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Vegetation Response and Regrowth after Fire on Cumberland Island National Seashore, Georgia

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VEGETATION RESPONSE AND REGROWTH AFTER FIRE ON

CUMBERLAND ISLAND NATIONAL SEASHORE, GEORGIA

by Kathryn Louise Davison

NATIONAL PARK SERVICE - Southeast Region

Research/Resources Management Report SER-69

Reprint of a M.S. Thesis Submitted to the University of Georgia

1984

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KATHRYN LOUISE DAVISON Vegetation Response and Regrowth after Fire on Cumberland Island National Seashore. (Under the direction of DRS. CARL MONK and SUSAN BRATTON)

Vegetation response and post-fire regrowth were documented on Cumberland Island National Seashore, Georgia. Soils were sampled and canopy mortality was assessed. Four major community types were sampled seasonally for herbaceous and woody cover over two years following a fire which occurred in July of 1981. Results were compared to data from similar unburned, old burn, and prescribed burned sites. Burned site soils typically had higher pH values, and had higher concentrations of Ca and Mg. Mature hardwoods suffered high mortality only where the trees bordered the more flammable scrub or dense pine. The interiors of the hardwood forests did not burn extensively. This resistance to fire was highly correlated to the amount of *Quercus virginiana* within a stand. Mature individuals of *Pinus palustris*, *P. serotina* and *P. taeda* suffered high mortality, while *P. elliottii* survived all but the most severe burns. With the exception of pine species, post-fire regrowth was generally represented in pre-fire proportions. Nearly all aboveground vegetation was killed in the scrub and marsh communities. However, surviving roots, rhizomes, and graminoid hummocks sprouted prolifically. Within two years the burned marshes strongly resembled unburned marshes in vegetation cover and species diversity. Burned scrub vegetation was extremely dense and exceeded six feet in height two years after the fire. All pre-fire scrub species were represented in the regrowth.

INDEX WORDS: Fire Ecology, Fire survivorship, Maritime Hardwood Forest, Mixed Pine Oak Forest, Scrub, Cordgrass Marsh, *Quercus virginiana*, *Pinus*, *Serenoa repens*, *Spartina bakerii*.

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INTRODUCTION

Cumberland Island is the largest and southernmost of Georgia's barrier islands. Three lightning ignited fires exceeding 50 acres have occurred since the larger part of the island was designated national seashore in 1972. This is typical for the Southeastern Coastal Plain (SECP) where frequent natural fires have been a prominent feature throughout historic time and certainly since the late Pleistocene era (Komarek, 1966, 1968). The most recent fire, the South-Cut Fire started July 15, 1981 and burned for two weeks over 1700 acres (688 ha). The severity of this fire, administrative complications, and adverse publicity raised questions concerning the role of fire on Cumberland Island and the adequacy of the National Park Service fire management plan.

The role of fire has become increasingly controversial in the national parks over the last three decades. Until 1952, when fire was reintroduced to Everglades National Park in Florida, suppression of fire was the policy for all parks (Stottlemeyer, 1981). Suppression in ecosystems adapted to frequent fire changes successional patterns, and may cause vegetation to degenerate. Accumulating fuels increase the probability of a devastating fire. A recent study of the fire adapted chaparral found that, "fire control (suppression) reduces the number of fires, not the burned hectarage; fires consequently increase in size, spread rate, and intensity and become uncontrollable in severe weather conditions" (Minnich, 1983). Recent studies of vegetation and wildlife responses to fire have guided policies away from suppression and towards natural fire management (Stottlemeyer, 1981). Although research of fire in the national parks began in the Southeast, activity has centered in large western parks. The effects of fire on many park ecosystems remains unstudied.

There is an extensive literature concerning fire ecology in the SECP. Few authors, however, have dealt with the specific relationships of barrier islands whose plant communities are in varying stages of succession. Most of the literature on fire ecology in the SECP falls into one of two categories. The first describes fire as an ecosystem process in well defined plant communities which have not been grossly affected by man. The use of fire in the management of natural landscapes encompasses the second category. These publications describe fire as a tool used for specific objectives such as the production of good grouse habitat or pines to the exclusion of hardwoods (Komarek, 1974). While this literature is certainly helpful, it cannot be used as the sole source of information for a fire management plan. The vegetation patterns of Cumberland Island are complicated due to the interaction of the native ecosystem processes with a long history of human intervention. Logging of oak and pine, grazing of feral cattle, pigs and horses (the latter two of which still roam the island), and various agricultural practices have heavily influenced the flora. Hillestad et al. (1975) provided a quantitative inventory of the biota of Cumberland Island, a map of the major vegetation types, and discusses these impacts. A recent study of the island's fuels indicated that loading rates were different from those predicted by models developed for similar mainland systems. These unusually low fuel levels were probably due to the heavy grazing pressure exerted by feral pigs, horses, and native deer (Stratton and Bratton, 1982). Multiple objectives are implicit in management of a landscape rich in natural as well as historical resources; no one alternative is universally applicable. Managers must be able to predict the result of a given action to assess its short-term and long-term impact for the landscape. Towards this goal, further analysis of the role of fire on Cumberland Island is required.

The objectives of this study were to (1) document responses of vegetation in the 1981 South-Cut Fire Site to various intensities of fire, (2) record regrowth patterns in the same area during the following two years; and (3) test the hypothesis that canopy survival from fire is influenced by the species composition of the community. By comparison of the South-Cut Fire Site with old burn, prescribed burn, and unburned island sites and with results in the literature, patterns may be ascertained toward the long-term management of fire on Cumberland Island National Seashore.

DESCRIPTION OF STUDY AREA

LOCATION AND SIZE

Cumberland Island is about 34 km southeast of Brunswick, Georgia and about 62 km northeast of Jacksonville, Florida, the center of the island being located at 30 48' N latitude, 81 26' W longitude. Encompassing 23,227 acres (9404 ha), the island is 25 km long and 9 km broad at its widest point. It is bounded by the Intracoastal Waterway on the west, the St. Mary's River on the south, the St. Andrew's Sound and Little Cumberland Island on the north, and the Atlantic Ocean on the east (Figure 1).

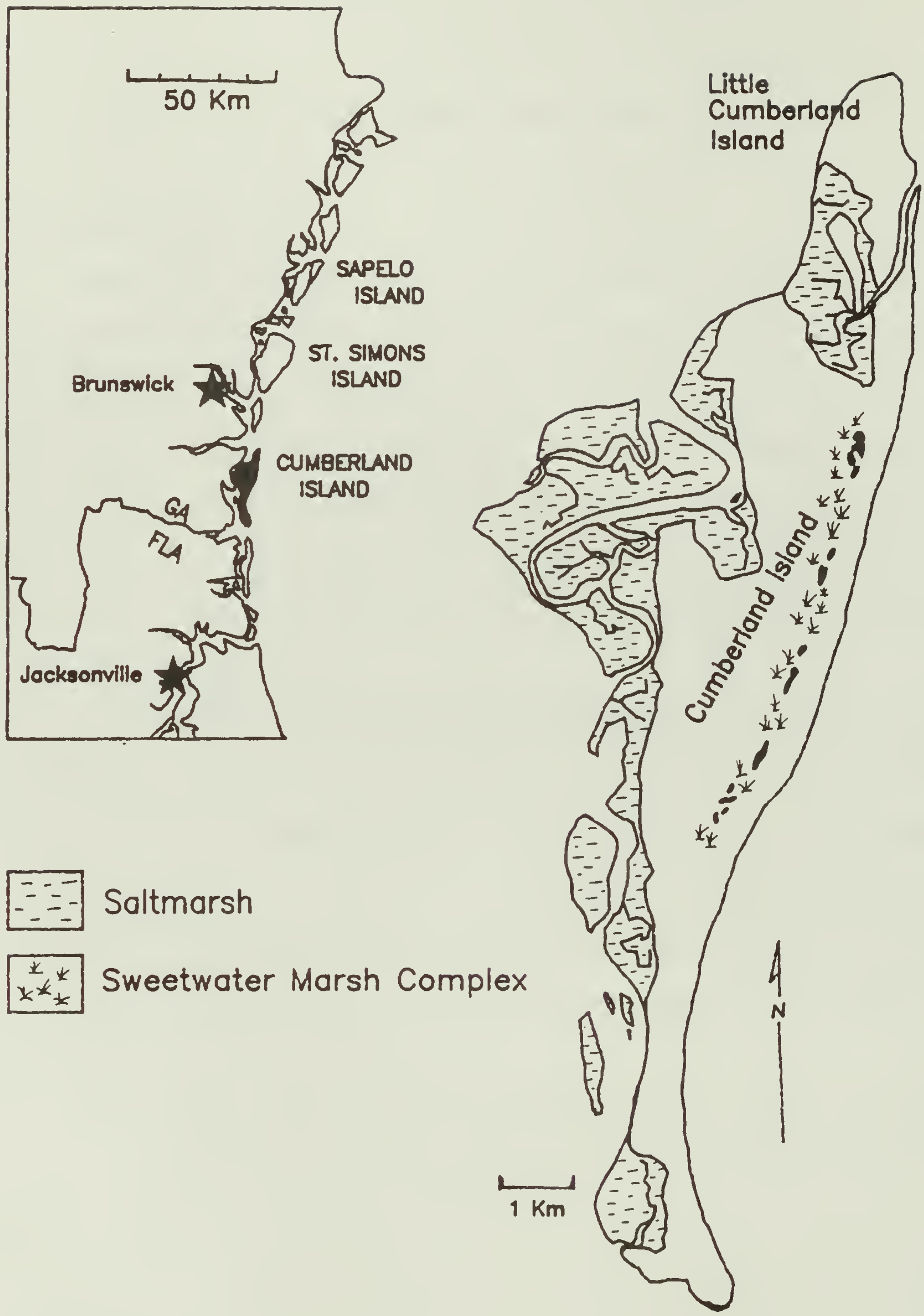
A grant from the Andrew W. Mellon Foundation to the National Park Foundation initiated acquisition of the island by the federal government. In 1972, Cumberland Island was designated a national seashore and became a part of the National Park system. Eighty percent of the island was administered by the National Park Service (NPS) as of 1981. The remainder was administered by the State of Georgia, the Army Corps of Engineers, or was privately owned.

The geology, soils, water resources, flora, fauna, and general history of Cumberland Island have been described in detail by Hillestad et al. (1975).

CLIMATE

The climatic patterns of Cumberland Island are represented by statistics from Jacksonville, Florida (Gale Research Co., 1981),

Figure 1. Cumberland Island, Georgia and vicinity.



50 Km
SAPELO ISLAND
ST. SIMONS ISLAND
Brunswick
CUMBERLAND ISLAND
GA
FLA
Jacksonville
Little Cumberland Island
Cumberland Island
N
1 Km
Saltmarsh
Sweetwater Marsh Complex

Brunswick, Georgia (Plummer, 1983), and McKinnon Airport on St. Simons Island (Duncan, 1982).

The climate of this area is classified as warm-temperate to subtropical. Precipitation patterns are influenced primarily by maritime air-masses flowing off the Atlantic. Mean annual precipitation at Jacksonville is 54.47 inches, and at Brunswick, 51.09 inches. More than half of the precipitation occurs during the summer months from June to September, while November is typically the driest month. Dry-wet periods in coastal Georgia follow 10-11 year cycles. Notably wet periods occurred in the mid 1940's and 1960's, with droughts occurring in 1931, 1954, and 1978-1981 (Plummer, 1983).

This area is characteristically warm and humid. Average relative humidity at Jacksonville is 75%. The mean number of days per year above 32°C is 82 at Jacksonville while only 49 on St. Simon's Island. Snowfall and icestorms are rare. The average number of days below 0°C is 14 at Jacksonville and 15 on St. Simon's Island.

Storms may have a significant effect on the flora of the islands. In 1964, Hurricane Dora passed through an area just southwest of Jacksonville with 82 mph winds (Gale Research Co., 1981). The SECP is noted particularly for lightning storms, having the highest incidence of lightning events in the United States (Komarek, 1974). In Jacksonville, there is an average 64 days per year during which one or more thunderstorms occurs. These storms occur primarily from the late spring to fall.

GEOLOGY

Cumberland Island is part of a chain of sea islands extending from Cape Hatteras, North Carolina to Talbot Island, Florida formed in response to the rise and fall of sea level associated with the glaciation periods of the North American Continent. The island chain is separated from the mainland by 6-10 km of saltmarsh with the islands separated from each other by estuary sounds which are generally several kilometers wide. Elevation is low, 4-8 meters above sea level, with the exception of dunes which are constantly being reworked by wind and water, and may exceed 15 meters.

Cumberland Island is a compound barrier island constructed of deposits from two major fluctuations in sea level. Sediments of Pleistocene age (50,000-25,000 years before present) deposited over an older surface of Pliocene marl make up more than ninety percent of the island. The perimeter of the island is composed of more recent sediments dating from the beginning of the Holocene epoch (6,000 y.b.p.) through the present (Henry et al., 1975).

