THE INFLUENCE OF SUMMER WILDFIRES VERSUS WINTER CONTROLLED

BURNS ON FOREST COMPOSTTION ON SAPLEO ISLAND, GEORGIA

by

NATHAN R. VODAS

(Under the Direction of Albert J. Parker)

ABSTRACT

Controlled burns have been recently implemented on Sapelo Island, Georgia, to try to prevent wildfires. This study compares vegetation differences between summer wildfires started by lightning and winter control burns set by the Georgia Department of Natural Resources over the past six years. Thirty 10 X 25m control burn plots and ten 50X 25m wildfire plots were set up to see if vegetation composition in the overstory and understory changed following fire. Few measurable differences were seen between fire types, while year of burn had more meaningful results. Saw palmetto showed no statistical differences between fire types, while difference between years showed significant differences likely due to competition for light. Laurel oak is shade tolerant and was able to make it through the understory during the fire suppression era. With the reintroduction of controlled fire laurel oak should start to decrease. Species diversity increased on overstory plots with rapidly change occurring on wildfire plots.

INDEX WORDS: wildfires, controlled burns, Sapelo Island, Georgia

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DEDICATION

To my Mom and Dad -

Thank your for making the sacrifices that allowed me to improve myself

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# Chapter 1

# INTRODUCTION

Fire is a common disturbance agent in southern forests, both natural (lightning-ignited) and human-caused. In the past several decades vegetation managers in the coastal plain forest of the southeastern United States have adopted prescribed burn techniques to reintroduce fire into areas that have been historically altered by fire suppression. Controlled burns normally are set in the winter or spring, when cooler temperatures permit better control of fire spread. By contrast, natural fires are most common in mid-late summer in the southeastern coastal plain, when temperatures are highest, drought stress may become severe, and thunderstorms frequency is high. Hence there is a stark contrast in fire seasonality typical of controlled versus wildfire burns. This thesis explores the differences in woody plant species composition and diversity associated with these starkly contrasting fire regimes on Sapelo Island, a barrier island located along the coast of Georgia.

## Timing and Types of Fire

Fire seasonality may differentially influence the prevalence of pines and oaks in post-burn patches. In the pine barrens of New Jersey, Boerner (1981) found that wildfire decreased the biomass of both pine and oak species, whereas prescribed burns had little effect on tree biomass or survival. In southwestern Wisconsin the shade cast by the understory layer, rather than the canopy itself, was found to hinder the survival of oak seedlings (Lorimer et al. 1994), signifying the importance of repeated controlled burns on oak seedling recruitment. Thus, repeated prescribed burns in the understory can effectively promote oak regeneration by controlling the sprouting of other species (Arthur et al. 1998).

To try to reduce the number of wildfires and increase the live oak (*Quercus virginiana*) dominated hammock vegetation in the overstory on Sapelo Island, the Georgia Department of Natural Resources (GDNR) periodically conducts controlled winter burns over parts of the island to minimize the underbrush, which if left to accumulate, would elevate wildfire potential. When large wildfires do occur, they rarely consume the whole forest because of topography, variable wind velocity, the presence of natural fire breaks, vegetation type, fuel load, and fuel moisture status at the time of the fire. This results in a heterogeneous pattern of burn severity (Turner et al. 1994).

Wild and controlled fires will be compared in this study, to test for significant differences in species composition and diversity. Vegetation managers on Sapelo Island provided several maps of historical burns, with each patch categorized according to burn type/season (winter-spring control burns versus summer wildfires) and year of most recent burning. I assigned all burned patches to one of six categories: controlled burns occurring in 1996-97, 1998-99, 2000-01; and wildfires occurring in 1996-97, 1998-99, 2000-01.

## Research Objectives

This study will compare summer wildfires versus winter controlled fires to see if a change in the burn season yields different vegetation composition on Sapelo Island.

The study is significant in that it will help GDNR determine whether it is achieving the goal of increasing the hammock ecosystem, which is believed to be the climax community on the island, by having controlled burns during winter, and suppressing summer wildfires which can devastate the hammock ecosystem.

The specific research hypotheses of this thesis are that:

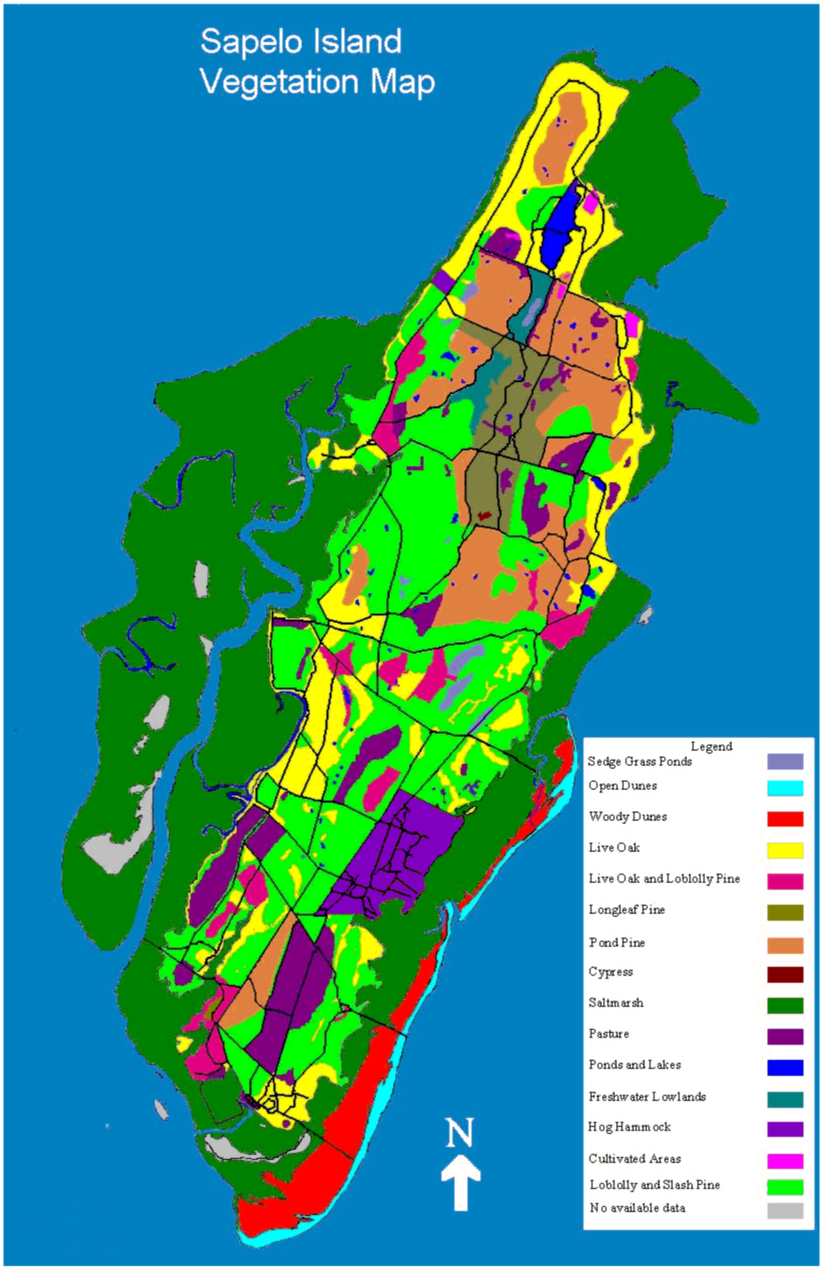
1. Species diversity will be higher in the most recently burned plots.
2. For a given burn age, wildfire plots will have a greater species diversity than the controlled burned sites.
3. Saw palmetto will not show significant differences between control and wild fire burns.
4. Oak species will increase in coverage in controlled burn sites, whereas pine species will increase in coverage in wildfire burn sites.

# Chapter 2

## STUDY AREA

Sapelo Island is the fourth largest island in a string of barrier islands off the coast of Georgia. It is located approximately 80 km south of Savannah, Georgia. Sapelo Island is a remnant of Pleistocene barrier islands. Its core formed approximately 111,000 to 25,000 BP, while the beach ridges along its seaward margin accreted to it during the Holocene. The soils of Sapelo Island are derived mainly from quartz sand and have a high permeability, which results in low water holding capacity and rapid leaching (Sullivan 1999).

Sapelo Island is located in a subtropical climate, and experiences short, mild, winters and long, hot, humid summers. Weather data have been collected continuously on Sapelo Island since 1957. From these data, the average high in summer is 31.4$^{o}$C and the average low in summer is 26.8$^{o}$C. The average high in winter is 16.7$^{o}$C and the average low in winter is 11.2$^{o}$C. The average annual rainfall on Sapelo Island is 132.26 cm. Rainfall is heaviest during late summer and early fall months due to hurricanes and tropical storms. On average, every month has at least 5.1 centimeters of rain, with as much as 18.31 centimeters of rain occurring in September (Southeast Regional Climate Center 2003). Sapelo Island has not suffered severe damage from a major hurricane since the late nineteenth century, but has been near the path of a hurricane several times, resulting in moderate wind damage and coastal beach erosion (Chalmers 1997).




Scale 1in=1550m

Figure 2.1 Sapelo Island Vegetation Map

The vegetation of the upland area of Sapelo Island includes pine flatwoods, scrubby flatwoods, prairies, hammocks, and swamps (Figure 2.1, Myers and Ewel 1990). Pine flatwoods dominate much of Sapelo Island. Flatwood stands are generally characterized by an open overstory of pines, an extensive low understory of wax myrtle

(*Myrica cerifera*), saw palmetto (*Serenoa repens*), and a sparse herbaceous layer. Fire strongly influences flatwood community structure and composition. The three dominant pines are longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii var. elliottii*), and pond pine (*Pinus serotina*), arranged sequentially along a topographic gradient from upland (more xeric) to lowland (more hydric) sites. Slash pine is less fire-tolerant then longleaf pine; thus slash pine is restricted to more mesic, less frequently burned sites. Pond pine is restricted to more acidic, poorly drained sites and often occurs with red bay (*Persea borbonia*) in the understory (Abrahamson and Hartnett 1990, Monk 1968). The scrubby flatwoods are slightly higher topographically and occupy better drained sites than pine flatwoods. Most of the vegetation in the scrubby flatwoods has small, leathery, tough leaves that often have revolute leaf margins, such as sand live oak (*Quercus geminata*). The dominant overstory pine in the scrubby flatwoods is longleaf pine, and the understory is dominated by saw palmetto. As with the flatwoods, fire plays a prominent role in structuring scrubby flatwoods vegetation.

