull separates species by Sandhill (SH), Upland (UP), Upland Pine Oak (UPO), Midslope Pine Oak (MPO), and Lowerslope Pine Oak (LPO) vegetation types. (d) Seedlings - Control at Last Measurement. Convex hull separates species by Sandhill (SH), Upland (UP), Upland Pine Oak (UPO), Midslope Pine Oak (MPO), and Lowerslope Pine Oak (LPO) vegetation types.

small trees and following up with herbicide application. In addition, areas of open canopy from past disturbances and lacking a longleaf pine seed source are replanted with longleaf pine seedlings. The combination of mechanical and chemical treatments in addition to regular fire has been effective in restoring herbaceous vegetation to the understory, which is the most diverse strata of longleaf pine habitat.

Our study found significant differences among the size classes of vegetation in relation to number of burns, pre versus post fire treatment, and treatment versus control plots (with the exception of the overstory vegetation). However, change in vegetation was also expected due to succession and natural disturbances. The edaphic conditions of sandhill and wetland savanna continue to maintain species abundance on those sites. Of the remaining vegetation types, the upland pine communities responded to fire in the overstory tree size class, the upland pine oak vegetation responded in the large saplings while wetland savanna saw increased large sapling encroachment aligning more with midslope pine oak vegetation.

When examining past prescribed burn history records and considering fire intensity and frequency, it is evident that the prescribed burning alone is not going to achieve longleaf pine restoration and has done little to effect species abundance and composition across the different vegetation types. However, efforts to use a combination

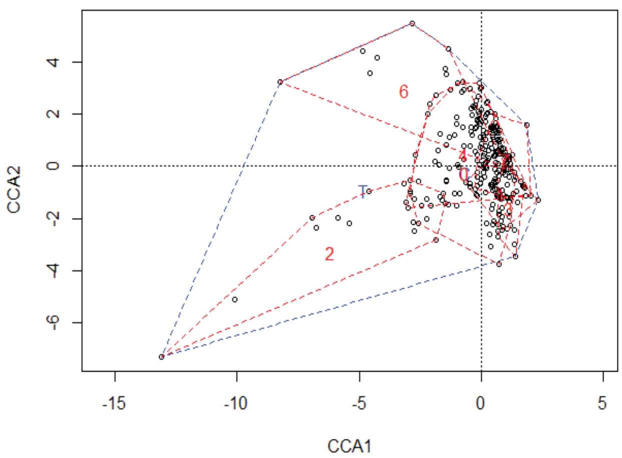

Figure 7: Overstory ordination based on pre-post, treatment assignment, and treatment levels. Blue convex hull represents treatment versus control. Red convex hull represents number of burns.

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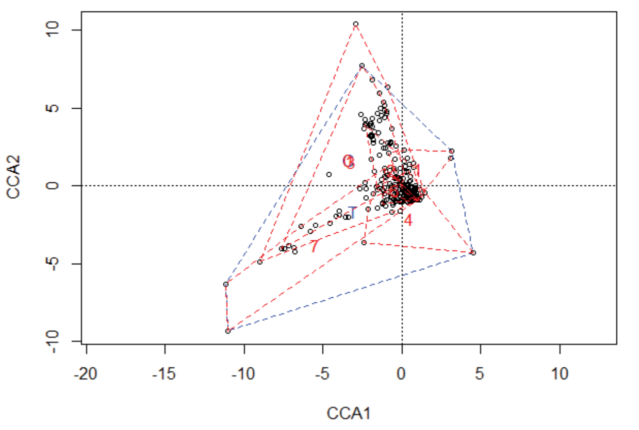

Figure 8: Small trees ordination based on pre-post, treatment assignment, and treatment levels. Blue convex hull represents treatment versus control. Red convex hull represents number of burns.