SOILS

Soils of the study areas on Cumberland Island are primarily of Pleistocene origin, with the exception of the freshwater marsh complex on Cumberland Island (Richardson and Worthington, 1975). These marshes often abut dunes composed of the younger Holocene sediments forming a mixture of sediments. The major difference between the two types of sediments is the presence of beach shell or pulverized $CaCO_4$ in the younger sands. Although the Pleistocene sediments are of littoral or shallow marine origin, they are typically devoid of beach shell.

Calcium carbonate becomes dissolved in acid soil solution and leached away over time.

Cumberland Island soils are classed in the Regosol group, sandy soils with a poorly differentiated profile. They are derived of quartz sands which are highly resistant to weathering. High permeability and low water holding capacity are characteristics allowing rapid leaching, especially in elevated areas. Without clay, the sandy soils are entirely dependent upon organic matter for cation adsorption sites, resulting in the typically low cation exchange capacity. Upland soils are acidic with the exception of areas enriched by salt marsh deposits or beach shell, such as Indian midden areas. Cations leached from soils are replaced by hydrogen ions. Acidity is enhanced on poorly drained sites by dissociation of adsorbed hydrogen into soil solution and production of organic and inorganic (sulfuric and nitric) acids (Richardson and Worthington, 1975).

Soils of the study sites on Cumberland Island were primarily of the Leon fine sand type. These soils are characterized by a darkly stained layer of accumulation within 76 cm of the surface. The water table is generally near the soil surface. Leon fine sand is also characterized by dense growth of *Serenoa repens* which may be one of the primary reasons this soil type is associated with fire (Hillestad et al., 1975).

GENERAL VEGETATION

Vegetation nomenclature follows Radford et al. (1964) or Godfrey and Wooten (1979, 1981).

Fire has been associated with four vegetation types on Cumberland Island: (1) marshes, (2) scrubs, (3) mixed pine-oak forests, and (4) hardwood forest borders with any of the above (Park records, 1972-1981).

Fire prone marshes are dominated by one or more graminoids and occur on soils periodically inundated. As high waters recede, either with tides or falling water table, a loosely packed fuel is left in the accumulation of dead and live blades. Graminoid marshes, as any grassland form continuous fine fuels which burn intensely. Most grasslands thrive on a short fire cycle and often require periodic burns to impede woody invasion and succession to forest (Daubenmire, 1968; Vogl, 1974; Kucera, 1981).

Three marsh types were investigated in this study: (1) Freshwater grass marsh dominated by *Spartina bakerii*, (2) Sawgrass marsh dominated by *Cladium jamaicence*, and (3) Slough/high saltmarsh dominated by *Spartina patens*.

The Sweetwater marsh complex extends along nearly two-thirds the eastern length of the island. These marshes lie just behind the secondary dunes from Lake Whitney to just beyond Willow Pond (Figure 1). Formed by old dune/slough depressions of ancient shorelines, the marshes are zoned according to hydroperiod. Areas of year-round standing water support freshwater prairies which burn only rarely if peat is ignited during a severe drought. Areas which are dry for part of the year support sawgrass marsh. This is one of the common vegetation types in Everglades National Park and is reported to thrive on a yearly burning cycle (Wade et al., 1980). Areas which are under the water table only during the wet summer season support freshwater grass marsh. This marsh type is the most common of the marsh types extending along the Sweetwater complex, and occurs in isolated patches across the island. Sloughs which empty into saltmarsh support dense borders of salt meadow cordgrass, Spartina patens. This marsh grades into saltpan vegetation dominated by saltgrass, Distichlis spicata and blackrush, Juncus roemerianus.

Pine and oak scrubs occupy much of the sterile Leon fine sand on the northern end of the island, most of Table Point, and a small area on the south end near Old House Road. Ninety percent of the island's scrub acreage has burned since the park came into being and it was in this vegetation type that the South-Cut Fire started (Park records, 1972-1983). Both of the scrubs are characterized by dense tangled branches of shrubs interspersed with pines.

Pine scrub is dominated by pond pine, Pinus serotina, which forms a canopy above the shrub layer. This species exhibits two fire adaptive traits: the ability to sprout epicormically from dormant buds after defoliation by fire, and serotinous cones for which the species is named. These cones remain on the tree for several years. Resin binds the cone scales causing them to open slowly and dispense seed over a long period of time. However, if a fire occurs the cones open simultaneously in response to heat, scattering the large seed reservoir on newly exposed soil. Pond pine survives all but the most severe crown fires which usually occur during droughts (Christensen, 1981). Species commonly found in the shrub layer include: Serenoa repens, Lyonia spp., Ilex glabra, Myrica cerifera, Persea borbonia, and Vaccinium myrsinites. This community, also known as pocosin, has been described in detail, particularly concerning its fire ecology and use of fire by prescription to encourage pine growth (Woodwell, 1958; Hough and Albini, 1978, Komarek, 1974). Pine scrub occupies poorly drained, acidic soils and grades into cordgrass marsh in areas of periodic standing water. Pine scrub grades into oak scrub with better drainage of soil, usually following elevation changes.

Oak scrub shares many species with pine scrub, with the exception of Lyonia lucida and Ilex glabra. One of two oaks, Quercus virginiana or Q. myrtifolia, dominates the scrub forming a low, open canopy. Large pines, P. elliottii or P. serotina, are scattered throughout. Serenoa repens is very common, and other small tree species include: Lyonia ferruginea, Q. chapmanii, Osmanthus americana, Persea borbonia, and Myrica cerifera. Herb cover is sparse, limited primarily to Panicum species. The oak scrub on Cumberland Island resembles descriptions of sand pine scrubs of northeastern Florida (Mulvania, 1931; Webber, 1935; Laessle, 1958; Veno, 1976) with the exception that sand pine, Pinus clausa, does not occur on the island. A similar community type was described as incipient live oak hammock in Welaka, Florida (Laessle and Monk, 1961), which is an apt description of Cumberland scrub where it grades into the live oak maritime forest described later.

Mixed pine/oak forest is the most common type of woodland on Cumberland Island comprising over forty percent of the wooded acreage. Pine stands occupy old fields, most of which supported sea island cotton and were abandoned after the Civil War. Stands of loblolly pine, Pinus taeda dominate old field sites of relatively fertile, mesic soils. Young oaks and small clumps of Serenoa repens are scattered throughout, and the forest floor supports many grasses and herbs where pine litter is not too dense. A large area of longleaf pine (P. palustris) occurs on the north end of the island near Terrapin Point. The area has been logged several times and is now mixed with large live oaks among other hardwood species. Longleaf pine typically grows in dry, open savannah in which fire occurs very frequently, at least once every 1-3 years. Accumulated pine needles and grasses are the major fuel source of the "cool" fires that characterize longleaf stands (Komarek, 1974; Christensen, 1981). This short fire rotation has not been the case on Cumberland Island. Large fires have occurred every 15-25 years on the north end of the island for the last 60 years (Turner, in press). Grazing by horses and the large deer population has kept grasses from accumulating (Stratton and Bratton, 1982). Fires spreading from adjacent scrub have been hot and have left deep scars on many of the pines and some of the oaks. Mature pines were killed with each fire and subsequently logged (Turner, in press). This area is presently an open park-like site of scattered mature pines and oaks with low grasses and forbs, and occasional sparce shrubs. Slash pines occur in mesic to poorly drained soils as single trees or in small groups. This species is usually associated with live oak in both the mesic hardwood forest and oak scrub. In the hardwood forest, slash pine is associated with a sparce grass herb layer and very little shrub cover. Serenoa repens occurs only in isolated patches.

The oak hardwood forest type of this study is a conglomerate of at least four community types described by Hillestad et al. (1975), and includes all mature forests dominated by hardwoods. The common characteristics of these forests are: (1) a large oak component, usually of Quercus virginiana; (2) a canopy which is at least 18 meters high and closed; (3) an understory of scattered small trees which is spacially distinct from the canopy; (4) a nearly continuous layer of Serenoa repens; and (5) a sparse to nonexistant herb layer. The most common expression of this type is the live oak maritime forest which occurs in areas of high exposure to wind and salt spray. This forest type is almost exclusively dominated by Quercus virginiana, and has been extensively described (Wells, 1939; Boyce, 1954; Bordeau and Oosting, 1959; Laessle and Monk, 1961; Stalter, 1974; and Rayner and Batson, 1976). Interior forests resemble the mixed hardwood forests of mainland areas described by Quarterman and Keever (1962), and include Quercus laurifolia, Magnolia grandifolia, Carya glabra, Quercus nigra, Nyssa sylvatica, Ilex opaca, and Acer rubrum among other species. Also included in this type are hardwood swamps and bays. Species common to these areas include: Nyssa aquatica, Persea palustris, Magnolia virginiana, Gordonia lasianthus, and Cephalanthus occidentalis.

STUDY SITES

The major study area was within the 1700 acres (688 ha) of the South-Cut Fire Site. The fire was ignited in scrub vegetation by lightning on the evening of July 15, 1981. A crown fire fed by gale winds and high fuel loadings burned through 1100 acres (445 ha) of pine and oak scrub during the next day. The freshwater marshes, dry since 1978, caught fire two days later and rapidly burned down to South-Cut Road which was an effective fire break. The fire was declared controlled on August 3, but not declared "out" until 21 days later after several days of heavy rains. Although the burned acreage was extensive, the fire was largely restricted to four community types: pine and oak scrubs, freshwater marsh, and mature pine/live oak forest. Major boundaries of the fire formed along the borders of these communities with mature hardwood forest (Figures 2 and 3).

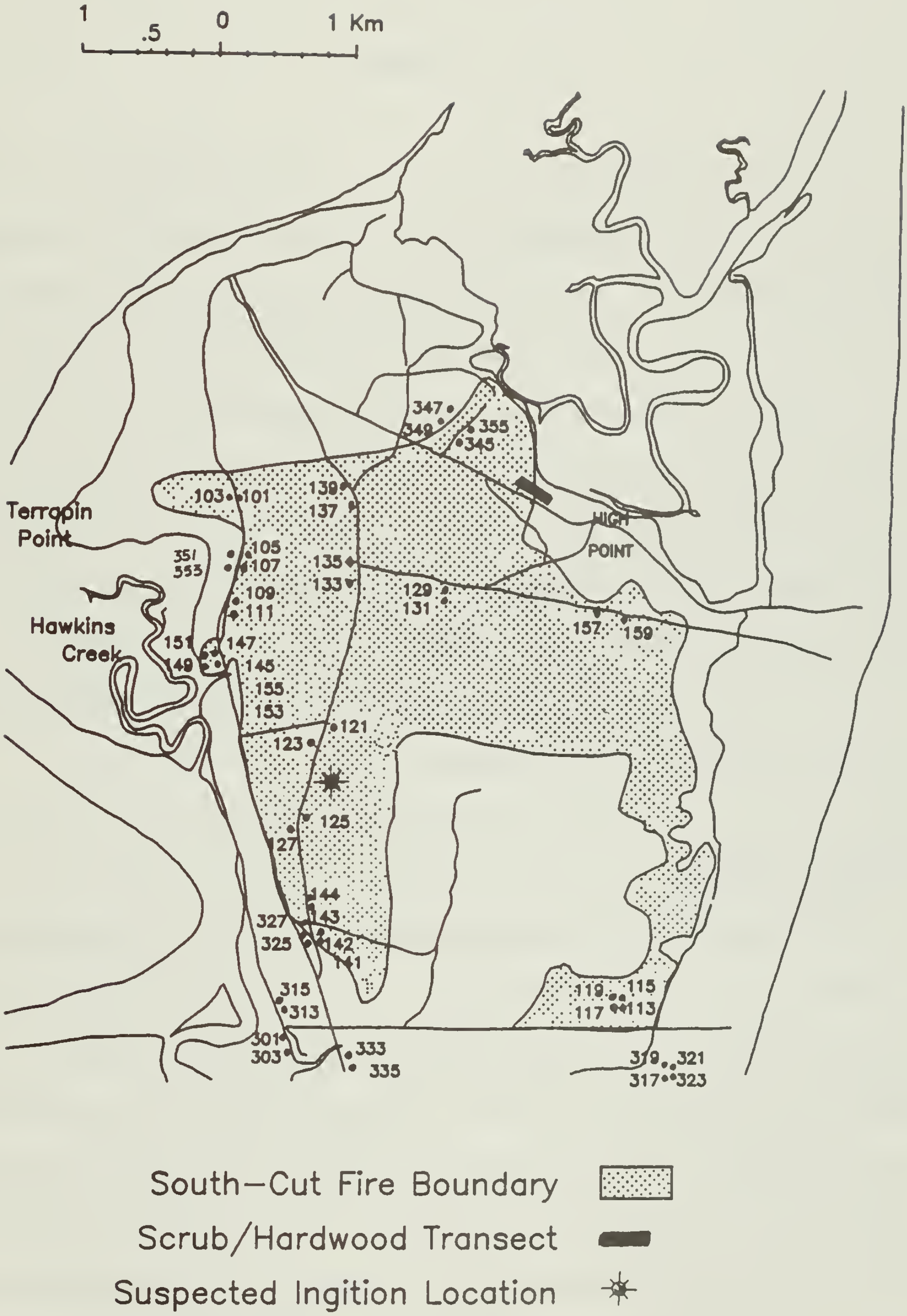
Two additional burn sites on Cumberland Island were investigated. The Table Point Fire occurred in 1977 and burned about 300 acres. This was an area of scattered mature slash and pond pines with a scrubby understory and a small amount of freshwater cordgrass marsh. The fire was hot and killed most of the pines. The area five years later was a scrub thicket of live oaks, ericaceous shrubs and *Myrica cerifera*. The Powerline Fire occurred in 1979 burning 55 acres mainly through a dry area of mature slash pines and live oak. Although the trees were scarred, this fire was not as hot and tree mortality was less extensive.