Prairies on Sapelo Island are open grassy expanses that include broomsedge (*Andropogon virginicus*), dwarf blueberry (*Vaccinium myrsinites*), wax myrtle, and cabbage palm (*Sabal palmetto*) (Abrahamson and Hartnett 1990).

Hammocks are temperate hardwood forests often found in narrow bands a few hundred meters wide. They occupy terrain between upland pine areas and bottomlands. Prominent hammock species include cabbage palm, laurel oak (*Quercus hemisphaerica*), southern magnolia (*Magnolia grandiflora*), water oak (*Quercus nigra*), and live oak (Platt and Schwartz 1990).

Freshwater swamps on Sapelo Island are associated with saturated soils or standing water for at least part of the year. All inland swamps are stillwater swamps, fed primarily through rainfall and groundwater. The dominant species found in swamps are swamp black gum (*Nyssa sylvatica* var *biflora*) and pond cypress (*Taxodium ascendens*).

Conventional wisdom holds that if fire were suppressed for long periods of time, most of the upland flatwood vegetation on Sapelo Island would presumably shift compositionally toward mesic hammock communities, which are dominated by live oak, laurel oak, and southern magnolia. With fire suppression the scrubby flatwoods would also presumably undergo slow structural change, eventually shifting toward a xeric hammock community dominated by sand live oak (Menges and Hawkes 1998).

Fires often burn completely through the understory of flatwood sites, preventing the invasion of hardwood species into the pine flatwoods. The species richness immediately increases following fire in pine flatwood settings. As time passes, species richness decreases, eventually returning to preburn levels (Mehlman 1992). The scrubby flatwoods burn very heterogeneously, causing some areas to be lightly burned and other areas to be totally burned every 5-20 years. The shrubs in the scrubby flatwoods rapidly return to preburn levels through sprouting within a few years after the fire, with little increase in species diversity (Menges and Hawkes 1998, Abrahamson and Hartnett 1990, Abrahamson 1984a).  Saw palmetto returns to preburn levels within one year after fire and sabal palmetto returns to preburn levels within five years after fire in the scrubby flatwoods (Abrahamson 1984b).

In hammocks, fires generally start in surrounding habitats and creep into the area, burning only litter in the hammock. These fires generally occur when extended periods of drought cause the soil to dry out. Drought and fire play a major role in maintaining high, xeric hammocks on upper slopes, while many midslope hammocks tend to be mesic forest into which fires burn less frequently (Platt and Schwartz 1990). Many swamp tree species cannot resist fire, which causes the shape of swamps and cypress ponds to be controlled by burning patterns. Many other species, such as pond pine, generally occur at the edge of swamps and depend on fire, as evidenced by their serotinous cones. When fire does occur, pond cypress survives more readily than many of the hardwoods in these swamps (Ewel 1990).

The first evidence of human activity on Sapelo Island dates from approximately 4000 years ago, when prehistoric Native Americans left behind shell middens, earthen mounds, and pottery fragments. During the 17$^{th}$ century, the Spanish established missions, but by the end of the 17$^{th}$ century Sapelo Island became a British colony. In 1733 Sapelo Island became a part of the newly formed colony of Georgia. The island remained in private ownership from 1802 to 1969 and was used for producing cotton and sugar on plantations. In 1969 Annemarie Reynolds sold the northern half of the island to the State of Georgia to be administered by the GDNR. The rest of the island, with the exception of Hog Hammock and a small portion at the south end where the lighthouse is located, is under the control of the Sapelo Research Foundation (Chalmers 1997).

## Chapter 3

## METHODS

### Field Methods

Potential sample sites were selected randomly from an array of burn patches representing flatwoods, scrubby flatwoods, and hammocks of known recent fire history. The management history of these patches is known, including when they were burned and the seasonal timing and nature of the burn. A random point file was created with 300 coordinates in the vicinity of Sapelo Island using Erdas Imagine. The projection used to produce the point file was a Universal Transverse Mercator (UTM) projection in Zone 17R. These coordinates were plotted in Arc View 3.2 as an event theme. Next, eleven control burn maps of Sapelo Island were received from GDNR with dates of fires ranging from December 1995 to January 2001. These maps were used to create a new color-coordinated control burn map that showed when the last controlled burn occurred in each part of Sapelo Island. Burn years were categorized into three two-year increments: 1996-1997 burns, 1998-1999 burns, and 2000-2001 burns. From this map, ten random points were selected that were closest to road access in areas that had been affected by fires in each of the three controlled burns timing categories, resulting in a total of 30 controlled burn sample plots.

Each random data point selected for study defines the northeast corner of a 10 x 25m plot. A Garmin GPS 12 was used to navigate to the coordinates of the randomly generated point. This corner was then marked with a half inch piece of PVC. Next a steel tape and a lensatic compass were used to mark off the remaining three corners of the plot, as well as the midpoint of the 25m boundary lines. Collectively the total area sampled in the 30 controlled burn sites was 0.75 ha. Wildfires comprise fewer, larger patches on Sapelo Island, so that random selection of 10 distinct patches of each burn type was not possible. To match sampling areas for controlled burn plots, I sampled five contiguous 10 x 25m plots in each of two wildfire patches for each burn age category. Each 10 x 25m plot was treated separately in data analysis; so that there are ten $250m^2$ plots in each of the six patch types (2 burn treatments x 3 burn ages). In total 1.5 ha of area was sampled for this study.

Sixty plots were initially sampled in summer 2002. Twelve of these plots were subsequently deemed unsuitable due to errors in the record of management history. The 12 plots were replaced by 12 other plots sampled in March 2003. No PVC pipe was placed in any of the plots sampled in March 2003, but all other techniques followed the sampling protocol described above.

Each plot was sampled for overstory and understory species composition and the spatial distribution of cover by species was drawn on graph paper. Each square on the graph paper represented a 1m x 1m area that was sampled in the field. If tree or shrub species overlapped, then the tree or shrub that could be seen from the line of sight on the ground over that spot was mapped as the species occupying that area in the overstory or understory of that plot. Areas labeled open on the understory plots were areas of bare ground, and areas labeled open on the overstory plots were areas that had no canopy coverage.

Analytical Methods

Areal cover of overstory and understory species in each plot was calculated with a geographic information system. Species cover values were imported into SPSS 11.0 for Windows, and a two-way analysis of variance was done to find if there was a systematic contrast in species composition among two main effects: burn type and time since last fire, plus their interaction. Species cover was compared for 19 species in the understory and14 species in the overstory. The following species were examined closely: live oak, laurel oak, water oak, longleaf pine, slash pine, loblolly pine (*Pinus taeda*), and pond pine in the overstory, and saw palmetto, wax myrtle, grass, and red bay in the understory. Bare ground in the understory and open areas in the overstory were also calculated and examined for systematic contrast between control burns and wildfires. Vegetation data often widely depart from the assumptions of ANOVA, which are normal distribution and equal variance in each group. The cover data from Sapelo Island collected in this study contains many zero values, and does not meet strict ANOVA requirements. With this in mind, the results should be guardedly accepted; the main findings are more than likely valid, since ANOVA results are very robust.

To determine if the seasonality of burn is systematically affecting species diversity, two-way ANOVA was used to detect significant differences in the Shannon-Weiner Diversity Index. The formula for the Shannon-Weiner Diversity Index is $H' = -\Sigma p_i \ln p_i$, where $p_i$ represents the proportion of individuals belonging to species i; and values range from a value of 0.00 for plots with one species, and a value up to 7.00 or more for plots that are rich in species (Barbour et al. 1987).

Detrended Correspondence Analysis (DCA) was used to arrange sample plots according to species composition of the understory and the overstory layer. DCA arranges plots based on similarity; plots with many shared species will be placed close to each other on a DCA diagram, while dissimilar plots will be widely separated. Two-way ANOVA was used to detect significant differences in DCA axis scores associated with burn type and time since last burn categories. In this case, DCA axis scores are being used as summary variables for overall species composition.

# Chapter 4

# RESULTS

This chapter provides a quantitative summary of the effects of different burn treatments and recovery periods on the species composition and diversity of both understory and overstory layers of vegetation in upland areas of Sapelo Island. This chapter includes: descriptive statistics of species cover and Shannon-Weiner diversity index values, results from two-way ANOVA models that test for differences in species composition and diversity associated with burn type and time since last fire, and the results of detrended correspondence analysis (DCA).

## Understory Composition

The understory on Sapelo Island was composed of many different plant species in burned areas (Tables 4.1, 4.2, and 4.3). Bare ground covers large areas in many of the recently burned plots (25.6% of the total area). Saw palmetto and grass were the two dominant understory vegetation components in the areas that have been burned on Sapelo Island during the past six years. Common minor associates on burned plots included loblolly pine, red bay, switch cane, wax myrtle and yaupon holly. Laurel oak, live oak, and wax myrtle were more prevalent in the understory of controlled burns than in the understory of wildfire plots. By contrast, American holly, slash pine, and yaupon holly were more common in wildfire plots on Sapelo Island than on controlled burn plots.