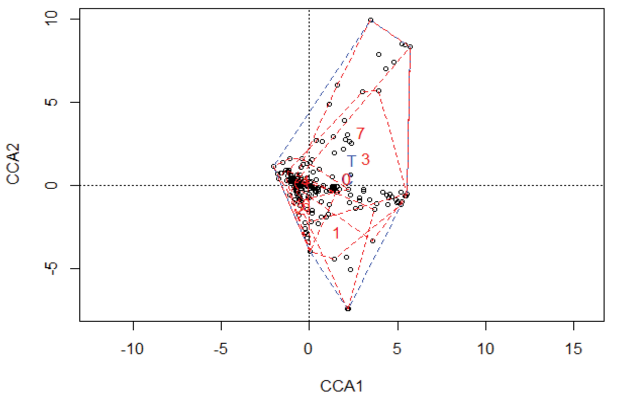

Figure 9: Large Saplings ordination based on pre-post, treatment assignment, and treatment levels. Blue convex hull represents treatment versus control. Red convex hull represents number of burns.

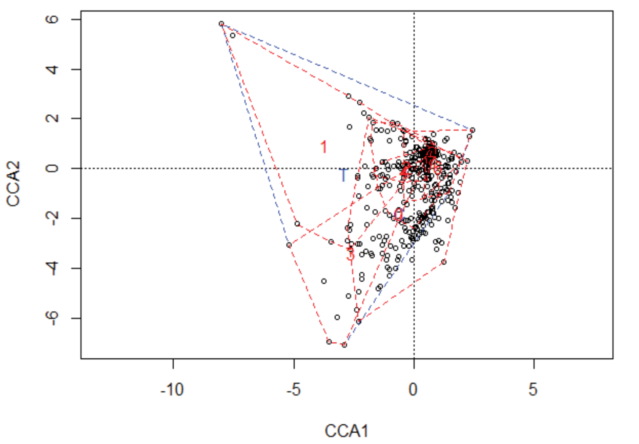

Figure 10: Seedlings ordination based on pre-post, treatment assignment, and treatment levels. Blue convex hull represents treatment versus control. Red convex hull represents number of burns.

of management treatments and restoration techniques to restore forest conditions including mechanical and chemical treatments will effectively open the midstory vegetation and dense overstory.