In addition to studies on Cumberland Island, vegetation which had been burned under prescription was sampled in June and July of 1982 on Sapelo Island. Fire was used to remove hazardous scrub fuels around pine timber and improve forage for wildlife. Four plots were laid out in an area burned in a low intensity winter fire which occurred in February of 1982. Two other plots were laid out in vegetation burned in a similar manner in 1977, but which had not burned since. This area is located approximately 45 km north of the South-Cut Site on Cumberland Island and is assumed to be influenced by the same general climatic and geologic factors.

Figure 2. Major plant communities on the north end of Cumberland Island


1
.5
0
1 Km
PINE
SCRUB
OAK
SCRUB
OAK
SCRUB
Sand
Lake
Whitney
Atlantic
Ocean
Saltmarsh
Pine/Oak
Forest
Hardwood
Forest
Freshwater
Marsh
Dune
Scrub

Figure 3. Plot Locations and boundary of the South-Cut Fire Site.


1 .5 0 1 Km
Terrapin Point
Hawkins Creek
HIGH POINT
347
349
355
345
139
137
103
101
351
353
105
107
135
133
129
131
109
111
157
159
151
149
147
145
155
153
121
123
125
127
144
143
327
325
142
141
315
313
119
117
115
113
301
303
333
335
319
317
321
323
South–Cut Fire Boundary
Scrub/Hardwood Transect
Suspected Ingition Location

METHODS

Vegetation sampling consisted of three segments: 1) seasonal sampling in the South-Cut Fire Site, 2) comparison sampling of unburned, old burn and prescribed burned sites, and 3) a transect across one of the boundaries of the South-Cut Fire.

Prior to sampling, maps and aerial photographs of the island were reviewed. These included the plant community map drawn up by Hillestad et al. (1975) and a set of false color infra-red aerial photographs taken by the Forest Service in late August of 1981 of the South-Cut Site. Film sensitive to relative amounts of reflected infra-red radiation represented healthy, damaged and dead vegetation as different colors, thus mapping fire severity.

SEASONAL SAMPLING

To characterize community responses to fire according to severity, a block design was constructed which required a sample of each community type within three fire severities, and a sample of similar communities in unburned areas. Fire severity types were measured by scorch height as: ground fire, 0-1.5 meters; shrub fire, 1.5-4 meters; and crown fire, 4+ meters. Vegetation sampling in the South-Cut Fire site was begun in December of 1981. Thirty sites were selected on the basis of field observations of community type and scorch height. Nearly all of the pine scrub on the island was involved in the

South-Cut Fire, and there was no site within the pine scrub where the scorch heights were any less than two meters. Therefore, the no burn and low fire severity categories could not be sampled for this community.

Once a site was selected, a pair of 20 meter lines were laid out in homogeneous vegetation roughly parallel to the nearest road or trail. The lines were at least five meters, but usually ten to fifteen meters away from the road; and at least ten meters apart from one another. Both ends of each line were referenced by distance and azimuth to witness trees which were marked with numbered aluminum tags. The locations of the line and witness trees were described with reference to the nearest landmarks, and their general location was marked on a United States Geological Survey topographic map. At a later date, permanent markers made of concrete filled polyvinyl chloride pipe with a numbered brass plug were laid out to mark each plot.

Herbaceous and woody vegetation were recorded by percent cover within ten subplots along alternating sides of the twenty meter line. Woody vegetation was recorded within a four meter square subplot. Herbaceous cover was recorded within a one meter square area inside the woody subplot.

The thirty lines were resampled as described above during April, 1982. Four additional lines were marked and sampled to complete the block design. The thirty-four lines were revisited seasonally in July and September of 1982, and March, June, and September of 1983.

Trees and soils were sampled in April, 1982. Plots of 20 X 20 meters were constructed for tree sampling, extending from the seasonal sampling line in the direction opposite from the nearest road or trail. Tree species, diameter at breast height to the nearest cm (dbh), and vitality (dead or alive) were recorded for every individual with a dbh greater than or equal to 2.5 cm. Soils were sampled at two depths within each plot at 0-12 inches and 12-24 inches. The shallow sample was a mixture of at least four subsamples taken with an eight inch soil core at random locations within the plot. The deep soil sample was a single sample removed from the profile of a thirty inch deep pit. The soil samples were placed in paper bags and allowed to air dry and were sent to the Soil Testing Laboratory, Cooperative Extension Service, Athens, Georgia for analysis. The samples were analyzed for pH and buffer pH and soil macronutrient content by plasma emission spectrophotometer after double acid extraction according to the methods laid out by Isaac and Johnson (1983).

Environmental variables including elevation, distance and aspect from shores, and distance from open water were noted from topographic maps for each plot. Field notes of distance to the nearest road or trail, canopy height and relative closure, evidence of past fires, and disturbances other than fire (such as grazing, hog and armadillo rooting, logging, and insect damage to canopy trees) were also recorded for each plot.

COMPARISON PLOTS

Twenty plots within unburned communities similar to those sampled in the South-Cut site were sampled for herb and woody percent cover, trees, and soils in the manner described above. In addition, eight plots on Table Point in two fire sites of different ages, and six plots on Sapelo Island in sites under timber management which had been burned under prescription were sampled as above. These plots were not resampled.

TRANSECT STUDY

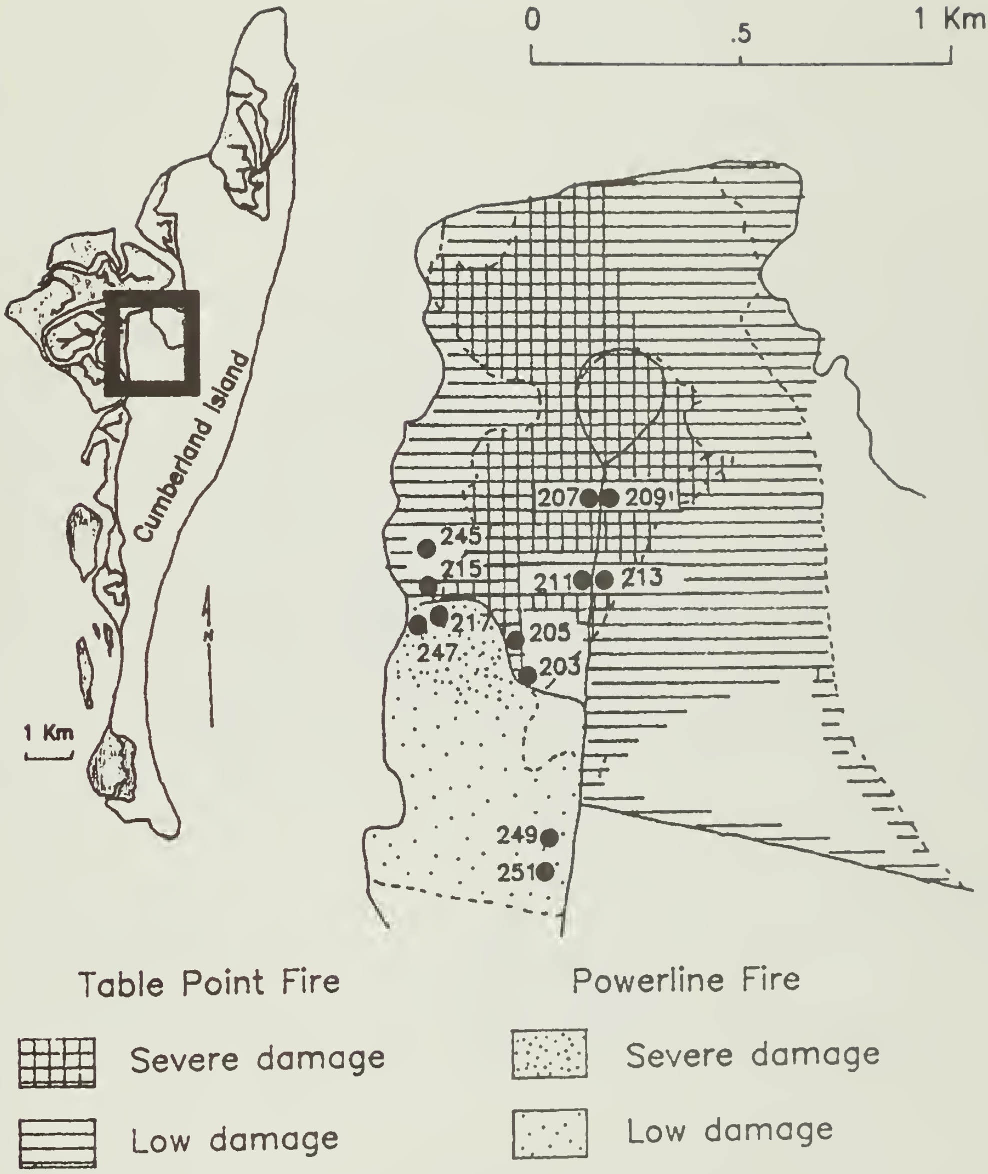
A boundary of oak scrub and oak hardwood forest in the South-Cut site was studied for tree and soil composition in November of 1982. The site was adjacent to the Candler property gate, 30 meters north of Candler Road. Fire had crowned in the oak scrub and killed nearly all aboveground vegetation, but remained low and finally went out in the oak hardwood. In order to sample the transition of communities and tree mortality, a transect along a 90 meter line was laid out perpendicular to the fire boundary. The transect ran from the unburned oak hardwood, through the fire boundary and into the completely scorched oak scrub. On either side of the line nine pairs of replicate plots, 10 X 40 meters, were constructed. Within the plots all individuals with dbh greater than 2.5 cm at were recorded for species, dbh (to the nearest mm) and vitality on a four point scale: 1) dead before fire or fire kill/no sprouts, 2) fire kill/sprouting, 3) scorched/ alive, and 4) healthy. Soil was sampled in each plot by soil core at five random locations within the plot. Each soil core was divided into three sections: 0-3 inches, 3-6 inches, and 6-9 inches. The soil sections were placed in labeled paper bags, mixed, and allowed to air dry before sending them to the Soil Testing Laboratory.

Figures 3, 4, and 5 show the location of sampling plots and the transect on Cumberland Island, and sampling plots on Sapelo Island, respectively.

ANALYTICAL METHODS

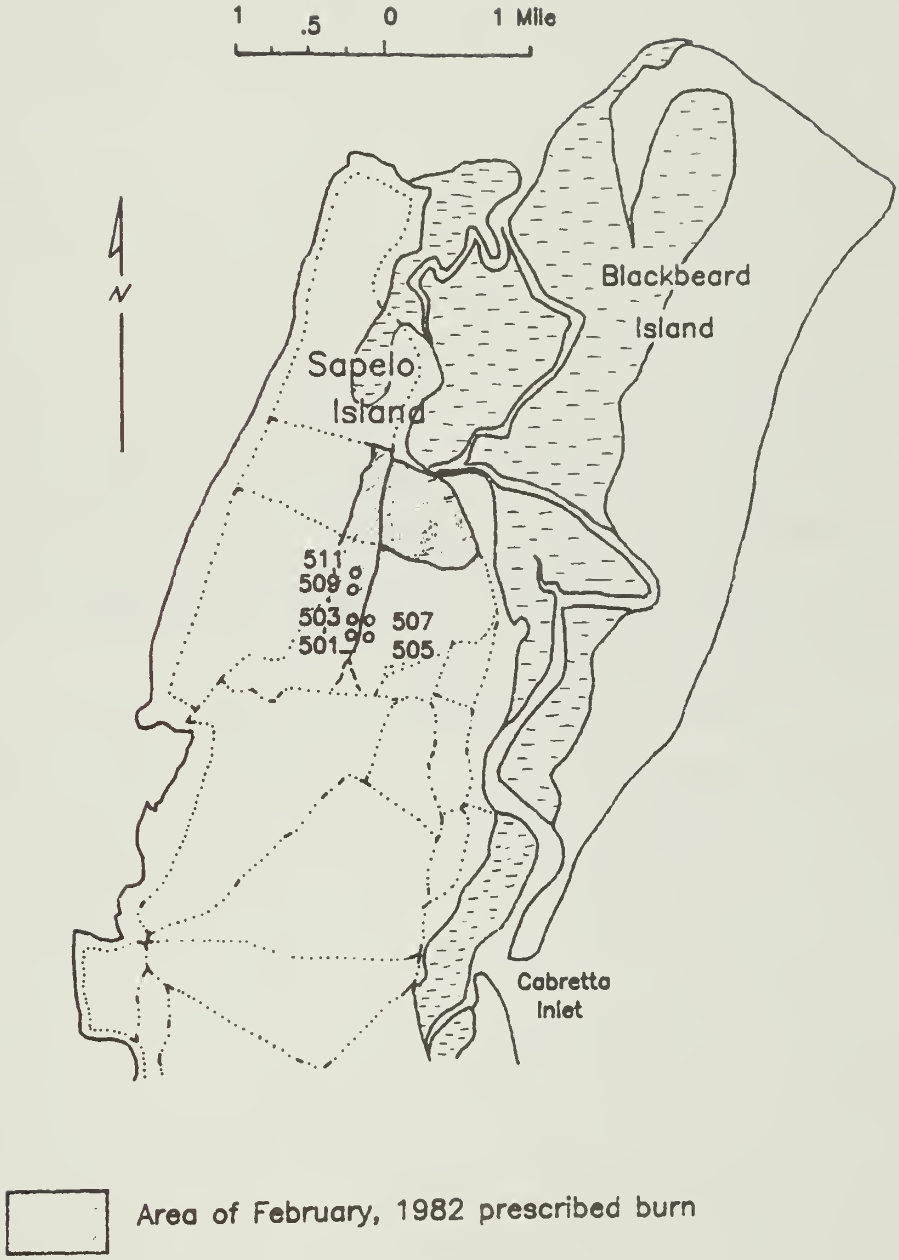
Percent cover data were averaged over the ten subplots for each species in each sample. Tree data were used to calculate density,

Figure 4. Plot locations and boundaries of the Table Point and Powerline fire sites.