Table 4.1 Average Cover Values in $m^2$ for Each "Species" in the Understory

| Species | Controlled burn Plots | | Wild Fire Plots | | Average for Plots All | |
|---|---|---|---|---|---|---|
| | Mean | Standard Deviation | Mean | Standard Deviation | Mean | Standard Deviation |
| Bare ground | 60.561 | 76.675 | 67.481 | 84.829 | 64.021 | 80.242 |
| American holly | 0.002 | 0.010 | 6.984 | 22.257 | 3.493 | 15.997 |
| Cabbage palm | 0.222 | 0.844 | 0.212 | 0.550 | 0.217 | 0.706 |
| Cactus | 0.036 | 0.197 | 0.000 | 0.000 | 0.018 | 0.140 |
| Fern | 0.000 | 0.000 | 1.736 | 8.978 | 0.868 | 6.355 |
| Grass | 48.979 | 86.484 | 51.799 | 64.332 | 50.388 | 75.582 |
| Hickory | 0.047 | 0.259 | 0.000 | 0.000 | 0.024 | 0.183 |
| Laurel oak | 7.773 | 29.903 | 0.000 | 0.000 | 3.886 | 21.328 |
| Live oak | 4.788 | 24.346 | 0.998 | 5.467 | 2.893 | 17.598 |
| Loblolly pine | 16.960 | 36.824 | 12.206 | 32.493 | 14.583 | 34.514 |
| Longleaf pine | 0.123 | 0.610 | 0.000 | 0.000 | 0.061 | 0.432 |
| Pond pine | 0.000 | 0.000 | 1.048 | 3.546 | 0.524 | 2.542 |
| Red bay | 13.275 | 37.306 | 9.015 | 17.463 | 11.145 | 28.958 |
| Saw palmetto | 54.080 | 84.981 | 64.050 | 89.538 | 59.065 | 86.692 |
| Slash pine | 0.000 | 0.000 | 3.691 | 10.179 | 1.845 | 7.373 |
| Sweet gum | 2.046 | 11.207 | 0.000 | 0.000 | 1.023 | 7.925 |
| Switch cane | 20.328 | 54.730 | 3.029 | 13.430 | 11.678 | 40.460 |
| Water oak | 0.593 | 3.250 | 0.000 | 0.000 | 0.297 | 2.298 |
| Wax myrtle | 15.527 | 38.119 | 8.226 | 17.239 | 11.877 | 29.561 |
| Yaupon holly | 4.659 | 13.384 | 19.524 | 38.820 | 12.091 | 29.748 |

Table 4.2 Average Cover Values in $m^2$ for Each "Species" by Years in the Understory Control Burn Plots

| Species | Control Burn Plots | | | | | |
|---|---|---|---|---|---|---|
| | 1996-1997 | Standard Deviation | 1998-1999 | Standard Deviation | 2000-2001 | Standard Deviation |
| Bare ground | 20.040 | 34.245 | 84.766 | 93.326 | 76.878 | 79.308 |
| American holly | 0.000 | 0.000 | 0.006 | 0.018 | 0.000 | 0.000 |
| Cabbage palm | 0.000 | 0.000 | 0.618 | 1.412 | 0.047 | 0.149 |
| Cactus | 0.000 | 0.000 | 0.108 | 0.342 | 0.000 | 0.000 |
| Fern | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Grass | 72.431 | 83.559 | 49.330 | 98.795 | 25.169 | 78.210 |
| Hickory | 0.000 | 0.000 | 0.142 | 0.449 | 0.000 | 0.000 |
| Laurel oak | 20.824 | 50.317 | 0.000 | 0.000 | 2.494 | 7.888 |
| Live oak | 0.000 | 0.000 | 13.330 | 42.154 | 1.035 | 3.272 |
| Loblolly pine | 33.367 | 54.534 | 5.246 | 16.253 | 12.268 | 25.597 |
| Longleaf pine | 0.000 | 0.000 | 0.334 | 1.055 | 0.035 | 0.110 |
| Pond pine | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Red bay | 6.916 | 14.550 | 10.727 | 28.959 | 22.183 | 57.392 |
| Saw palmetto | 50.808 | 87.055 | 49.303 | 85.708 | 62.130 | 90.756 |
| Slash pine | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Sweet gum | 0.000 | 0.000 | 0.000 | 0.000 | 6.138 | 19.411 |
| Switch cane | 22.548 | 52.540 | 32.220 | 78.731 | 6.218 | 17.573 |
| Water oak | 0.000 | 0.000 | 0.000 | 0.000 | 1.780 | 5.629 |
| Wax myrtle | 17.438 | 32.952 | 3.369 | 5.344 | 25.776 | 57.294 |
| Yaupon holly | 5.629 | 17.801 | 0.501 | 1.187 | 7.847 | 15.078 |

Table 4.3 Average Cover Values in $m^2$ for Each “Species” by Years in the Understory Wildfire Plots

| Species | Wildfire Plots | | | | | |
|---|---|---|---|---|---|---|
| | 1996-1997 | Standard Deviation | 1998-1999 | Standard Deviation | 2000-2001 | Standard Deviation |
| Bare ground | 155.509 | 79.390 | 40.471 | 55.816 | 6.466 | 14.552 |
| American holly | 20.952 | 35.652 | 0.000 | 0.000 | 0.000 | 0.000 |
| Cabbage palm | 0.636 | 0.822 | 0.000 | 0.000 | 0.000 | 0.000 |
| Cactus | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Fern | 0.000 | 0.000 | 0.000 | 0.000 | 5.206 | 15.480 |
| Grass | 4.299 | 8.929 | 129.935 | 36.530 | 21.164 | 39.850 |
| Hickory | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Laurel oak | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Live oak | 2.994 | 9.469 | 0.000 | 0.000 | 0.000 | 0.000 |
| Loblolly pine | 36.619 | 49.079 | 0.000 | 0.000 | 0.000 | 0.000 |
| Longleaf pine | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Pond pine | 0.000 | 0.000 | 0.000 | 0.000 | 3.143 | 5.762 |
| Red bay | 0.000 | 0.000 | 0.000 | 0.000 | 27.045 | 20.996 |
| Saw palmetto | 13.163 | 25.075 | 0.422 | 0.620 | 178.565 | 57.076 |
| Slash pine | 0.000 | 0.000 | 11.072 | 15.590 | 0.000 | 0.000 |
| Sweet gum | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Switch cane | 0.000 | 0.000 | 9.086 | 22.805 | 0.000 | 0.000 |
| Water oak | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Wax myrtle | 15.827 | 24.275 | 0.440 | 0.934 | 8.411 | 15.356 |
| Yaupon holly | 0.000 | 0.000 | 58.574 | 48.109 | 0.000 | 0.000 |

There were significant differences in means for bare ground, loblolly pine, grass, and saw palmetto in the overall two-way ANOVA model for understory composition (Table 4.4). Burn type produced no significant contrast in composition, whereas differences among the three age categories were significant for grass, loblolly pine and saw palmetto. Likewise burn type/ age interactions were significant for bare ground, grass and saw palmetto cover in the understory.  A significant interaction term suggests that burn type is indirectly influencing aerial coverage of plant species. Specifically, the response of the vegetation variable across the range of burn ages differs significantly with burn type.

Table 4.4 ANOVA of the Understory Composition on Sapelo Island

Statistically significant models outcomes, main effects, and interaction terms are emphasized with bold type.

| | Model | | Burn Type | | Year | | Burn Type * Year | |
|---|---|---|---|---|---|---|---|---|
| | F | P | F | P | F | P | F | P |
| Bare Ground | **6.868** | **0.000** | 0.167 | 0.684 | 2.478 | 0.093 | **14.608** | **0.000** |
| Grass | **4.839** | **0.001** | 0.028 | 0.868 | **5.628** | **0.006** | **6.456** | **0.003** |
| Loblolly Pine | **2.583** | **0.036** | 0.323 | 0.572 | **6.007** | **0.004** | 0.288 | 0.751 |
| Saw Palmetto | **8.873** | **0.000** | 0.331 | 0.468 | **12.553** | **0.000** | **9.464** | **0.000** |

Overstory composition

The overstory is made up of small and large individuals of a number of tree species in burned areas of Sapelo Island (Tables 4.5, 4.6, and 4.7).  Open canopies from recent burns encompassed large areas in the overstory of many of the plots, especially the wildfire plots, which averaged 38.1% of canopy openness. Live oak and slash pine were the dominant tree species in areas that have been burned during the past six years on Sapelo Island. Other species, such as laurel oak, loblolly pine, pond pine, and water oak were minor overstory associates in sampled plots. Longleaf pine, loblolly pine, and live oak were more evident in areas that have been controlled burned, whereas pond pine and laurel oak were more commonly found in wildfire plots and were statistically significant in the overstory plots.

Table 4.5 Average Cover Values in $m^2$ for Each "Species" in the Overstory

| Species | Control Plots | | Wild Fire Plots | | Average for All Plots | |
|---|---|---|---|---|---|---|
| | Mean | Standard Deviation | Mean | Standard Deviation | Mean | Standard Deviation |
| Open | 75.140 | 64.480 | 115.690 | 84.427 | 95.419 | 77.236 |
| American holly | 0.000 | 0.000 | 1.266 | 4.299 | 0.633 | 3.081 |
| Cabbage palm | 0.000 | 0.000 | 1.570 | 7.385 | 0.785 | 5.238 |
| Laurel oak | 14.633 | 40.419 | 25.495 | 49.088 | 20.064 | 44.915 |
| Live oak | 63.406 | 87.634 | 41.675 | 76.540 | 52.540 | 82.306 |
| Loblolly pine | 32.827 | 54.723 | 8.711 | 23.094 | 20.769 | 43.381 |
| Longleaf pine | 12.542 | 44.961 | 0.000 | 0.000 | 6.271 | 32.149 |
| Pond pine | 4.497 | 16.385 | 15.833 | 28.176 | 10.165 | 23.555 |
| Red bay | 0.379 | 1.759 | 0.000 | 0.000 | 0.190 | 1.248 |
| Red maple | 3.808 | 14.492 | 0.000 | 0.000 | 1.904 | 10.340 |
| Slash pine | 28.478 | 45.652 | 27.803 | 57.452 | 28.141 | 51.448 |
| Swamp magnolia | 0.000 | 0.000 | 2.566 | 10.036 | 1.283 | 7.154 |
| Sweet gum | 1.412 | 6.854 | 0.000 | 0.000 | 0.706 | 4.858 |
| Water oak | 12.060 | 28.922 | 9.382 | 27.830 | 10.720 | 28.172 |
| Wax myrtle | 0.816 | 4.471 | 0.000 | 0.000 | 0.408 | 3.162 |

Table 4.6 Average Cover Values in m$^2$ for Each “Species” by Years in the Overstory Control Burn Plots

| Species | Control Burn Plots | | | | | |
|---|---|---|---|---|---|---|
| | 1996-1997 | Standard Deviation | 1998-1999 | Standard Deviation | 2000-2001 | Standard Deviation |
| Open | 65.889 | 58.797 | 74.141 | 62.539 | 85.393 | 76.263 |
| American holly | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Cabbage palm | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Laurel oak | 26.619 | 48.111 | 16.050 | 50.754 | 1.231 | 3.458 |
| Live oak | 65.134 | 91.447 | 58.016 | 79.402 | 67.069 | 100.138 |
| Loblolly pine | 44.354 | 53.225 | 5.659 | 17.894 | 48.468 | 72.501 |
| Longleaf pine | 0.000 | 0.000 | 33.946 | 74.880 | 3.680 | 11.639 |
| Pond pine | 0.000 | 0.000 | 12.786 | 27.301 | 0.704 | 2.227 |
| Red bay | 0.000 | 0.000 | 0.952 | 3.010 | 0.185 | 0.585 |
| Red Maple | 11.424 | 24.085 | 0.000 | 0.000 | 0.000 | 0.000 |
| Slash pine | 25.412 | 43.467 | 41.558 | 56.238 | 18.466 | 36.761 |
| Swamp Magnolia | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Sweetgum | 0.000 | 0.000 | 0.000 | 0.000 | 4.235 | 11.752 |
| Water oak | 8.719 | 14.617 | 6.893 | 21.797 | 20.569 | 43.406 |
| Wax myrtle | 2.449 | 7.744 | 0.000 | 0.000 | 0.000 | 0.000 |