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References

1. Simberloff D (1993) Species area and fragmentation effects on old growth forest: Prospects for longleaf pine communities. Proceedings 18th Tall Timbers Fire Ecology Conference. Tall Timbers Research Station, Tallahassee, Florida, USA, pp: 1-13.
2. Frost CC (1993) Four centuries of changing landscape patterns in the longleaf pine ecosystem. In: Hermann SM (ed.), The longleaf pine ecosystem: ecology, restoration, and management. Proceedings 18th Tall Timbers Fire Ecology Conference. Tall Timbers Research Inc., Tallahassee, Florida, pp: 17-43.
3. Harcombe PA, Glitzenstein JS, Knox RG, Orzell SL, Bridges EL (1993) Vegetation of the longleaf pine region of the west gulf coastal plain. In: Hermann SM (ed.), The longleaf pine ecosystem: ecology, restoration, and management. Proceedings 18th Tall Timbers Fire Ecology Conference, Tall Timbers Research Inc., Tallahassee, Florida, pp: 83-104.
4. Barnett JP (1999) Longleaf Pine Ecosystem Restoration: The Role of Fire. Journal of Sustainable Forestry 9: 89-96.
5. Smith L (2001) The History and Character of Longleaf Pine Systems in the West. In: Kush JS (ed.), Forest for our future - restoration and management of longleaf pine ecosystems: Silvicultural, ecological, social, political, and economic challenges. Proceedings of the 3rd Longleaf Alliance Conference, Alexandria, LA. Longleaf Alliance Report No. 5, pp: 1-3.
6. Outcalt KW (2001) Natural stand dynamics in longleaf pine: how climate disturbances shape the community. In: Kush JS (ed.), Forest for our future - restoration and management of longleaf pine ecosystems: Silvicultural, ecological, social, political, and economic challenges. Proceedings of the 3rd Longleaf Alliance Conference, Alexandria, LA. Longleaf Alliance Report No. 5, pp: 29-31.
7. Means BD (1996) Longleaf Pine Forest: Importance to Biodiversity. In: Kush JS (ed.), Longleaf Pine: A Regional Perspective of Challenges and Opportunities. Proceedings of the 1st Longleaf Alliance Conference, Mobile, AL. Longleaf Alliance Report No. 1, pp: 12-14.
8. Johnson R, Gjerstad D (1998) Landscape-Scale Restoration of the Longleaf Pine Ecosystem. Restoration and Management Notes 16: 41-45.
9. Robbins LE, Myers RL (1992) Seasonal effects of prescribed burning in Florida: a review. Tall Timbers Research Inc., Miscellaneous Publication No. 8.
10. Goebel PC, Palik BJ, Kirkman LK, Drew MB, West L, et al. (2001) Forest ecosystems of a Lower Gulf Coastal Plain landscape: multifactor classification and analysis. Journal of the Torrey Botanical Society 128: 47-75.
11. Stambaugh MC, Guyette RP, Marschall JM (2011) Longleaf pine (Pinus palustris Mill.) fire scars reveal new details of a frequent fire regime. Journal of Vegetation Science 22: 1094-1104.
12. Waldrop TA, White DL, Jones SM (1992) Fire regimes for pine-grassland communities in the southeastern United States. Forest Ecology and Management 47: 195-210.
13. Hermann SM (2001) A brief overview of fire and season of burn in native longleaf pine ecosystems. In: Kush JS (ed.), Forest for our future-restoration and management of longleaf pine ecosystems: silvicultural, ecological, social, political, and economic challenges. Proceedings of the 3rd Longleaf Alliance Conference, Alexandria, LA. Longleaf Alliance Report No. 5, pp: 53-57.
14. Heyward F (1939) The relation of fire to stand composition of longleaf pine forests. Ecology 20: 287-304.
15. Landers JL, Van-Lear DH, Boyer WD (1995) The longleaf pine forests of the southeast: requiem or renaissance? Journal of Forestry 93: 39-44.
16. Haywood JD, Grelen HE (2000) Twenty years of prescribed burning influence the development of direct-seeded longleaf pine on a wet pine site in Louisiana. Southern Journal of Applied Forestry 24: 86-92.

17. Glitzenstein JS, Platt WJ, Streng DR (1995) Effects of fire regime and habitat on tree dynamics in north Florida longleaf pine savannas. Ecological 83: 755-767.

18. Hodgkins EJ (1958) Effects of fire on undergrowth vegetation in upland southern pine forests. Ecology 39: 36-46.

19. Streng DR, Harcombe PA (1982) Why don't east Texas savannas grow up to forest? American Midland Naturalist 108: 278-294.

20. Drewa PB, Platt WJ, Moser EB (2002) Fire effects on resprouting of shrubs in headwaters of southeastern longleaf pine savannas. Ecology, pp: 755-767.

21. Liu C, Harcombe PA, Knox RG (1997) Effects of prescribed fire on the composition of woody plant communities in southeastern Texas. Journal of Vegetation Science 8: 495-504.

22. Platt WJ, Glitzenstein JS, Streng DR (1991) Evaluating pyrogenicity and its effects on vegetation in longleaf pine savannas. In: Hermann SM (ed.), High intensity fire in wildlands. Proceedings 17th Tall Timbers Fire Ecology Conference, Tall Timbers Research Inc., Tallahassee, Florida, USA, pp: 143-161.

23. Kush JS, Meldahl RS, Boyer WD (2000) Understory plant community response to season of burn in natural longleaf pine forests. Tall Timbers Fire Ecology Conference Proceedings 21: 32-39.

24. Marks PL, Harcombe PA (1981) Forest vegetation of the Big Thicket, southeast Texas. Ecological Monographs 51: 287-305.

25. Jurney D, Evans R, Ippolito J, Bergstrom V (2001) Fire history of the west gulf coastal plain. In: Kush JS (ed.), Forest for our future - restoration and management of longleaf pine ecosystems: silvicultural, ecological, social, political, and economic challenges. Proceedings of the 3rd Longleaf Alliance Conference, Alexandria, LA. Longleaf Alliance Report No. 5, pp: 13-15.