0
.5
1 Km
Cumberland Island
1 Km
N
207
209
245
215
211
213
217
205
247
203
249
251
Table Point Fire
Severe damage
Low damage
Powerline Fire
Severe damage
Low damage

Figure 5. Plot locations on the north end of Sapelo Island.



Area of February, 1982 prescribed burn

basal area, and an importance value for each species in each plot before and after the fire according to vitality scores. Density was calculated as the actual number of trees multiplied by 250 to be reported in units of trees per hectare. Basal area was calculated from tree size scores and reported in units of m2 ha-1. Because each plot was analyzed separately, species frequency was equal to one for each species in the plot. Importance values were calculated as the sum of the relative density, relative basal area, and the relative frequency. Importance values reflect only the density and basal area; frequency is the same for each species. Relative frequency was included in the importance value to bring the sum of the relative values to the standard unit of three hundred which has been used in other studies (Quarterman and Keever, 1962; Monk, 1965).

Principal components analysis was used to test the hypothesis that species composition within a stand influenced survival in the South-Cut fire. A data matrix of the prefire basal area of live tree species for each plot was analyzed by a principal components program set written by G. Estabrook, of the University of Michigan. The first two principal components were used to create a two dimensional ordination of the plots. All of the seasonal plots except plot 105, and four of the transect plots (T4, T5, T8, and T15) were included in the final matrix. The original matrix which included plot 105 indicated that this plot was unique, setting it off by itself and clumping the rest of the plots. Removal of the unique plot provided a wider scatter of remaining thirty-one plots. Gauch and Whittaker (1972) provided a discussion of principal components analysis, its interpretations and limitations.

Basal area of _Quercus virginiana_ was also plotted directly against percent survival of total stand basal area and a regression fitted to the plot.

RESULTS

Mean soil pH, buffer pH, and macronutrient values of burned and unburned community types are given in Table 1. Vegetation response and regrowth data are presented by community type. Soil and vegetation cover data for the final sample (September, 1983) are presented in Appendicies 1 and 2, respectively.

MARSHES

Freshwater marsh soils were acidic with pH values that ranged from 3.6 to 4.4 and generally nutrient poor. The fire burned deeply into the peat of all the marshes, burning down to sand substrate in the cordgrass marshes. However, at least 20 cm of peat remained in burned sawgrass marsh plots. Shallow samples from these plots could not be analyzed as soils because they contained too much organic matter. Deep samples could not be taken in any of the sawgrass marshes as the water table was 30 cm above the soil surface even in the dry early spring of 1982. Unburned sawgrass marsh sampled had the highest pH buffer values recorded in this study. There were no major differences between burned and unburned freshwater marsh soil values. Soil pH and nutrient values of the dry cordgrass marsh plots, 129 and 131, were exceptionally low as were those of the Table Point marsh, which burned in 1977. One of the Table Point marsh samples had an unusually high amount of Ca,

TABLE 1. Means and standard deviations of shallow soil sample pH, buffer pH (pH B), and macronutrient (Kg Ha^{-1}) values from burned (B) and unburned (U) sites according to community types.

Starred column indicates the number of samples used in calculations.

Community Type		*	pH $\bar{x}$	pH sd	pH B $\bar{x}$	pH B sd	P $\bar{x}$	P sd	K $\bar{x}$	K sd	Ca $\bar{x}$	Ca sd	Mg $\bar{x}$	Mg sd
Saltmarsh	B	2	5.00	.07	7.52	.04	38	12	160	40	730	4	457	124
Saltmarsh	U	2	4.70	.07	7.42	.04	9	1	150	66	346	146	306	145
Freshwater cordgrass, wet	B	2	4.30	.14	7.48	.12	3	1	18	12	421	11	175	40
Freshwater cordgrass, dry	B	2	3.75	.21	7.45	.24	15	1	22	3	143	58	27	12
Freshwater cordgrass	U	2	4.15	.07	7.45	0	20	12	34	2	239	30	61	9
Freshwater sawgrass	U	2	4.35	.07	7.70	.39	90	36	45	3	462	165	124	54
Pine scrub	B	5	4.28	.25	7.43	.15	15	8	93	36	427	151	176	67
Oak scrub	B	6	4.28	.28	7.41	.15	16	7	86	29	331	102	115	64
Successional oak scrub	B	2	4.10	.00	7.72	.12	22	15	134	18	890	87	269	80
Oak scrub	U	2	4.25	.35	7.58	.20	16	2	58	20	102	34	47	28
March edge loblolly pine/oak	B	2	4.30	.56	7.25	.16	27	13	117	30	574	305	185	24
Upland longleaf pine/oak	B	2	5.35	.07	7.55	.00	121	8	31	1	1080	266	89	34
Upland slash pine/oak	B	2	4.60	.14	7.43	.04	43	45	44	12	657	393	85	34
Marsh edge loblolly pine/oak	U	2	5.00	.42	7.45	.04	63	0	37	12	119	47	34	4
Upland loblolly pine/oak	U	2	5.00	.07	7.62	.04	45	36	26	8	1704	238	85	19
Upland slash pine/oak	U	2	4.80	.21	7.65	.08	56	1	25	2	141	86	22	1
Oak hardwood	B	4	3.90	.26	7.43	.27	16	10	121	32	399	49	225	131
Mesic hardwood	B	2	4.25	.35	7.65	.31	29	36	68	9	2090	352	222	64
Mesic hardwood	U	2	4.35	.50	7.60	.31	20	4	58	24	1692	45	217	38

measuring 1610 kg ha^{-1}. This high reading was probably due to a fragment of shell from the adjacent dirt road, as the deeper soil sample from the same area and the samples from the replicate plot indicated the more typical level of Ca, less than 450 kg ha^{-1}. Saltmarsh soils had higher pH values ranging from 5.1 in the burned saltmarsh to 4.8 in the unburned saltmarsh. Macronutrient values, particularly Ca and P, were higher in burned saltmarsh than in unburned saltmarsh.

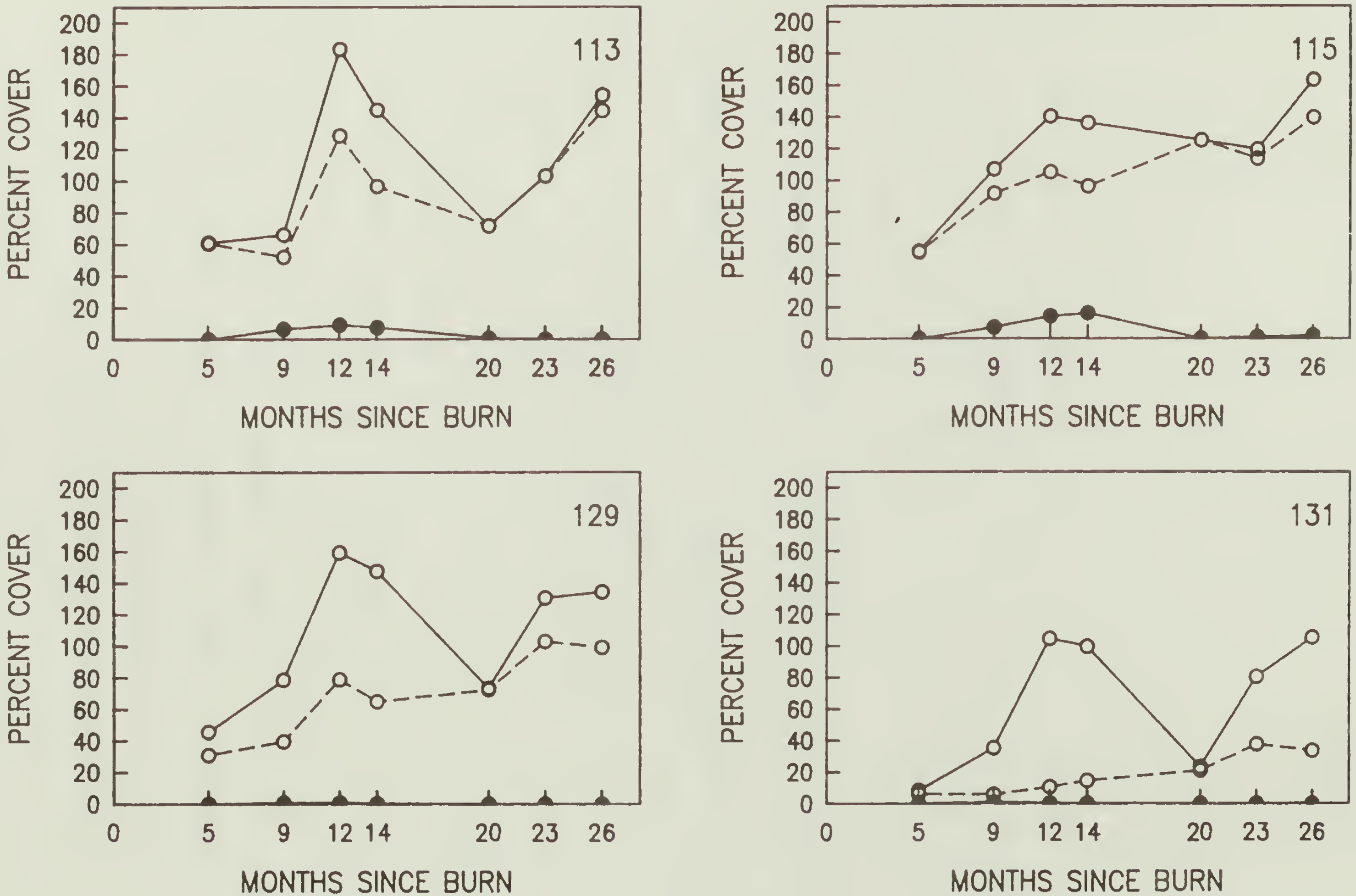
Marsh dominated by *Spartina bakerii* was the most widely sampled type of marsh. Post-fire regrowth within this type was dominated by *Spartina bakerii* in all but plot 131 (Figure 6). This plot was the driest of the marshes studied, and supported a more varied herb cover of sedges, rushes and panic grass. The other three plots showed a substantial amount of herbaceous cover even in December, 1982. This was due to the growth habit of *Spartina bakerii* which forms tight hummocks. After the fire had passed through cordgrass, the hummocks remained and had put out new blades by the time of the first sample, five months after the fire. The fifth sample of all *Spartina bakerii* plots indicated a sharp decline of percent cover, with nearly all herbaceous cover represented by *Spartina*. The water level was very high during this season and only the tall cordgrass hummocks reached the surface. Wet cordgrass marshes, represented by plots 113 and 115 also differed from the dry cordgrass marshes in species presence. Marsh prairie species such as *Polygonum hydropiperoides*, *Sagittaria latifolia*, *Nymphoides aquatica*, *Nymphaea odorata*, *Limnobium spongia*, and *Utricularia* spp. appeared in the wet marsh plots with the rising water during the first year after the fire. Many of these species

Figure 6. Post-fire regrowth in freshwater cordgrass marsh.