Table 4.7 Average Cover Values in $m^2$ for Each "Species" by Years in the Overstory Wildfire Plots

| Species | Wildfire Plots | | | | | |
|---|---|---|---|---|---|---|
| | 1996-1997 | Standard Deviation | 1998-1999 | Standard Deviation | 2000-2001 | Standard Deviation |
| Open | 69.702 | 53.850 | 74.892 | 81.293 | 202.501 | 29.780 |
| American holly | 3.797 | 6.991 | 0.000 | 0.000 | 0.000 | 0.000 |
| Cabbage palm | 4.709 | 12.622 | 0.000 | 0.000 | 0.000 | 0.000 |
| Laurel oak | 76.486 | 58.574 | 0.000 | 0.000 | 0.000 | 0.000 |
| Live oak | 33.329 | 57.613 | 91.698 | 103.780 | 0.000 | 0.000 |
| Loblolly pine | 26.134 | 34.823 | 0.000 | 0.000 | 0.000 | 0.000 |
| Longleaf pine | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Pond pine | 0.000 | 0.000 | 0.000 | 0.000 | 47.499 | 29.780 |
| Red bay | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Red Maple | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Slash pine | 0.000 | 0.000 | 83.410 | 74.041 | 0.000 | 0.000 |
| Swamp Magnolia | 7.699 | 16.753 | 0.000 | 0.000 | 0.000 | 0.000 |
| Sweetgum | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Water oak | 28.145 | 43.690 | 0.000 | 0.000 | 0.000 | 0.000 |
| Wax myrtle | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

In the overstory two-way ANOVA overall model, there were significant differences associated with open areas, laurel oak cover, and pond pine cover. Significant differences between burn types were evident for open areas and pond pine cover. For both year and burn type *year interactions, significant differences were identified for open areas, laurel oak cover, and pond pine cover. Canopy cover was significantly greater in control burn plots than in wildfire plots.

Table 4.8 ANOVA of the Overstory Composition on Sapelo Island
Statistically significant models outcomes, main effects, and interaction terms are emphasized with bold type.

| | Model | | Burn Type | | Year | | Burn Type * Year | |
|---|---|---|---|---|---|---|---|---|
| | F | P | F | P | F | P | F | P |
| Open | **7.112** | **0.000** | **6.278** | **0.015** | **9.046** | **0.000** | **5.595** | **0.006** |
| Laurel Oak | **6.339** | **0.000** | 1.274 | 0.264 | **10.906** | **0.000** | **4.305** | **0.018** |
| Pond Pine | **13.195** | **0.000** | **7.065** | **0.010** | **11.427** | **0.000** | **18.029** | **0.000** |

Understory Diversity

Average understory diversity index values were higher in more recently burned wildfire plots (Figure 4.1). Understory diversity values declined in the oldest wildfire plots. By contrast, understory diversity on control burn plots was greatest on the oldest plots.

The two-way ANOVA model based on understory Shannon-Weiner diversity index values did not yield a statistically significant outcome (F=2.302; P=0.05).

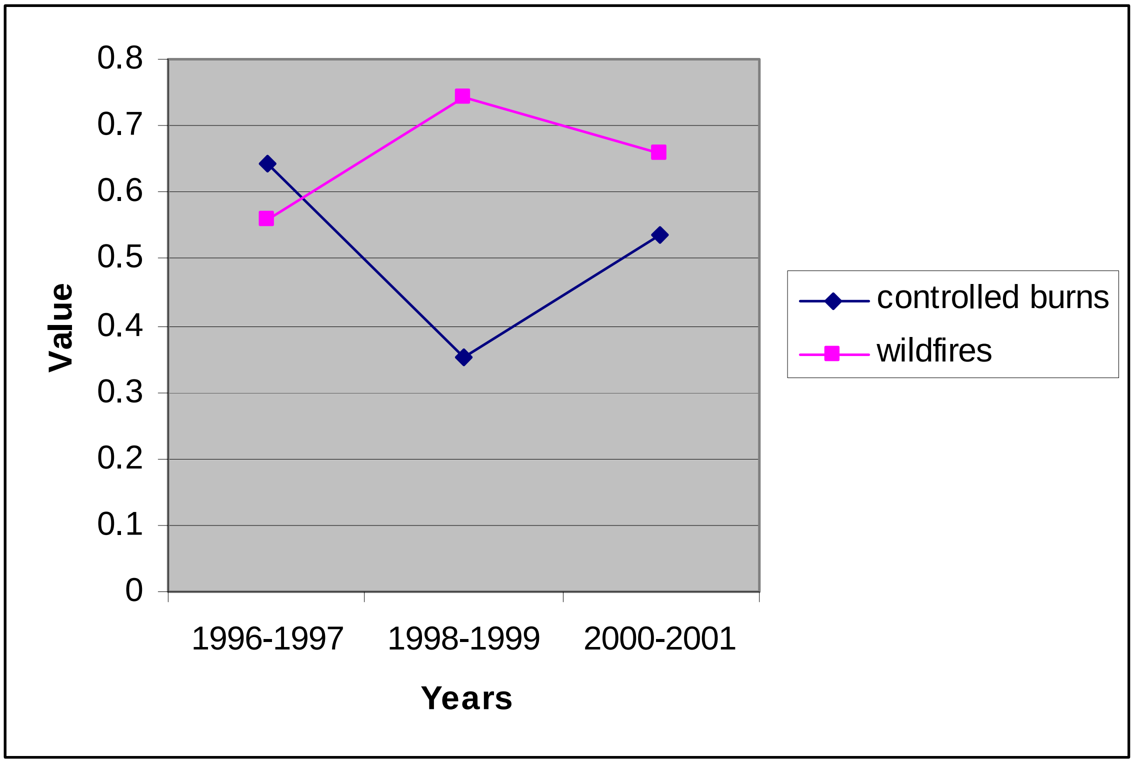



Figure 4.1 Average Shannon-Wiener Diversity Chart for the Understory *

*The average Shannon-Weiner value was derived by averaging Shannon-Weiner indices for all 10 plots in each burn type and age category

Overstory Diversity

Overstory diversity values were greatest in the oldest burned plots of both control and wildfire areas (Figure 4.2). Overstory diversity rose dramatically on wildfire plots with time, whereas overstory diversity changes were muted on control burn plots.

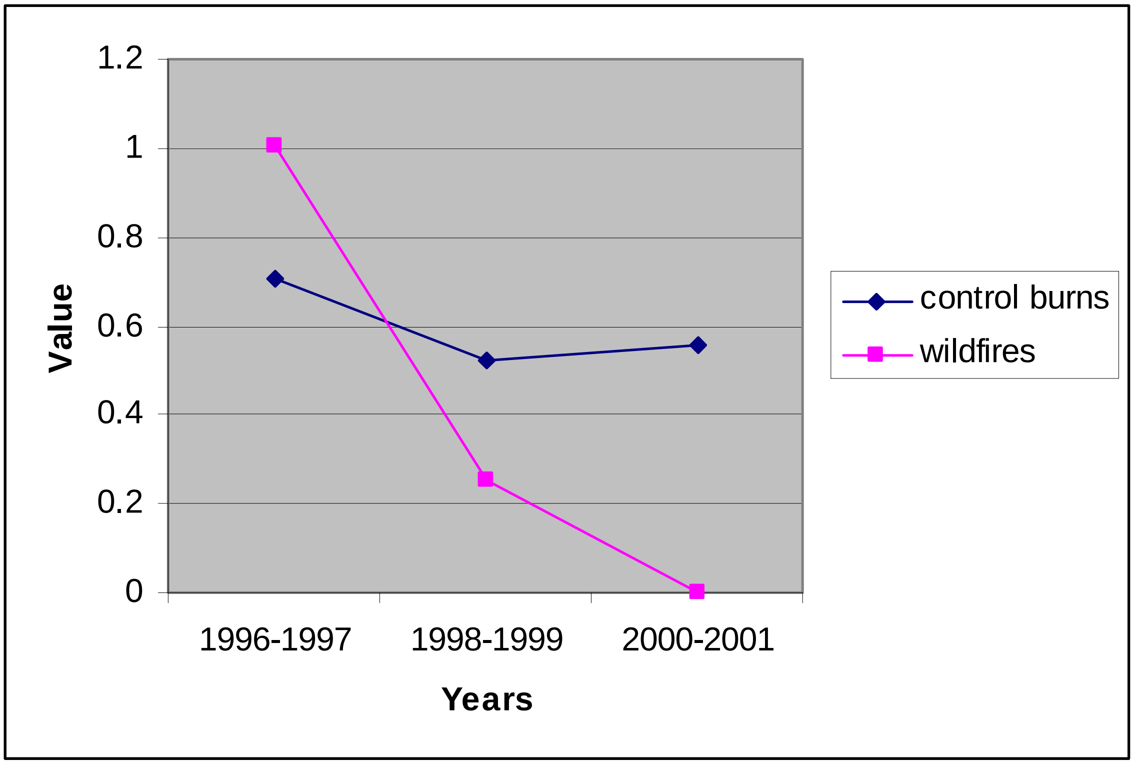



Figure 4.2 Average Shannon-Wiener Diversity Chart for the Overstory *

*The average Shannon-Weiner value was derived by averaging Shannon-Weiner indices for all 10 plots in each burn type and age category

The two-way ANOVA model base on Shannon-Weiner diversity index values for the overstory was highly significant (Table 4.9). Interestingly, this contrast in overstory diversity is manifest in burn age and burn type*age interaction, but not with burn type. A significant interaction term underscores the fact that the response of species diversity across the range of burn ages differs significantly with burn type. In essence, overstory diversity increased dramatically with time since last wildfire, but differed little with time since last controlled burn.