Total herb cover

Spartina bakerii cover

Total shrub cover


113
115
129
131
PERCENT COVER
MONTHS SINCE BURN
0
5
9
12
14
20
23
26
200
180
160
140
120
100
80
60
40
20

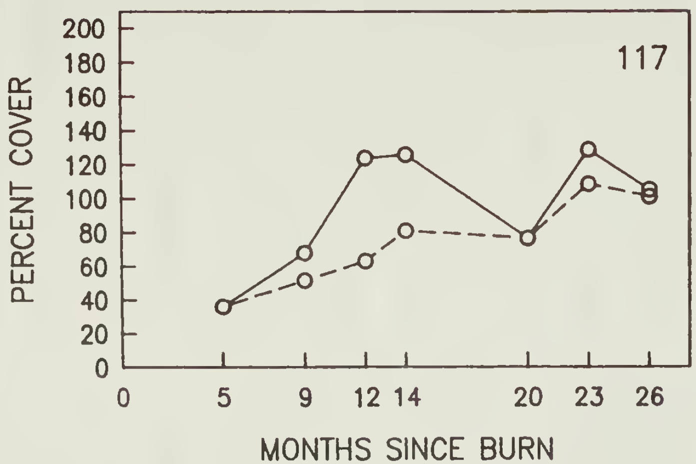
became less abundant as cordgrass filled the area between hummocks with live and dead blades. Decodon verticillatus, the persistent shrub of these wet plots flowered heavily during September of 1982. The shrub did not flower well in 1983 as the plants were all but completely underwater. The dry plots had standing water along the entire length of the sampling transect during the second year only, which never exceeded one foot in depth. Species of smaller stature than cordgrass became established and survived partial inundation. The more common of these were: Pluchea spp., Proserpinica pectinata, Panicum spp., Xyris spp., Juncus spp., and Eleocharis spp.. It was noted during the June, 1982 sample that grazers, presumably horses perferred burned grass regrowth to unburned grasses. Andropogon virginicus had been cropped to about four inches within marshes of the burned side of South-Cut Road, yet no grazing was evident on the same species a few meters away in the unburned marsh.

Sawgrass marsh regrowth is represented in Figure 7. By the end of the second year, vegetation cover in the burned plots had not reached that observed in the unburned plots 317 and 319 which was nearly 200% average cover. The sawgrass marshes were much less diverse than any of the cordgrass marshes, Cladium being a more exclusive dominant. Ferns, tentatively identified as Woodwardia virginica germinated on high peat and sawgrass clumps in the spring of 1982. Pluchea and Cyperus also appeared on elevated peat clumps. However, most of these species did not survive inundation later in 1982. As the water level rose, only the truly aquatic herbs remained in any quantity: Polygonum, Ludwigia linaris, and Nymphaea odorata which occurred primarily in areas of open water where Cladium had fallen. One small stem of Rubus sp. was noted

Figure 7. Post-fire regrowth in freshwater sawgrass marsh.

Total herb cover

Cladium jamaicense cover


117
PERCENT COVER
200
180
160
140
120
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80
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40
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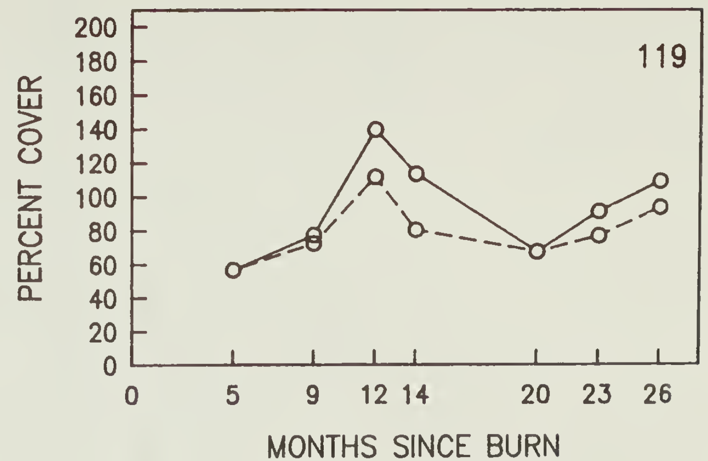
0
0
5
9
12 14
20
23
26
MONTHS SINCE BURN


119
PERCENT COVER
200
180
160
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5
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12 14
20
23
26
MONTHS SINCE BURN

during the second sample while the marsh was still relatively dry, but it disappeared with the rising water. Deer scat was also noted during the second sample, indicating that the marsh was probably being grazed. However, no evidence of grazing was noted on the plants of this marsh type as had been noted in cordgrass marshes.

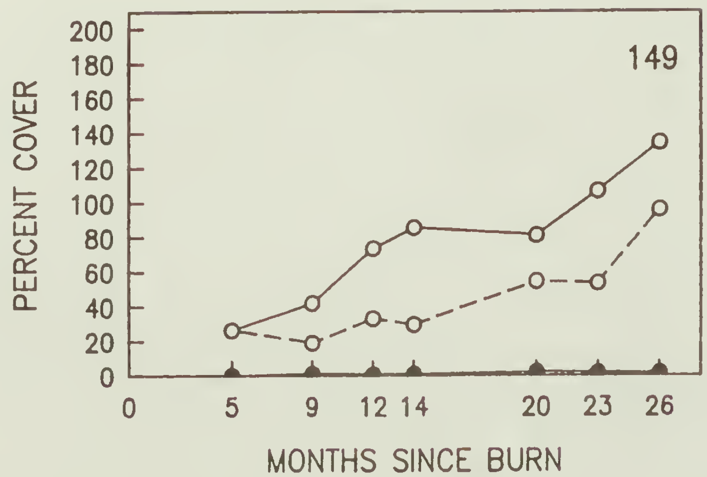
The regrowth patterns of salt meadow cordgrass, Spartina patens were very similar to that of the freshwater cordgrass. The brackish cordgrass is also a hummocked species with roots firmly established in sand. All of the soil organic matter was removed, leaving bare sand and graminoid clumps. The average percent cover was lower in this marsh type (Figure 8) than in the freshwater marshes (Figure 6 and 7). This was largely due to the sharp zonation of the saltmarsh. The sampling lines were laid across a zone change between salt meadow and salt pan. Salt pan is characterized by moderate to sparse vegetation cover. It is dominated by Distichlis spicata, a grass of small stature (1-3 dm), and scattered halophytes. Vegetative cover in salt meadow was comparable to that of the freshwater marshes and was composed of larger (4-10 dm) grasses and sedges: Juncus roemerianus, Fimbristilis spidacea and Cyperus spp. as well as Spartina patens. Two hundred percent cover in this vegetation was not uncommon in samples two years after the fire. Species diversity was higher in the burned saltmarsh plots than in the unburned plots. The halophytes of the salt pan appeared to have sprouted from preexisting roots. These attained cover similar to that of unburned plants within the first year, flowering and fruiting in both years after the fire. Much of the herb cover in the first year was of annual composite species, Eupatorium capillifolium and Senecio vulgaris. These grew in tall, lush stalks during the first

Figure 8. Post-fire regrowth in saltmeadow cordgrass marsh.

Total herb cover

Spartina patens cover

Total shrub cover


149
PERCENT COVER
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140
120
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5
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12
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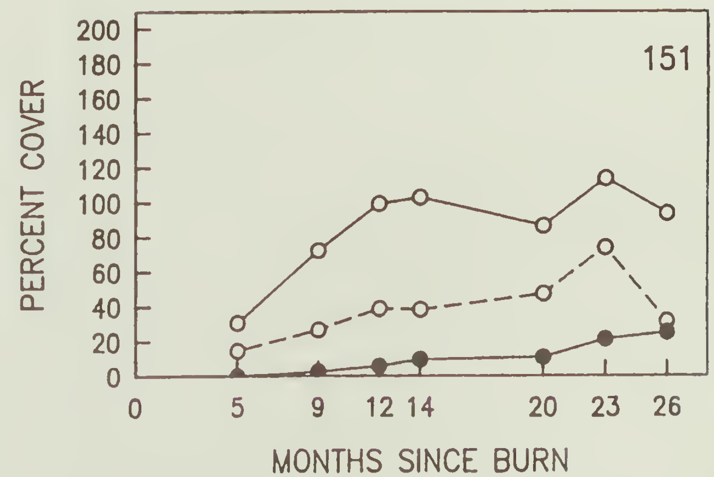
23
26
MONTHS SINCE BURN


151
PERCENT COVER
200
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20
23
26
MONTHS SINCE BURN

year, but became less common during the second year. Woody vegetation was sparce, represented almost exclusively by saltmarsh elder, Iva frutescens which sprouted from pre-existing roots.

SCRUBS

Scrub soils were generally acidic and sterile. Unburned and low fire severity areas tended to have lower pH and nutrient values than those in which a large amount of vegetation and soil organic matter had been consumed. The pH values ranged from 5.1 in a pine scrub where all of the trees and soil organic matter had been consumed to 3.8 in an oak scrub which had experienced a very low "cool burn." Soil nutrient values were more variable, but followed the same trend. Oak scrub soils will be discussed in further detail in the transect results.

Throughout most of the pine scrub tree mortality was very high, 95-100% in plots where Pinus serotina was a strong dominant (plots 133, 135, 121, 123, 125) as shown in Table 2. Pine scrub graded into oak scrub in plots 123 and 127, the latter of which was the only scrub pine plot in which a few of the pines survived. The most destructive burn appeared to have taken place at the site of plots 133 and 135. Standing dead pines of this site had few lateral branches. These had been consumed as had all of the soil organic matter. Most of the shrub rootstocks and large rhizomes of Serenoa repens were exposed and severely burned. Woody regrowth was very limited (Figure 9). Ground cover was primarily charcoal litter and mosses during the first year after the fire. Herbs dominated by Eupatorium capillifolium, Andropogon virginicus, and various sedges and rushes, formed most of the cover during the second year. Five pine seedlings were noted in

TABLE 2. Importance values of pine scrub species before the South-cut Fire.

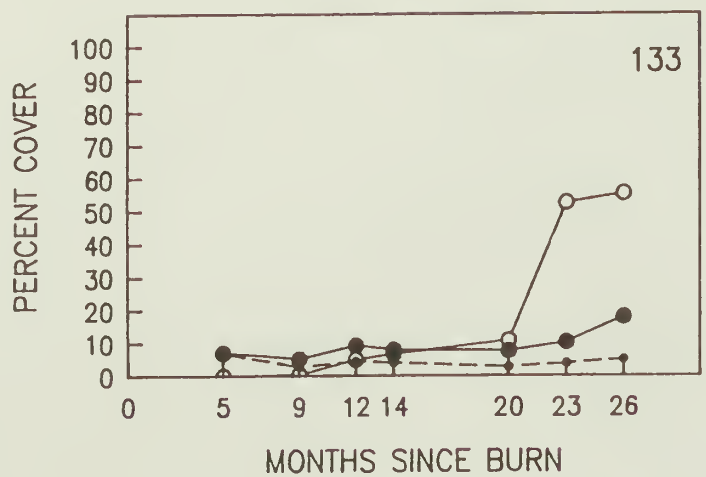
PLOTS	133	135	123	121	125	127
Pinus serotina	172	217	136	244	248	80
Myrica cerifera		27	18	56		16
Persea borbonia	68	30				15
Lyonia ferruginea	26		65		52	84
Lyonia lucida	34					17
Ilex glabra		27	18			
Quercus virginiana			42			45
Quercus myrtifolia			21			18
Quercus chapmanii						24
Basal area removed "by fire-kill"	15.79	30.00	24.68	5.70	5.34	7.76
Percent BA survival	0	0	0	0	5	25
Fire Severity	Very Severe		Severe		Mod. Severe	

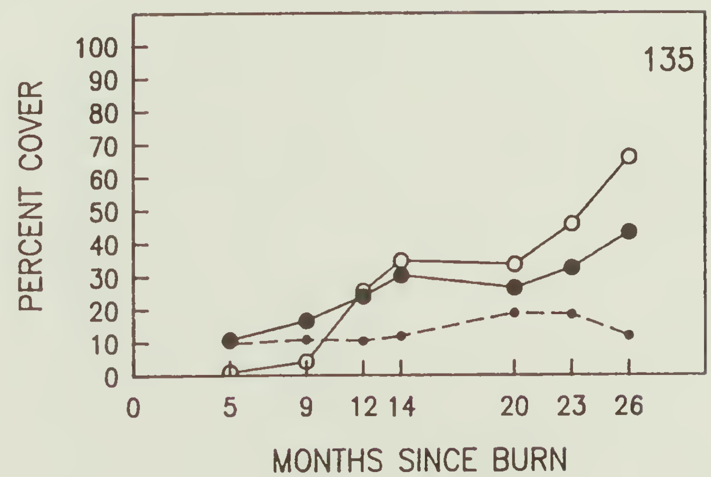
Figure 9. Post-fire regrowth in severely burned pine scrub.

Total herb cover

Total shrub cover

Serenoa repens cover


133
PERCENT COVER
100
90
80
70
60
50
40
30
20
10
0
0
5
9
12 14
20
23
26
MONTHS SINCE BURN


135
PERCENT COVER
100
90
80
70
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20
10
0
0
5
9
12 14
20
23
26
MONTHS SINCE BURN

plot 135, which survived to the second year. Two pine seedlings which did not survive were noted in September of 1982 in plot 133. Pond pine did not sprout in this area.

Regrowth in most of the pine scrub acreage was vigorous and almost exclusively woody, represented by plots 121-7 in Figure 10. Shrub cover in plots 121 and 125 was split between _Lyonia lucida_, _Serenoa repens_ and _Ilex glabra_. Plots 123 and 127 were more strongly dominated by _Serenoa_. _Lyonia ferruginea_, _Quercus virginiana_ and _Quercus myrtifolia_, which were sparsely scattered or non-existent in plots 121 and 125, were common in plots 123 and 127 located just across Bunkley Trail. Elevation and drainage may have affected these species distributions. The more xeric species (_L. ferruginea_ and the _Quercus_ spp.) were also common in oak scrub. _Serenoa_ cover in the pine scrub plots was very stable, remaining between 15-40 percent with little fluctuation within the seasonal samples of any given plot. Pond pine also sprouted from pre-existing roots. Pine sprouts were found most often on individuals which were smaller than 10 cm before the fire. Most of the sprouts did not survive; of the 182 sprouts counted in plots 121, 123, 125, and 127 only 47 (26%) were alive in the last sample. However, by that time, twenty-six months after the fire, several of the survivors were robust, 2-4 cm diameter saplings which may serve as a seed source to repopulate the area. _Panicum_ species and _Pteridium aquilinum_ represented most of the scant herb cover.

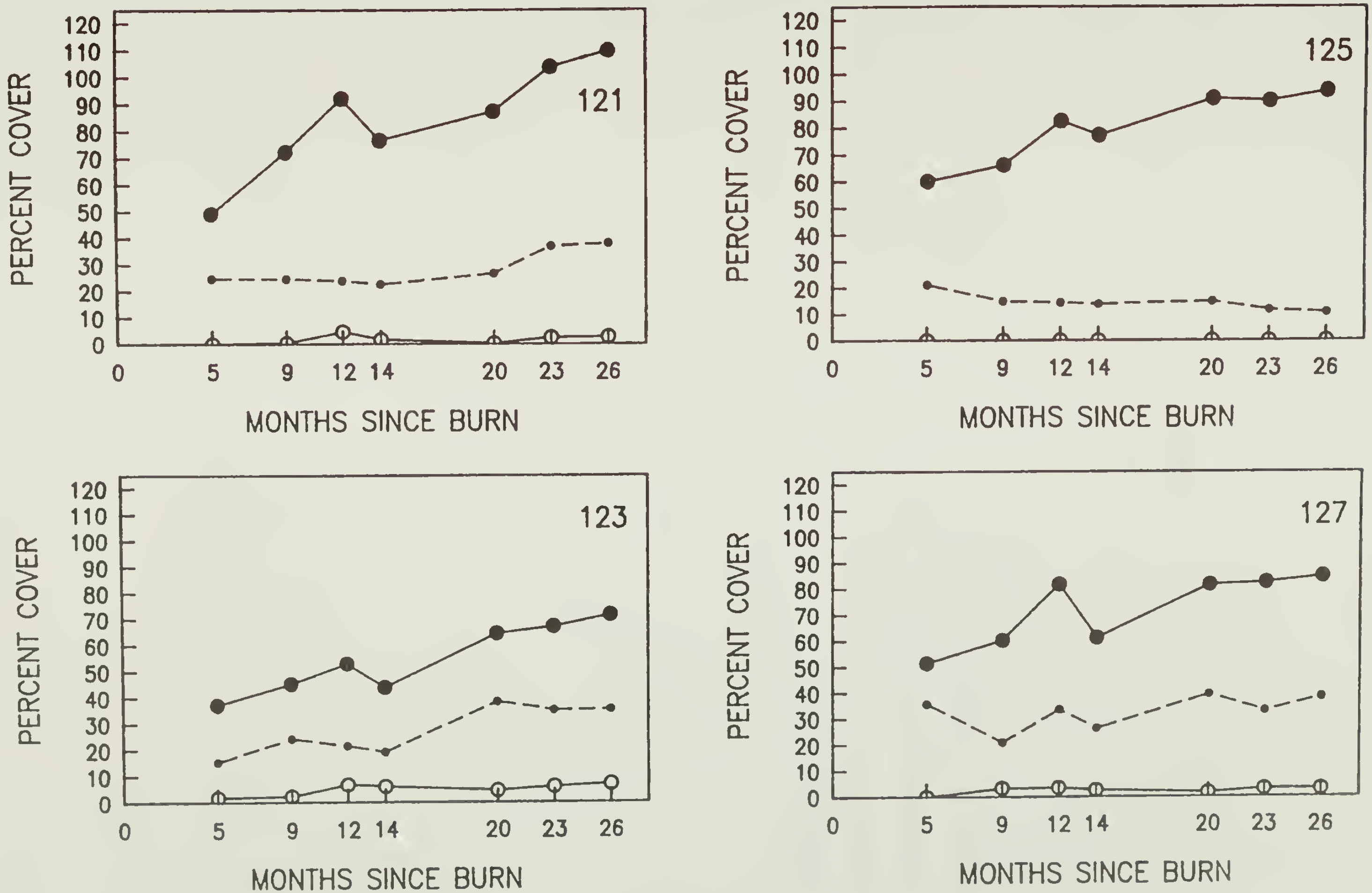
Table Point and Sapelo Island pine scrub samples indicated many of the same patterns as shown in Table 3. Most of the pines (including the cones) in the Table Point scrub had been destroyed, much as in the South-Cut site. Pine regrowth was very limited. Shrub cover was

Figure 10. Post-fire regrowth in pine scrub.

Total herb cover

Total shrub cover

Serenoa repens cover



121
125
123
127
PERCENT COVER
MONTHS SINCE BURN
0
5
9
12 14
20
23
26
0
10
20
30
40
50
60
70
80
90
100
110
120

TABLE 3. Importance values of species in pine scrub comparison plots.

	Table Point			Sapelo Island		
PLOTS	203	205	501	503	507	509
Pinus serotina		118		59	240	300
Myrica cerifera	79	34				
Lyonia ferruginea		104		41		
Lyonia lucida	66	44				
Quercus virginiana			119	62		
Quercus myrtifolia				34		
Pinus elliottii			181	103	60	
Persea borbonia	156					

predominantly of Myrica cerifera and Serenoa repens, although species found in the South-Cut site also occurred in this area. Myrica, which was slightly over 1.5 meters in height in the spring of 1982, exceeded 2 meters by the summer of 1983. Herb cover was more extensive in this area, averaging 34% with Eupatorium capillifolium and Andropogon virginicus being the most common species. The prescribed burns on Sapelo left most of the pines alive. Shrub species had been killed to the ground, but these resprouted. Shrub cover in the four month old burn was dominated by Serenoa repens, Vaccinium myrsinites, and Galactia elliottii. These three species, especially Galactia were also common in the first year regrowth of the South-Cut scrub; all flowered and fruited heavily that year. The five year old burn site on Sapelo was thick with oaks, various ericads, and Myrica which were approximately 1-2 meters high. Serenoa repens averaged 35-45% cover. Herbs followed a reciprocal pattern to palmetto averaging 35-15% cover, respectively. Pines were the only tree species larger than 2.5 cm dbh.

Response to fire was more variable in oak scrub than in pine scrub, depending upon the dominance and size of the live oaks, Quercus virginiana. Very little canopy mortality occurred in areas in which live oak was the dominant species, and the majority of these individuals was larger than 8 cm dbh. Oak scrub in which the majority of trees were smaller than 8 cm dbh burned in a destructive crown fire and suffered 90-100% mortality of all species present. The importance value of Quercus virginiana was increased in every stand where this species had been dominant before the fire as shown in Table 4. Understory species such as Lyonia ferruginea and Myrica cerifera generally decreased in importance after fire, but were well represented in the

TABLE 4. Importance values of oak scrub species before (B) and after (A) the South-Cut fire.

	109	111	137	139	157		159		345		355	
	B	B	B	B	B	A	B	A	B	A	B	A
Quercus virginiana	47		57	54	104	141	160	300	81	84	57	62
Quercus myrtifolia	31	25	140	103					22	24	70	70
Quercus chapmanii		90			32	39			16	18	34	32
Lyonia ferruginea	117	46	27	117	129	77	140	0	81	84	90	87
Persea borbonia	56	65	15	26	35	43			15	16	20	20
Vaccinium arboreum		16	20						20	22	29	29
Myrica cerifera		43							13	0		
Vitis rotundifolia	19	16										
Pinus serotina			22									
Asimina sp.			21									
Ilex opaca	28											
Osmanthus americana									51	51		
Basal area removed "by fire-kill"	15.51	14.05	14.91	11.76	3.59		4.44		1.21		1.81	
Percent BA survival	0	0	0	0	71		60		95		90	
Fire Severity	High		High		Moderate				Low			

regrowth. Plots 109 and 111 were unique among the scrub plots, although this site had the general appearance of burned oak scrub. The site bordered a more mature mesic hardwood forest, and plots 109 and 111 were found to contain large individuals of species more common to that forest type scattered among the scrubby oaks and Lyonia. These included Ilex opaca, Persea borbonia and Vitis rotundifolia, all of which were killed by the crown fire fueled by the scrub vegetation.

The importance values of tree species in Table Point oak scrub, which burned in 1977, follow the same pattern as was found in the South-Cut site oak scrub as indicated in Table 5. Quercus virginiana was codominant with Lyonia ferruginea. The oaks were represented by individuals of 8 cm dbh or larger and Lyonia was represented by many small individuals. Although Myrica was represented in the shrub cover, no stems were large enough to be counted as trees.

The unburned scrub oak plots were located adjacent to burn plots 345 and 355 and resemble them strongly. The major difference between the burned and unburned plots after the fire was the dominance of Lyonia ferruginea in the unburned plots. Dominance of this species had been reduced in favor of Quercus virginiana in the burned plots.

Regrowth was dominated by Serenoa repens, except in plots 137 and 139 which were thick with Quercus myrtifolia. Serenoa averaged 15-65% cover. Serenoa cover was highest where oak sprouts (Q. virginiana and Q. myrtifolia) were not numerous. Serenoa regrowth followed a seasonal pattern in oak scrub that was not found in pine scrub. Serenoa increased cover during spring and summer, and plateaued or decreased cover during the winter of both year's regrowth. The second year's cover generally exceeded that of the previous year (Figures 11 and 12).

TABLE 5. Importance values of species in oak scrub comparison plots.

	Table Point		Unburned	
	207	209	347	349
Quercus virginiana	149	114	94	69
Quercus myrtifolia			28	29
Quercus chapmanii			37	26
Lyonia ferruginea	151	124	104	110
Persea borbonia		62	19	16
Vaccinium arboreum			18	15
Myrica cerifera				13
Osmanthus americana				21

Figure 11. Post-fire regrowth in scrub oak, Moderate burn (plots 157 and 159); Light burn (plots 345-355).