Table 4.9 ANOVA for the Shannon-Weiner Diversity Index for the Overstory

| Model | | Burn Type | | Year | | Burn Type*Year | |
|---|---|---|---|---|---|---|---|
| F | P | F | P | F | P | F | P |
| **8.429** | **0.000** | 3.161 | 0.081 | **12.988** | **0.000** | **6.504** | **0.003** |

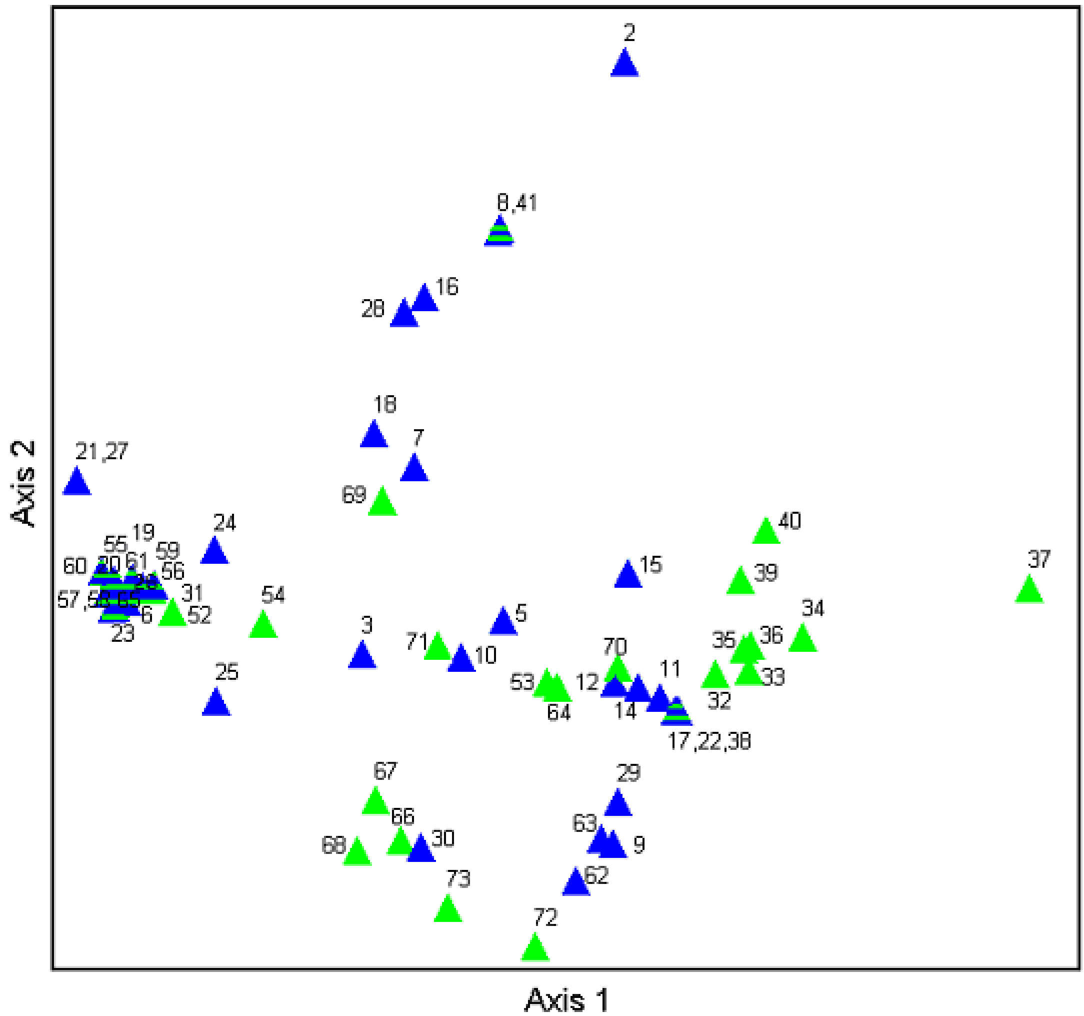
DCA Results for the Understory

The DCA explained 32.5% of the total variance in understory species composition. Axis one explained 14.7% of understory species variance in cover on sample burned plots on Sapelo Island, and had an eigenvalue of 0.831. The second axis eigenvalue was 0.663, accounting for another 11.8% of compositional variance. Axis 3 was statistically and ecologically less useful.

Table 4.10 Eigenvalues from the Detrended Correspondence Analysis (DCA) for the Understory

| | Eigenvalue | % variance explained |
|---|---|---|
| Axis 1 | 0.831 | 14.7 |
| Axis 2 | 0.663 | 11.8 |
| Axis 3 | 0.339 | 6.0 |

Figure 4.3 and 4.4 show the plot of DCA site scores on the first two axes. The spatial arrangement of points is identical in both figures; however, figure 4.3 categorizes sites according to burn type, whereas Figure 4.4 categorizes sites according to time since last burn. Although sites were fairly well dispersed in the DCA plot, visual inspection revealed no obvious clustering of sites according to burn type.




= Control and Wildfire Site (6, 17, 19, 20, 22, 23, 26 and 31 are control fire sites and 38, 55-61 and 65 is a wildfire site)
= Wildfire Site
= Control Fires Site

Figure 4.3 DCA of Sapelo Island Understory by Fire Type

On Figure 4.4, the 1998-1999 and 2000-2001 burn plots tended to cluster in the DCA diagram, whereas 1996-1997 plots were more widely dispersed in the DCA diagram.

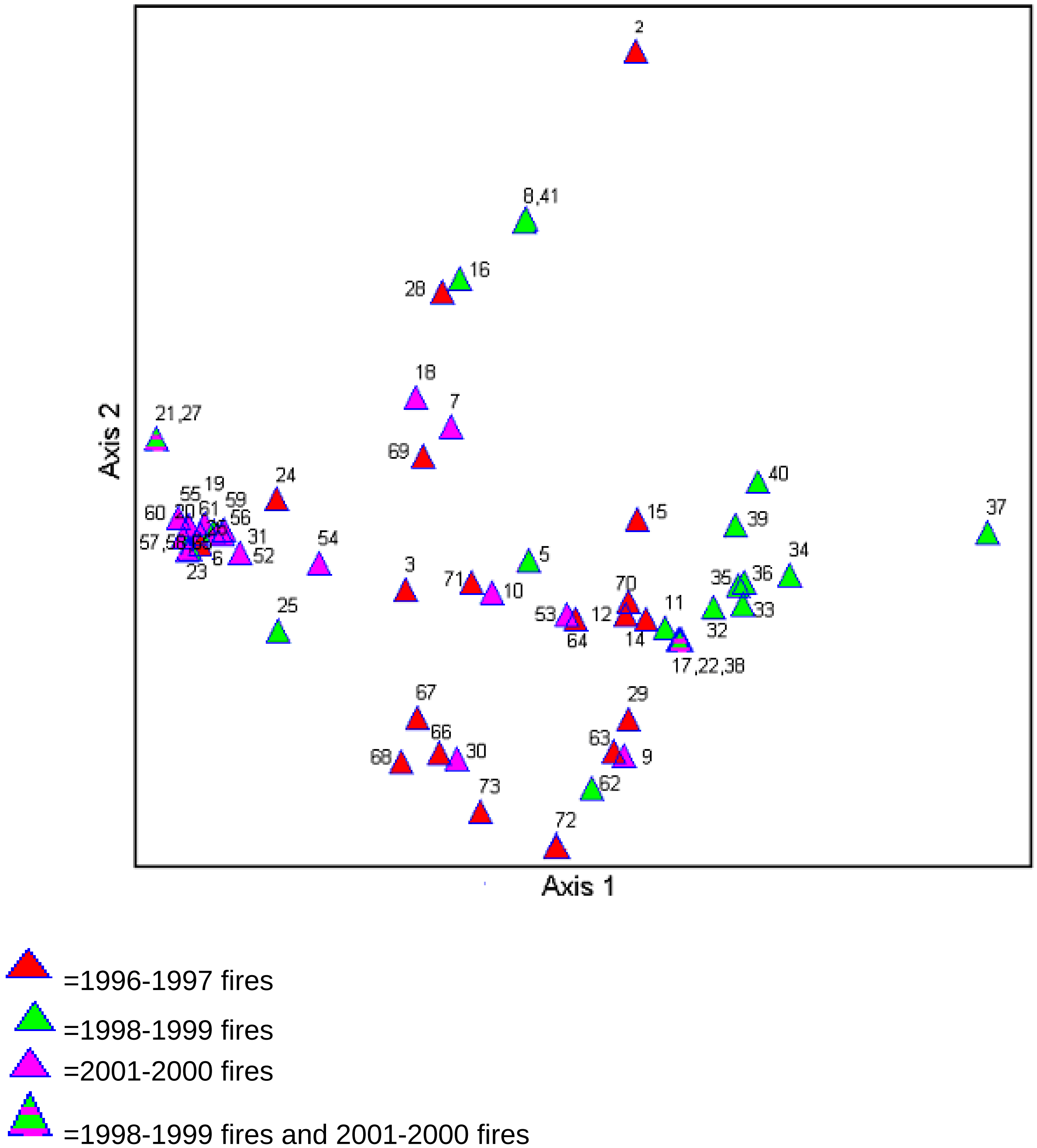



Figure 4.4 DCA of Sapelo Island Understory by Years

There was no apparent ecological pattern to understory species composition in the sampled plots, as arranged by DCA. Pines, oaks, and other hardwood species intermingle in the species DCA plot.

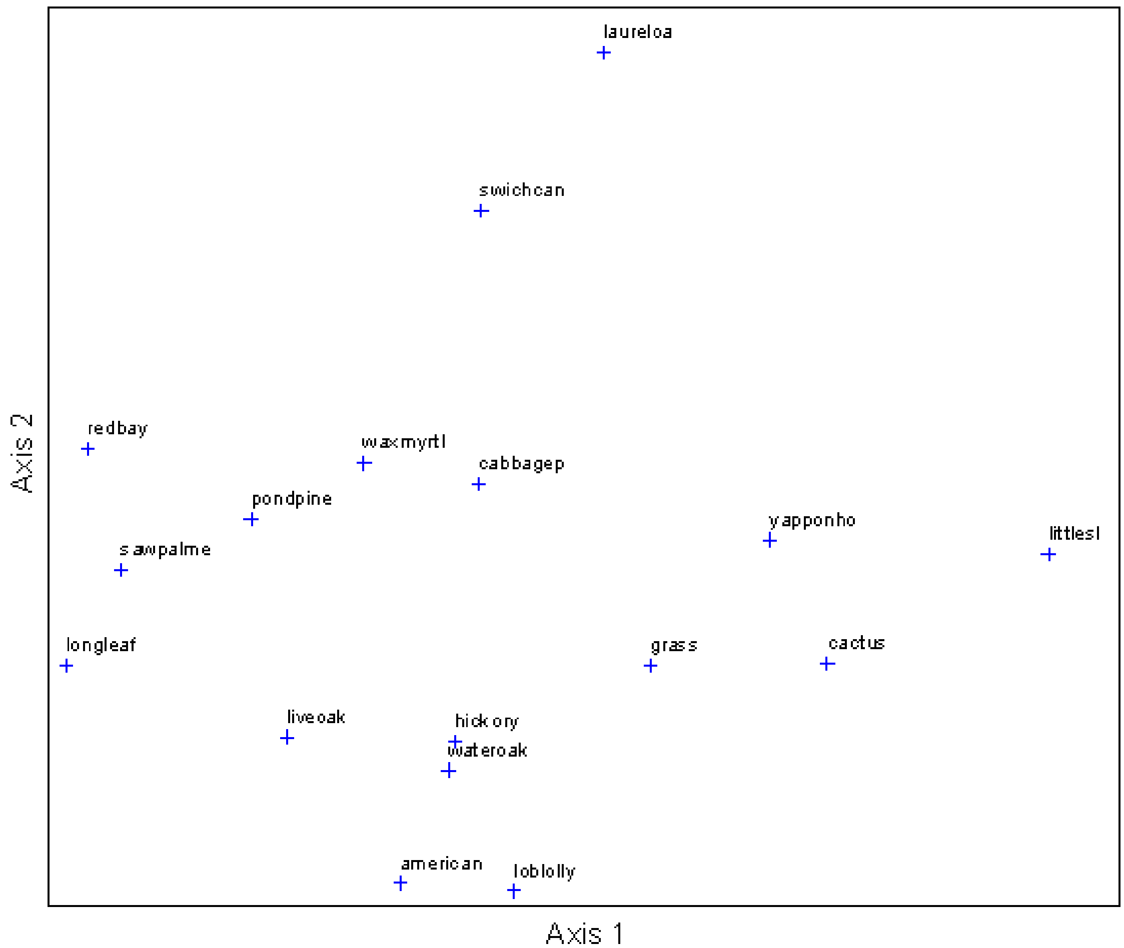



Figure 4.5 DCA of Sapelo Island Understory Species

The two-way ANOVA of the understory DCA axis scores yielded significant differences in Axis 1 scores among burn ages, as well as for the interaction term. The length of the recovery period since the most recent burn affected understory species composition on Sapelo Island, whereas the burn type (control versus wildfire) showed little direct influence on understory composition.  A significant interaction term suggests that burn type is indirectly influencing Axis 1, or that Axis 1 shows a response across the range of burn ages that differs significantly with burn type.

Table 4.11 ANOVA from the DCA Summary for the Understory

| | Model | | Burn Type | | Year | | Burn Type * Year | |
|---|---|---|---|---|---|---|---|---|
| | F | P | F | P | F | P | F | P |
| Axis 1 | **10.748** | **0.000** | 1.030 | 0.315 | **14.574** | **0.000** | **11.780** | **0.000** |
| Axis 2 | 1.544 | 0.192 | 1.621 | 0.208 | 1.084 | 0.345 | 1.964 | 0.150 |

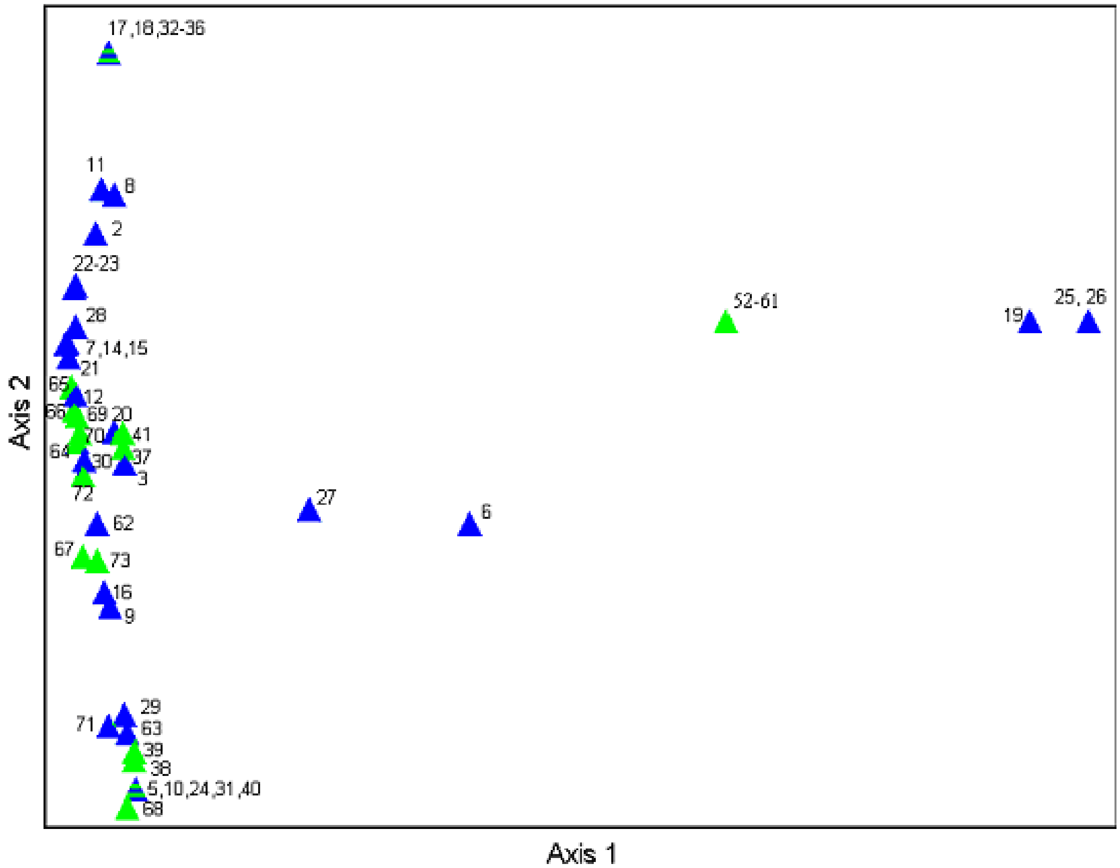
DCA Results for the Overstory

The DCA explained 40.8% of the total variance in overstory species composition among plots sampled on Sapelo Island. Axis 1 explained 19.3% and has an eigenvalue of 0.985. The axes 2 score eigenvalues was 0.657, and explained 12.9% of the overstory species compositional variance in the overstory. As with the understory DCA, the third axis of the overstory DCA was statistically weaker and ecologically uninterpretable.

Table 4.12 Eigenvalues from the DCA for the Overstory

| | Eigenvalue | % variance explained |
|---|---|---|
| Axis 1 | 0.985 | 19.3 |
| Axis 2 | 0.658 | 12.9 |
| Axis 3 | 0.438 | 8.6 |

DCA plots for the overstory displayed a pattern typical for an ordination strongly influenced by several outlier plots (Figure 4.6). The majority of plots were forced to very low Axis 1 scores by these outliers. Inspection of the species plots for this overstory data revealed that longleaf pine and pond pine were compositional outliners in these data (Figure 4.7). In order to examine overstory composition patterns more thoroughly, plots 19, 25, 26 and 52-61 were removed from the data set and DCA performed on the remaining sites.




= Control and Wildfire Site (5, 10, 24 and 31 are control fire sites and 40 are wildfire site)

= Wildfire Site

= Control Fires Site

Figure 4.6 DCA of Sapelo Island Overstory with Pond Pine and Longleaf Pine by Fire Type