Total herb cover

Total shrub cover

Serenoa repens cover

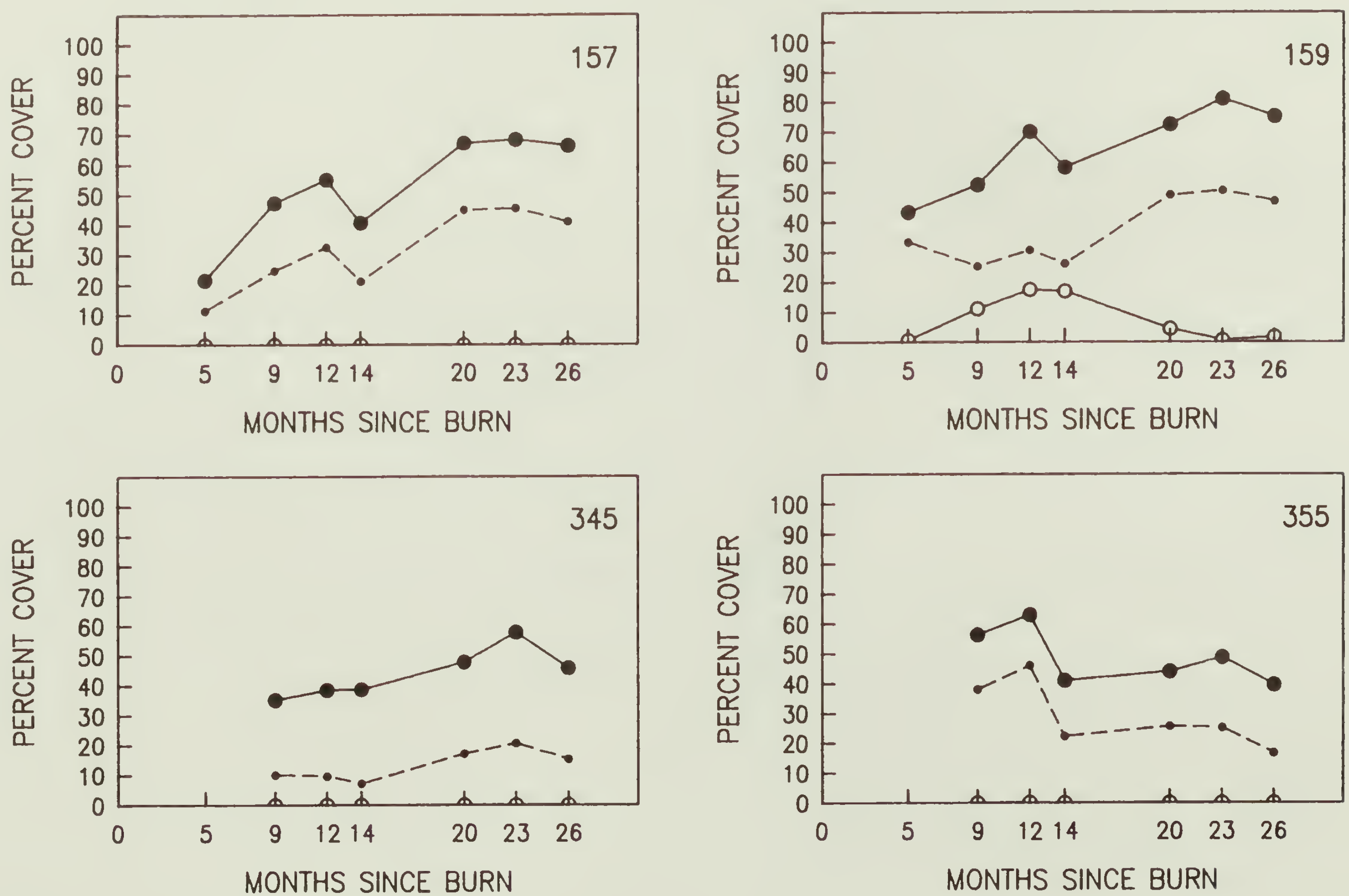
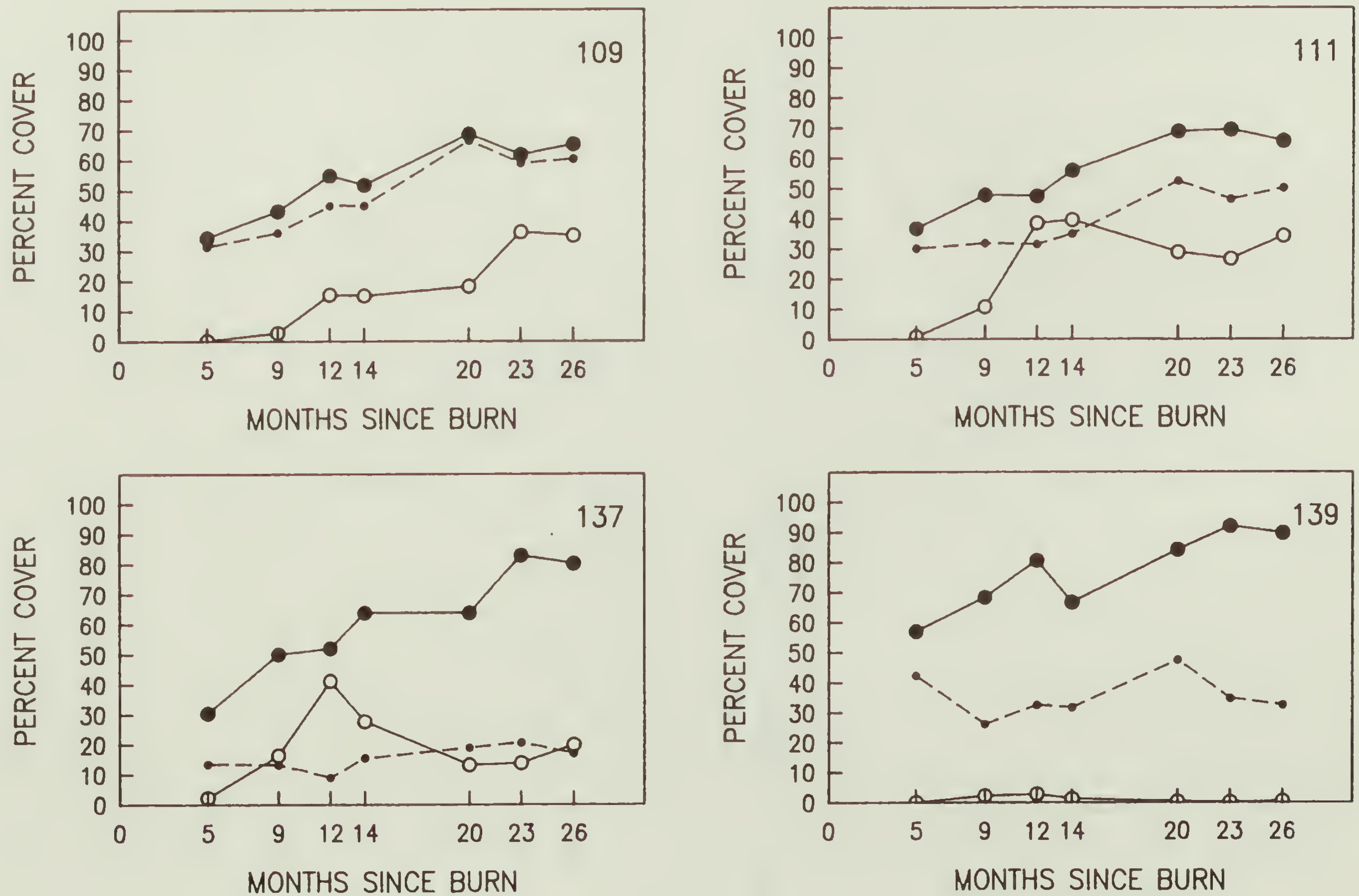

157
PERCENT COVER
100
90
80
70
60
50
40
30
20
10
0
0
5
9
12
14
20
23
26
MONTHS SINCE BURN
159
PERCENT COVER
MONTHS SINCE BURN
345
PERCENT COVER
MONTHS SINCE BURN
355
PERCENT COVER
MONTHS SINCE BURN

Figure 12. Post-fire regrowth in severely burned oak scrub.

Total herb cover

Total shrub cover

Serenoa repens cover


109
111
137
139
PERCENT COVER
MONTHS SINCE BURN

Oak sprouts did not suffer the mortality observed for sprouts of _Pinus serotina_. By July of 1982, new oak sprouts could not be easily distinguished from secondary branches of sprouts which had emerged earlier that year. Twenty-six months after the fire, many of the oak sprouts exceeded 2 cm at the base, were densely bushy, and over 2 meters high. Herb cover depended upon severity of burn, as shown in Figures 11 and 12. Herb cover was sparse to nonexistent, represented almost entirely by _Panicum_ species in areas where fire was moderate or low, represented respectively by plots 157-159 and 345-355. In areas which experienced severe fire, represented by plots 109-111 and 137-139, much of the soil had been cleared of small shrubs, stems, litter, and organic matter, and was exposed to sunlight. These conditions favored establishment of herbs which were dominated by _Panicum_ and _Eupatorium capillifolium_.

Pine/Oak Forest

Soil nutrient and pH values for pine/oak plots were variable between replicate plots, within the same type, and between types. Given the large variation between replicates, no major differences between burned and unburned soils could be determined, except that cation values for Ca, Mg, and K were generally higher in burned soils than in unburned soils from stands of the same pine species.

Pine/oak forests were subdivided into two groups: upland and saltmarsh edge, mainly on the basis of understory and herb differences. _Serenoa_ and hardwood shrubs were much more abundant in the pine stands on the saltmarsh edge, while upland pine/oak sites were characterized by a grassy, open forest floor. Saltmarsh pine/oak was represented by

TABLE 6. Importance values of pine/oak species before (B) and after (A) the South-Cut fire.

PLOT	149		151		145		147		103		101		153		155	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Pinus elliottii													31	32	30	30
Pinus palustris									147	163	129	196				
Pinus taeda	132	0	209	0	198	300	53	0								
Quercus laurifolia	69	0			23	0	103	300					55	60	65	65
Quercus virginiana			48	300	25	0					52	104	79	70	84	84
Myrica cerifera	37	0			32	0					27	0	62	59	24	24
Vitis rotundifolia	61	0			22	0	60	0			27	0	20	21	97	97
Persea borbonia							84	0	75	137						
Juniperus silicicola			42	0					31	0						
Ilex opaca									46	0	61	0				
Vaccinium arborea													34	38		
Lyonia ferruginea													20	21		
Basal area removed "by fire-kill"	12.66		16.60		32.04		8.90		10.18		6.22		3.02		0.00	
Percent BA survival	0		8		7		28		42		75		94		100	
Fire Severity	Severe				Severe				Moderate				Low			

TABLE 7. Importance values of pine/oak species in comparison plots.

	Table Point				Powerline						Unburned			
	215	245	217	247	249	251	333	335	325	327	313	315	301	303
<u>Pinus serotina</u>	300	36	44											
<u>Pinus elliottii</u>		84					67	219						
<u>Pinus taeda</u>					138	215			101	52	140	50	47	*
<u>Quercus laurifolia</u>		48	53		162	85			28	72				
<u>Quercus virginiana</u>		60	156	168			176	81	35	137	51	166	200	199
<u>Myrica cerifera</u>	*	29				*	57		53		44			
<u>Vaccinium arboreum</u>									27	38	37	84		
<u>Vitis rotundifolia</u>					*				33				52	45
<u>Persea borbonia</u>	*	*	90	51							28			
<u>Lyonia ferruginea</u>	*	42	*	37										
<u>Ilex opaca</u>									28					
<u>Acer rubrum</u>														56

* Standing dead

plots 145, 147, 149, and 151 in Table 6; and by plots 215, 217, 245, 247, 301, 303, 313, and 315 in Table 7. Upland pine/oak was represented by plots 101, 103, 153, and 155 in Table 6; and by plots 249, 251, 333, 335, 325, and 327 in Table 7.

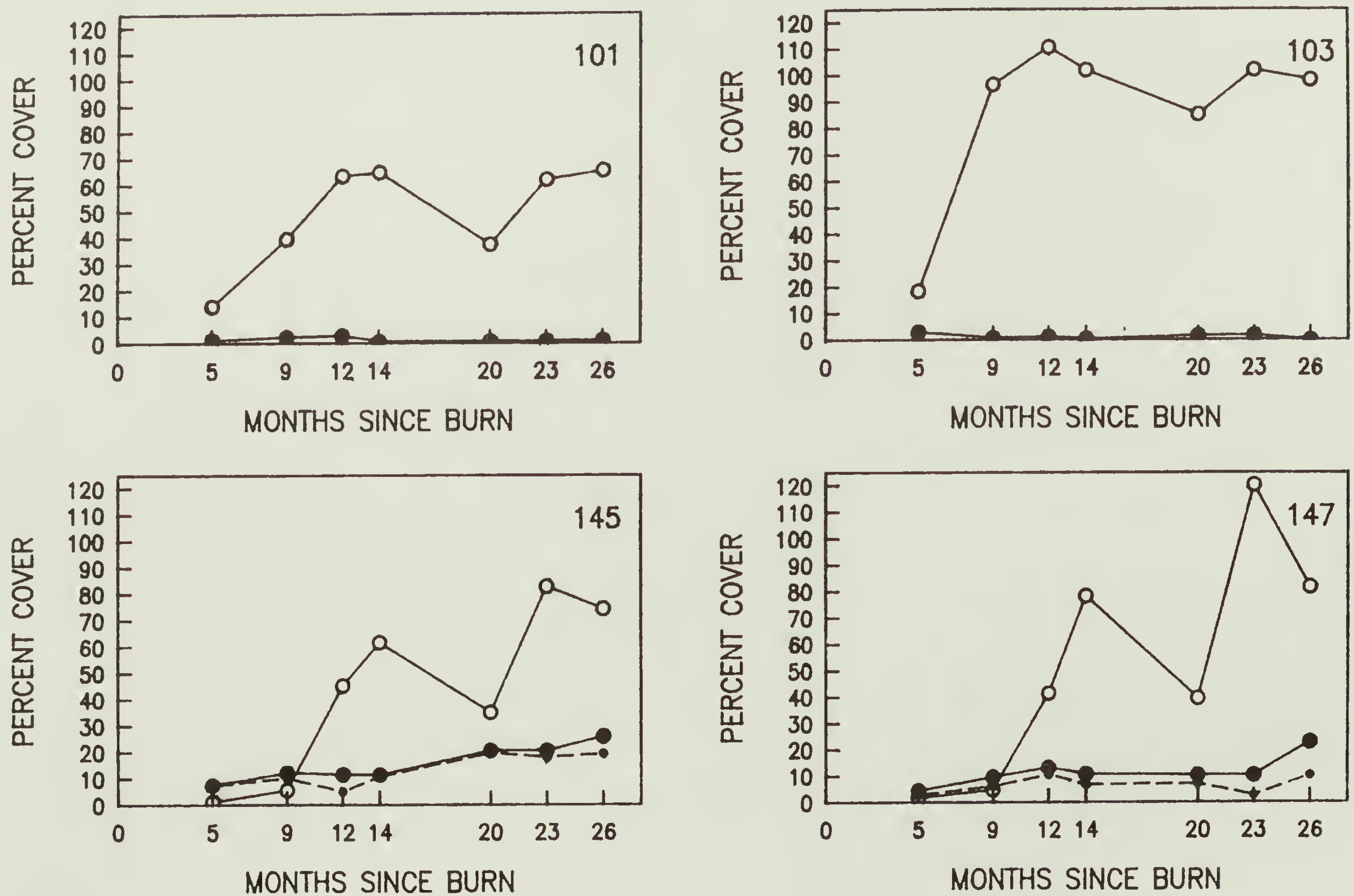
Canopy response to fire was variable in pine/oak forest, and appeared to depend upon understory and litter fuels, adjacent vegetation and wind speed during the fire. Mortality was high among loblolly, longleaf, and pond pines where wind brought the flames into the canopy. Mature hardwoods in the same areas suffered high mortality only if they were in close proximity to the pines. Two such areas existed in the South-Cut site where scorch heights reached 3-10 meters on the pines but less than one meter on the oaks. One was a longleaf pine/live oak stand near Terrapin Point (plots 101 and 103). Scars on the dead longleaf pines felled after the South-Cut fire indicated that hot fires had entered this stand from the same direction at least twice before. Ring counts indicated that these fires occurred in 1956 and 1934, and the pines themselves were about eighty years old. The other site was a loblolly pine/laurel oak stand adjacent to the saltmarsh slough of Hawkins Creek (plots 145, 147, 149, and 151). Mature hardwoods in plots 145 and 149 were in close proximity to the pines and suffered high mortality as well. A similar pattern was observed among the Table Point and Powerline plots: 215, 217, 245, and 247. Surviving hardwoods included _Quercus laurifolia_, _Q. virginiana_, and _Persea borbonia_. Smaller trees of _Lyonia ferruginea_, _Persea_, and _Myrica cerifera_ were among the standing dead, but were well represented in shrub cover.