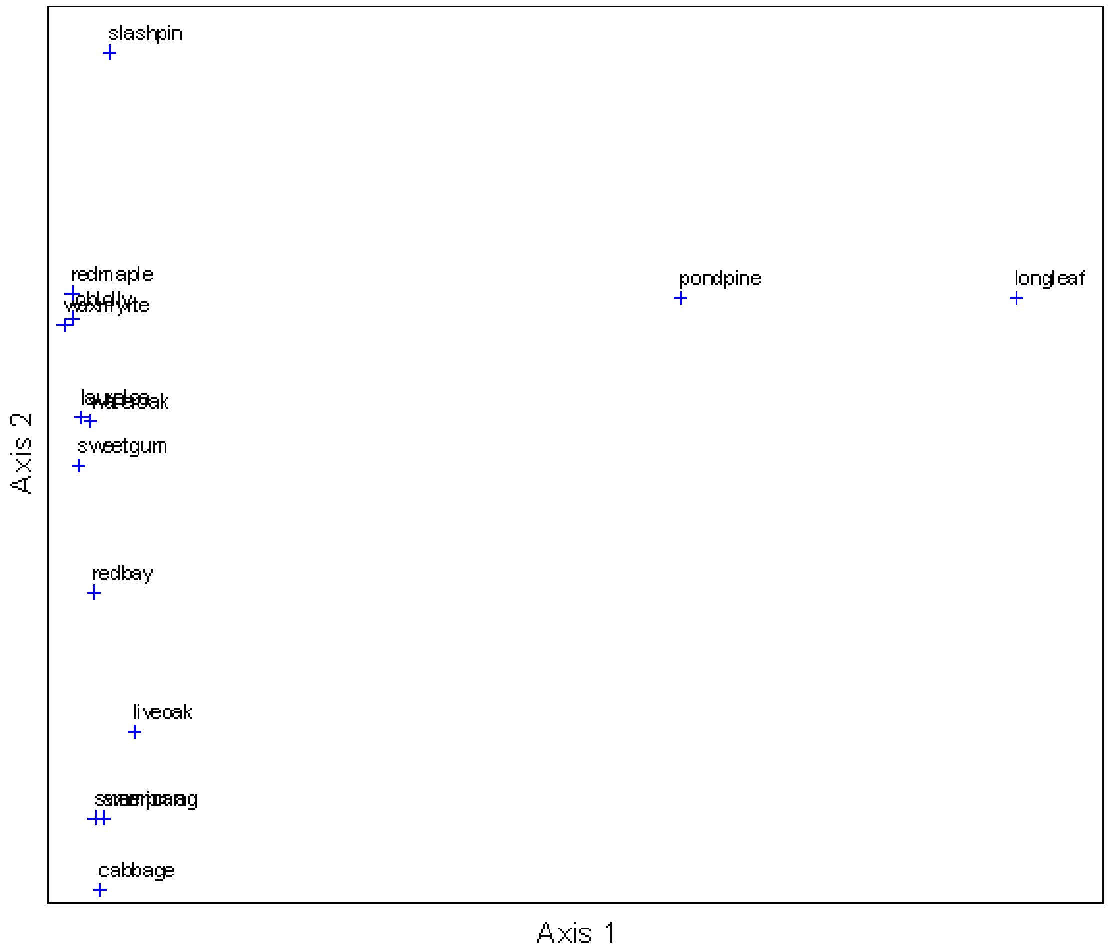


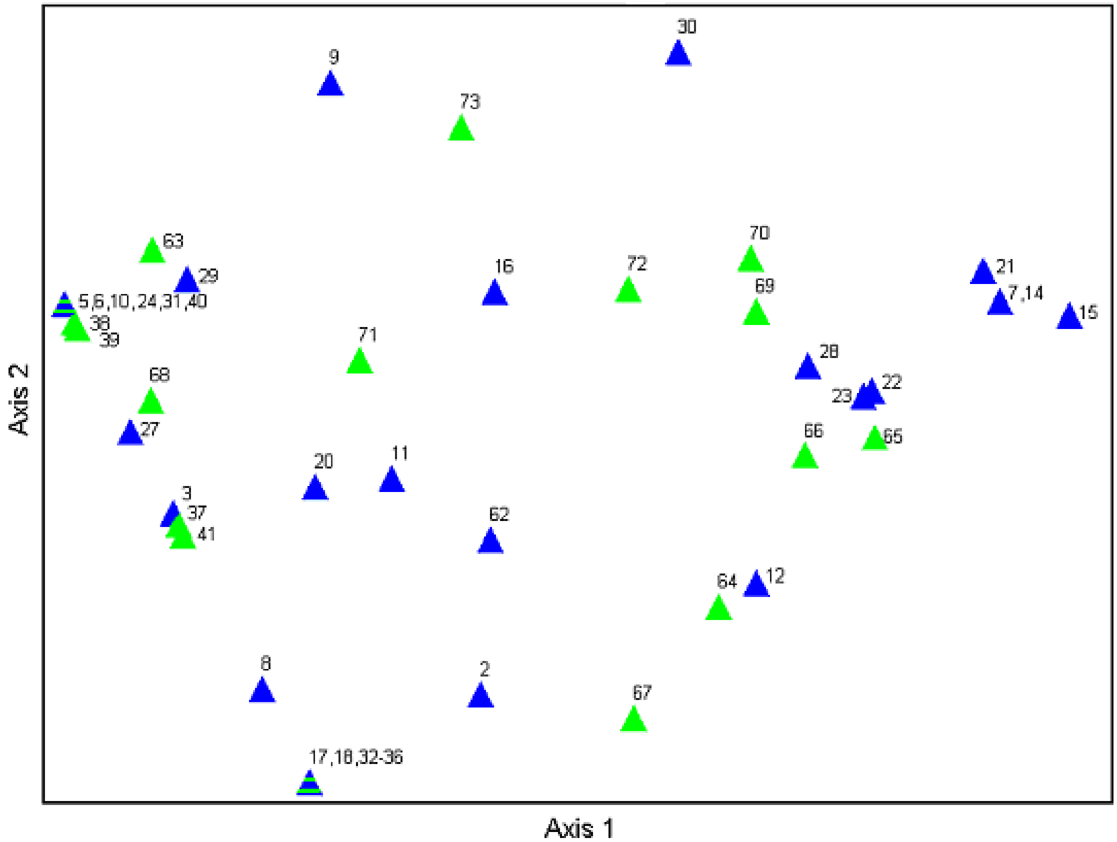

Figure 4.7 DCA of Sapelo Island Overstory Species with Pond Pine and Longleaf Pine

The DCA with outliers removed explained the most variance of all of the DCA's, with 42.8% of the total variance being explained in the overstory species composition. Axis one explained 23.5% and had an eigenvalue of 0.760. The second axis eigenvalue was 0.393 and explained 12.0% of the remaining overstory species variance. Once again DCA axis 3 is statistically and ecologically weak.

Table 4.13 Eigenvalues from the DCA for the Overstory without Pond Pine and Longleaf Pine

| | Eigenvalue | % variance explained |
|---|---|---|
| Axis 1 | 0.760 | 23.49 |
| Axis 2 | 0.393 | 12.03 |
| Axis 3 | 0.238 | 7.30 |

Burn type categories were not significantly separated along the DCA axes in the overstory analysis with outliers removed (Table 4.14, Figure 4.8). There was no strong or consistent overall compositional contrast between controlled and wildfire plots, both of which were widely dispersed in the DCA scatterplot.



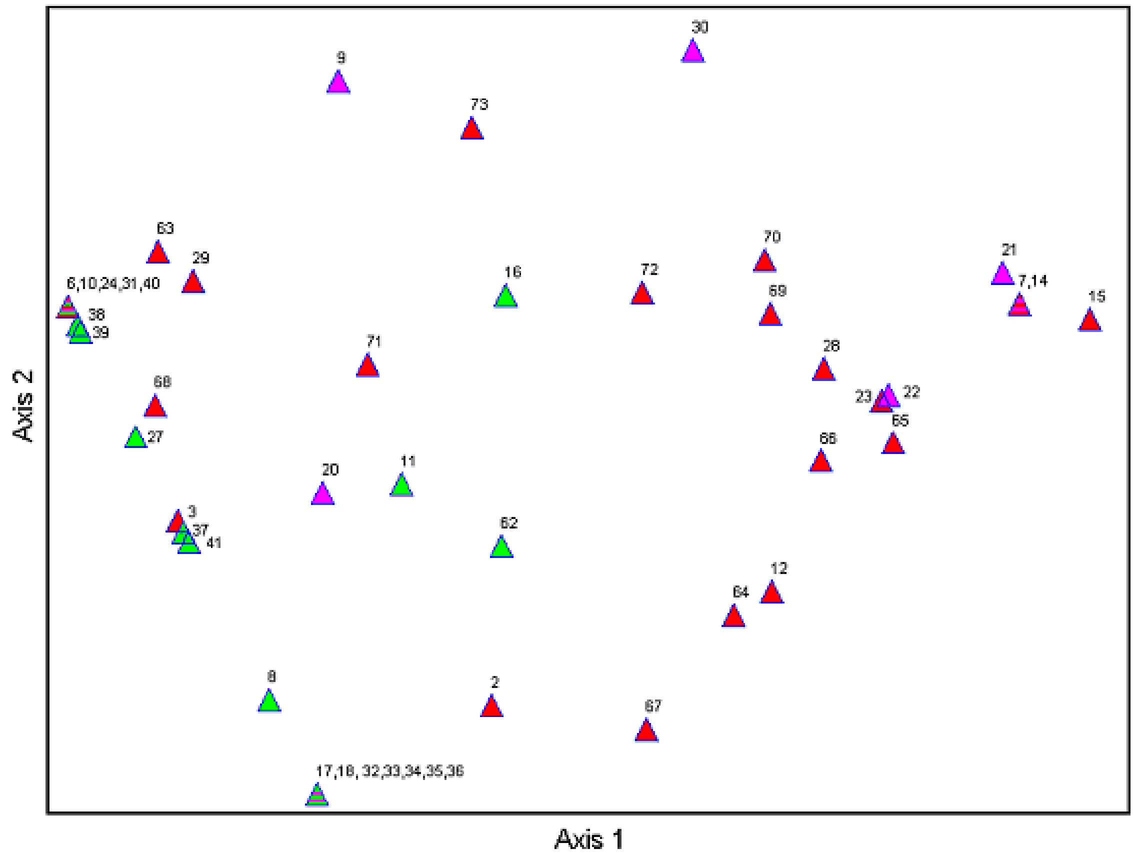

= Control and Wildfire Site (5, 6, 10, 17, 18, 24 and 31 are control fire sites and 32-36 and 40 is wildfire site)

= Wildfire Site

= Control Fires Site

Figure 4.8 DCA of Sapelo Island Overstory without Pond Pine and Longleaf Pine by Fire Type

Segregation between plots is difficult to observe but can vaguely be seen between the 1996-1997 fire sites and the 1998-1999 fire sites.




=1996-1997 fires

=1998-1999 fires

=2001-2000 fires

=1996-1997 fires and 2001-2000 fires

=1998-1999 fires and 2001-2000 fires

=All Years of fire found

Figure 4.9 DCA of Sapelo Island Overstory without Pond Pine and Longleaf Pine by Years

The species pattern for the DCA of Sapelo Island overstory with outliers removed showed no obvious ecological pattern (Figure 4.10). Typical environmental controls, such as site moisture (upland vs. lowland species), were not evident from this array of species. Similarly, no successional trend, like pines versus oaks, was evident.

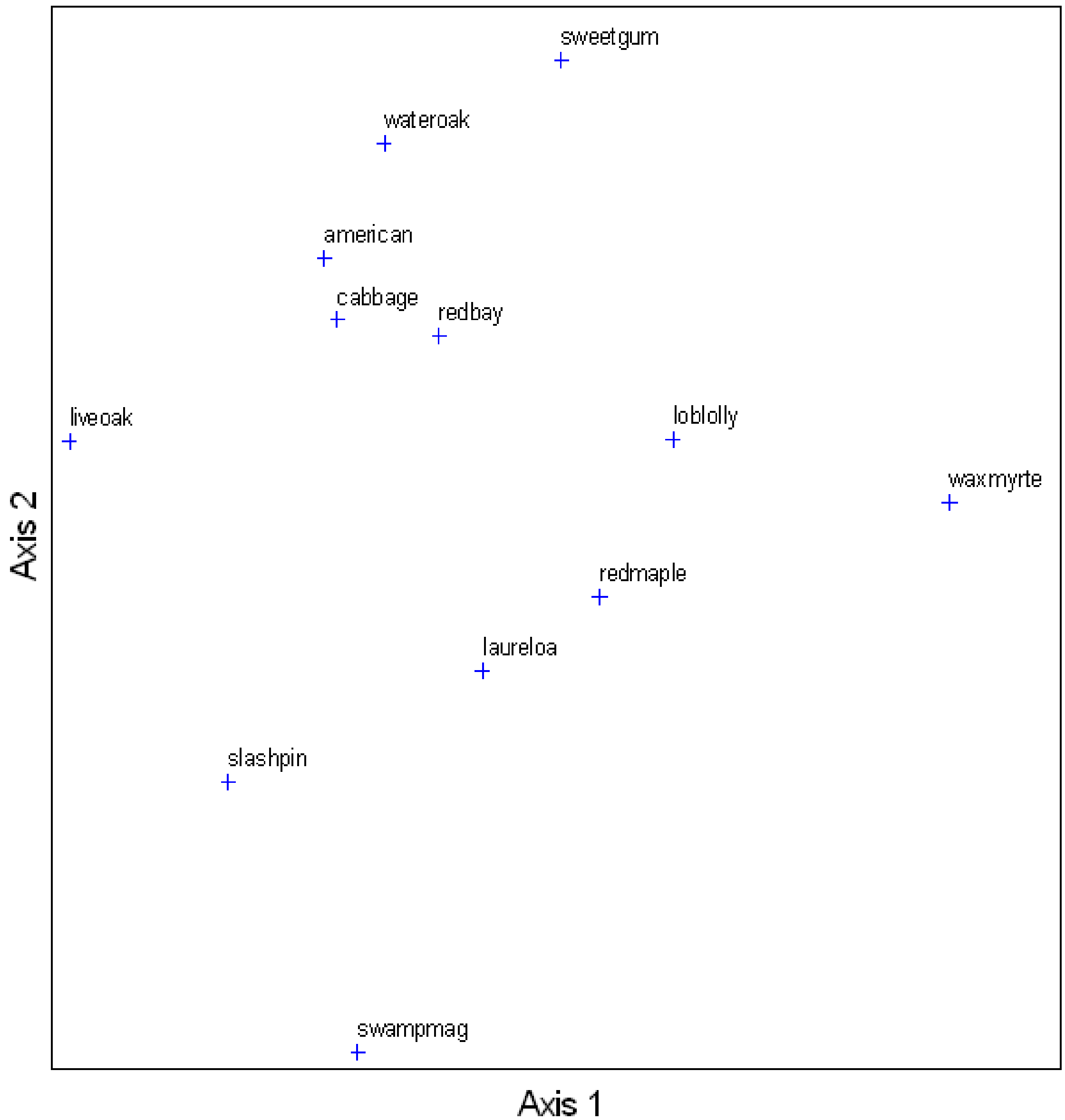



Figure 4.10 DCA of Sapelo Island Overstory Species without Pond Pine and Longleaf Pine

The ANOVA for the overstory DCA model with outliers removed was significant for axis 1 and axis 2. Both axes were significant for the burn year, but not for the burn type and the interaction term. However, the ANOVA revealed that overstory composition is significantly partitioned among burn ages on burned plots on Sapelo Island. (Table 4.14, Fig 4.9)

Table 4.14 ANOVA from the DCA Summary for the Overstory without Pond Pine and Longleaf Pine

| | Model | | Burn Type | | Year | | Burn Type * Year | |
|---|---|---|---|---|---|---|---|---|
| | F | P | F | P | F | P | F | P |
| Axis 1 | **3.907** | **0.009** | 0.001 | 0.978 | **7.236** | **0.002** | 0.450 | 0.506 |
| Axis 2 | **2.719** | **0.042** | 0.812 | 0.373 | **3.327** | **0.046** | 0.933 | 0.340 |

## Chapter 5

## DISCUSSION AND CONCLUSION

### Comparing Controlled Burns and Wildfires on Sapelo Island

A few measurable differences between controlled burn and wildfire plots were evident from this study. As might be expected, canopy openness is significantly greater on wildfire plots. These hotter fires would produce localized crowning in areas of dense fuel, thereby thinning the canopy layer. By contrast, flame heights associated with cooler controlled burns would rarely reach the canopy layer. Pond pine also showed interpretable differences for burn type on Sapelo Island. Pond pine differed significantly between controlled and wildfire burns plots because it needs a hot fire, which generally occurs with a wildfire, so that seed release from serotinous cones can occur.

One species that should have done well in wildfires is longleaf pine. But almost all of the longleaf pine community on Sapelo has been controlled burned during the past six years, with no wildfire occurring in this community over the duration of study. Frequent controlled burns should help to keep the longleaf pine community intact and possibly expand because longleaf pine seedling can withstand low intensity fire within one year after germination due to its dense tufts of green needles surrounding the terminal bud (i.e. the grass stage). Frequent low intensity controlled burns and low density of adult longleaf pines creates an environment favorable for longleaf pine seedlings to grow in the open spaces between adult trees (Platt et al. 1988).

The overstory and understory ANOVA's for burn type and understory diversity showed very little interpretable pattern, which means that control burns and wildfires did not produce consistent ecological contrasts, at least during the period of study on Sapelo Island. This may be due to the drought that persisted during the time of this study, the small sample size (which did not capture the full range of variability among burn patches), lack of comparable vegetation data before fire occurred or the short period of time for vegetation recovery in sampled plots. It may also say that Sapelo Island upland areas are rarely in a climax state and that they are vulnerable to exogenous influences such as fires, droughts, and floods, which affect different vegetation differently and create a heterogeneous landscape. Fire naturally generates a great deal of fine-scale heterogeneity immediately after burning, so that the intensity of a given fire and the weather immediately after the fire may greatly alter surviving seedbank viability and cause differential patterns of vegetation regrowth.

Comparing Effects of Recovery Period on Vegetation

The 'year of burn' category frequently yielded significant contrast in species composition or diversity index values among the sampled plots. Indeed, it was more prominent than burn type in differentiating among samples. The overstory diversity plots show an increased in diversity over time, especially in wildfire plots. The rapid increase in diversity from time since last fire was likely caused by the open areas of the overstory created by wildfires. This allowed the overstory trees that survived wildfire to compete for space that was opened by the wildfires, while understory trees were also able to be released into the overstory and compete for the space opened by the wildfire. The controlled burn plots also showed an increase in diversity in the overstory, but the increase was much smaller than for the wildfire sites, probably due to the canopy being unaffected by the lower flame height in a controlled burn.

Species such as grass, saw palmetto, loblolly pine, pond pine, and laurel oak showed significant differences associated with time since last burn. Generally the longer saw palmetto went unburned, the less dominant the species became, after it resprouted in the first two years after fire. The reason for saw palmetto becoming less dominant two years after fire is likely due to increased competition for light from other understory species. Other factors that might influence the regrowth of saw palmetto include the communities in which the sample was taken and drainage patterns (Abrahamson 1995). After a control burn, grass continuously increased between years, probably due to the stimulating effect of removal of above-ground tissue, whereas in the wildfire plots, the root mass of grasses was likely damaged by elevated root-zone soil temperatures.

Slash and longleaf pine are fire responding species with adaptations, such as thick bark, that promote persistence through a fire. By contrast, loblolly pine is considered to be much less fire resistant than the other two pines. Since moisture is a critical factor for loblolly pine to reproduce, it generally grows in areas where wildfires are less frequent (Carey 1992b). Growth of loblolly pine has been highly correlated with departures from the average rainfall from April to October, with years that have excessive droughts having large drop offs in annual growth (Baker and Langdon 1990). During the time of the study the Southeastern United States had been in a prolonged drought, which may have affected growth rates of loblolly pine. Other factors, such as sunlight availability, changes in drainage patterns, community type, and edaphic contrasts may also have contributed to the difference in loblolly pine abundance among the three recovery periods.

If pond pine areas are burned too frequently the species will be eradicated from the island. But by increasing the time between controlled burns in pond pine areas, the amount of litter and shrubs that are consumed on the ground will be greater and the fire will be hotter, thus helping the recruitment of pond pine on the island (Bramlett 1990). Pond pine likes moist, bare soil after a hot fire for release of seeds from their serotinous cones and subsequent germination; interannual variation in post-fire drought stress may explain why some years showed better pond pine recruitment than other years.

Oak Dynamics and Fire

The reason for laurel oak having a higher value in the overstory wildfire plots is due to fire suppression. Laurel oak is shade tolerant from seedling to adult, whereas water and live oak are relatively more shade intolerant. Laurel oak's ability to grow through the dense canopy and make its way to the overstory can be seen on Sapelo Island, where fire suppression has been enforced in the past (Carey 1992a). Now that fire is being reinstated into the ecosystem, laurel oaks' numbers should decrease, since it is a fire sensitive species. In the data set, laurel oak differed significantly by year. Past site history, including long fire-free periods and episodic drought, may explain why laurel oak differs significantly between years in the overstory.

Many of the live oak areas on Sapelo Island have saw palmetto in the understory, which is very flammable. When control burns occurred in the maritime forest the large live oaks were generally not affected by the flames that saw palmetto produces, because there is a vertical disjunction between the saw palmetto in the understory and live oak canopy. In other areas of the island, such as the scrubby flatwoods and the flatwoods, fuel ladders may permit controlled burns to reach the overstory and significantly increase canopy damage, especially in drier periods (Davison and Bratton 1988).

Management Implications

This study was not effective in helping to evaluate vegetation response to controlled burns on Sapelo Island, due to the absence of pre-burn baseline data. This made it difficult to interpret the future outcome of the control burn plots, because the pre-burn data were not available to determine if the new species were invading the area or if the existing sprouts and seedbank were the source of the new vegetation that occurred in each plot. But by having different areas of the island controlled burned at different times, this creates an environment suitable for many different plant species, which will allow for a diversity of communities on Sapelo Island.

Managing for the climax community, which is the hammock community where the live oak grows, is not reasonable because wildfires started by lightning can occur on any part of the island and destroy any community, including the hammock community where the live oak grows. Many of the communities on Sapelo Island, such as the flatwoods and the scrubby flatwoods, are fire dependent. Without fire, these communities will become structurally and compositionally altered, which would displace many associated plants and animals and lead to lower biological diversity. With the reintroduction of controlled fires, parts of the hammock community that had been converted into areas dominated by laurel oak should revert back to live oak dominance.

Shortcomings and Future Research

There were several shortcoming of this research project. First, the number of sites sampled should have been higher. Since there were six categories, each category should have had at least 15 sites, instead of ten. This would have reduced exposure to site-related idiosyncrasies in the data. If the wildfires would have covered more acreage on the island, then the wildfire plots could have been spread out over the island more broadly, instead of blocked into groups of five plots. This would have allowed for more habitats and different vegetation types to be explored. Having more plots would have given a better assessment of the total island and how different types of fire affect the island, especially in areas burned by wildfire.

Better data management of the island, which is improving with the addition of a fire database, would have been helpful in locating areas that were damaged by both controlled burns and wildfires. Another problem with the research design was not controlling for vegetation type. If all samples were taken from one vegetation type, such as the flatwoods, scrubby flatwoods, or hammocks, the results may have been more readily interpretable. Ideally, plots should be sampled before and after a fire, to account for the pre-burn legacies on post-burn outcomes. This could have easily been done for control burn plots, since control burns are started by management, but much harder to do with wildfires, due the randomness of lightning ignitions. Additional research should benefit by avoiding the design flaws that became apparent as this study was conducted.

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