Figure 13. Post-fire regrowth in longleaf pine/oak (plots 101 and 103), and loblolly pine/oak (plots 145 and 147).

Total herb cover

Total shrub cover

Serenoa repens cover


101
103
145
147
PERCENT COVER
MONTHS SINCE BURN
0
5
9
12
14
20
23
26
0
10
20
30
40
50
60
70
80
90
100
110
120

Woody regrowth in pine/oak was generally limited, as shown in Figure 13. Serenoa repens quickly replaced cover lost in the fire in plots 145 and 147, and represented nearly all woody regrowth in this area. Other sprouting species included Myrica cerifera, Persea borbonia, Salix caroliniana, and Prunus serotina. Most of these sprouts were overtopped by lush herb growth and fallen debris. Woody vegetation in all of the upland pine/oak stands was very similar, regardless of time since fire. Vine sprouts were very common, but did not cover much area. These species included Smilax spp., Vitis rotundifolia, Ampelopsis arborea, Parthenocissus quinquefolia, Gelsemium sempervirens, and Galactia elliottii. Other shrub species occurring in these areas included Quercus virginiana, Persea borbonia, Myrica cerifera, Asimina spp., and Ilex opaca.

Post-fire growth in pine/oak stands was predominantly herbaceous. Vegetation cover in plots 153 and 155 was very limited; neither woody nor herbaceous cover ever exceeded 15%. These plots were nearly identical to the unburned plots of the same type (333 and 335) after the first year. The most abundant type of vegetation in these areas were graminoids. These were heavily grazed as were the woody sprouts, especially those of Quercus virginiana and Persea borbonia. Uniola sessiliflora and Scleria triglomerata were found to be characteristic of upland pine/oak, although the Uniola was often grazed and difficult to identify.

Herbaceous regrowth in the saltmarsh edge pine/oak plots, which had experienced severe fire, was dense and varied. Plots 145 and 147 were covered with 1-2 meter high growth of Pteridium aquilinum, Eupatorium capillifolium, Senecio vulgaris, and Phytolacca americana among other species. Many of the trees killed by the fire fell during the spring and summer of 1982. This debris crushed much of the lush herb growth. Senecio and Phytolacca were much less abundant in the second year.

Herbaceous regrowth in the longleaf pine/oak (plots 101 and 103) was dominated by Eupatorium aromaticum in the first year after the fire. This regrowth became codominant with various grass species during the second year. The most notable feature of herb growth of this area was the high species diversity. Most of the grasses could not be identified because the grains had been grazed. However, there were at least seven grass species, several sedges, and ten forb species that occurred inside the transects and several more outside. Most of these species were found in samples of both years.

Oak Hardwood Forest

Samples of soils taken from the mesic hardwood forest were the richest in calcium of any studied, and were also relatively rich in the other soil nutrients. There were no major differences between burned and unburned soils except that Ca was highest in the burned plots, measuring 2338 and 1841 $kg \cdot ha^{-1}$ for plots 105 and 107, respectively versus 1723 and 1659 $kg \cdot ha^{-1}$ in the unburned plots 351 and 353. Soils from the live oak forest were acidic in the scrub border plots (pH 3.6 and 3.8) and were relatively low in soil nutrients.

Importance values of tree species in burned hardwood forest plots are given in Table 8. Importance values of Quercus virginiana increased after fire in all but plots 143 and 144 which bordered scrub, and experienced a relatively severe burn. Plot 143 contained a large live oak that had been dying of heart rot before the fire which did not

TABLE 8. Importance values of hardwood forest species before (B) and after (A) the South-Cut fire.

PLOTS	143		144		142		141		107		105	
	B	A	B	A	B	A	B	A	B	A	B	A
Quercus virginiana	119	111	76	73	120	125	144	150	140	203	87	88
Lyonia ferruginea	94	98	113	115	83	93	88	82			12	12
Persea borbonia	29	31	25	25	34	34	68	69	44	0	42	44
Myrica cerifera					19	22			67	0	46	41
Vitis rotundifolia	19	20	19	0	22	0					28	30
Vaccinium arborea			17	21	21	26					14	14
Ilex opaca	18	18									20	21
Acer rubrum									49	97	21	21
Magnolia grandiflora											17	17
Quercus nigra											12	12
Pinus elliottii			50	66								
Basal area removed "by fire-kill"	8.77		8.66		3.13		1.47		1.24		0.08	
Percent BA survival	70		72		93		96		97		100	
Fire Severity	Severe				Moderate				Low			

survive. Removal of this individual decreased the importance value of Quercus virginiana in the stand and the percent basal area survival, but did not affect the overall survival of the rest of the stand. If the heart-rotted oak is removed from the stand measurements, stand survival increases to about 91%, which was more typical of hardwood forest. Plot 144 graded into scrub vegetation and contained a single large pine. Although the pine survived the fire, much of the organic soil surrounding it was consumed. Shrub roots were exposed and burned; no sprouts from pre-existing vegetation appeared in this area. Plots 141 and 142 represented moderate fire severity. Most of the Serenoa foliage had been consumed, but very little if any of the organic soil. Vitis was the only species that was affected by the fire to any great extent in these plots. Plots 105 and 107 represented mesic hardwoods, the latter containing species such as Magnolia grandiflora and Quercus nigra which occurred in no other burn plot. Response to fire in these plots was very similar to the other oak dominated plots. Plot 107 was about 100 meters away from a scrub border and experienced a hotter burn than did plot 105. The smaller individuals of Myrica and Persea were killed in plot 107, but survived in plot 105. Table 9 presents the importance values of the comparison unburned hardwood plots. These plots were approximately 25-50 meters away from plots 105 and 107 and resemble them most. Plots 333 and 335 presented in Table 6 were adjacent to the site of the other oak hardwood plots 141-144. These plots were typed as pine/oak, but also resemble the oak hardwood forest in the dominance of Quercus virginiana and low species diversity.

Regrowth in the hardwood forests was almost entirely Serenoa repens as shown by Figures 14 and 15. The sampling lines in plots 143

TABLE 9. Importance values of mesic hardwood species in comparison plots.

	Unburned	
PLOTS	351	353
Quercus laurifolia		118
Quercus nigra	31	24
Persea borbonia	130	37
Myrica cerifera	92	32
Vitis rotundifolia	46	48
Ilex opaca		17
Pinus elliottii		24

Figure 14. Post-fire regrowth in severely burned (plots 141 and 142) and moderately burned (plots 143 and 144) oak hardwoods.

Total herb cover

Total shrub cover

Serenoa repens cover

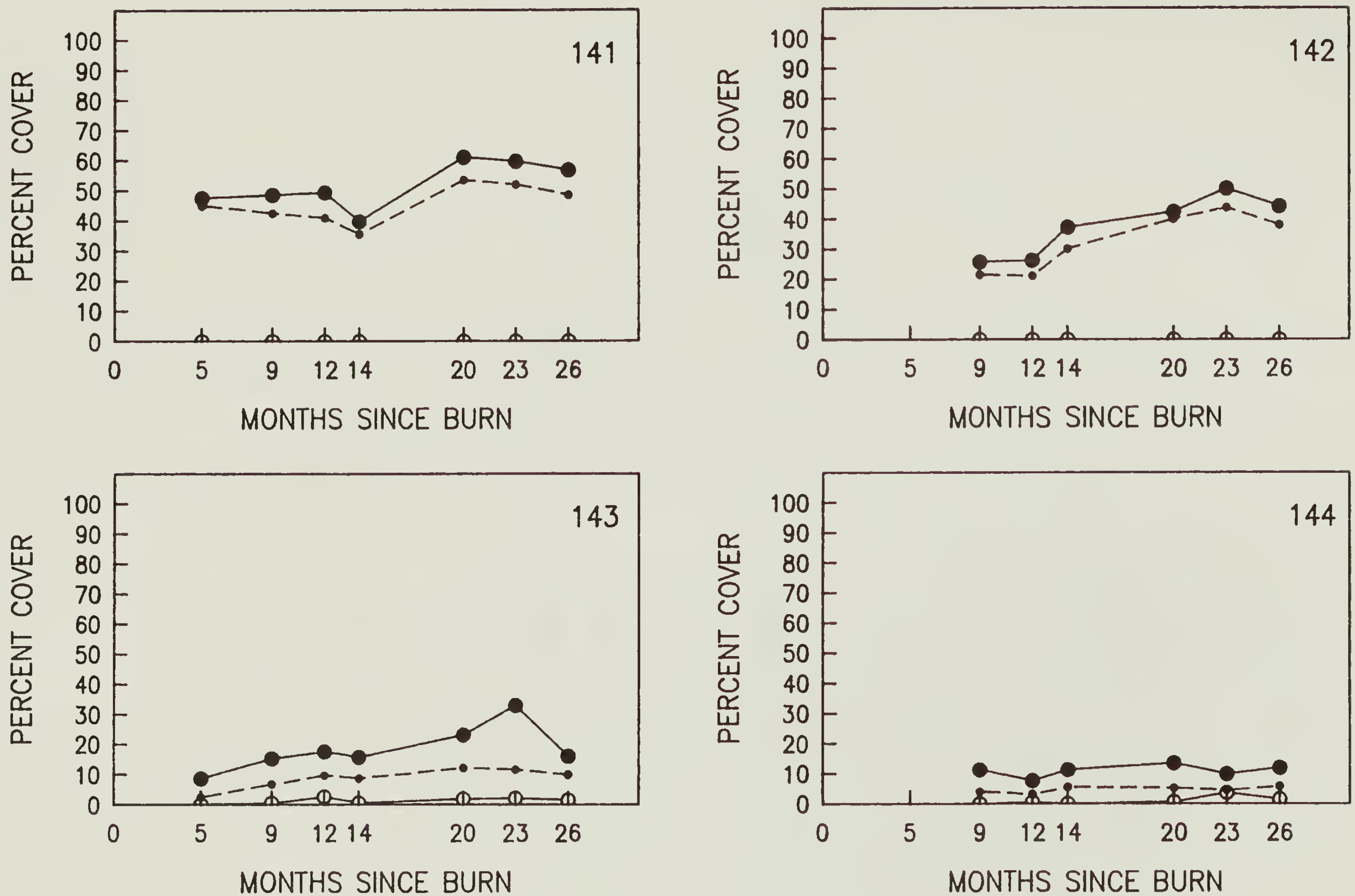
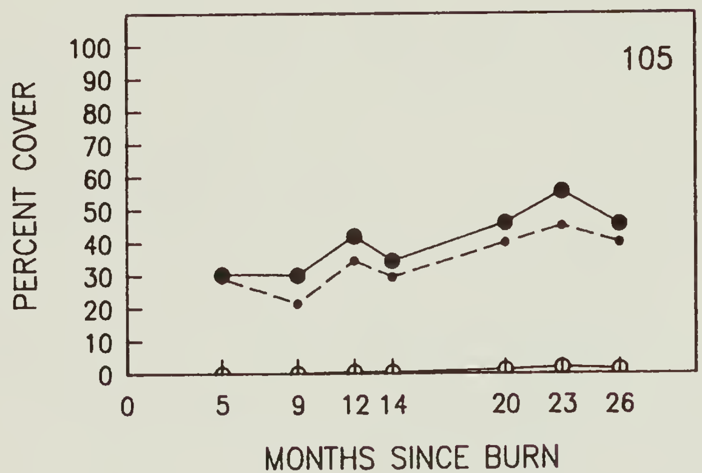

141
142
143
144
PERCENT COVER
100
90
80
70
60
50
40
30
20
10
0
0
5
9
12 14
20
23
26
MONTHS SINCE BURN

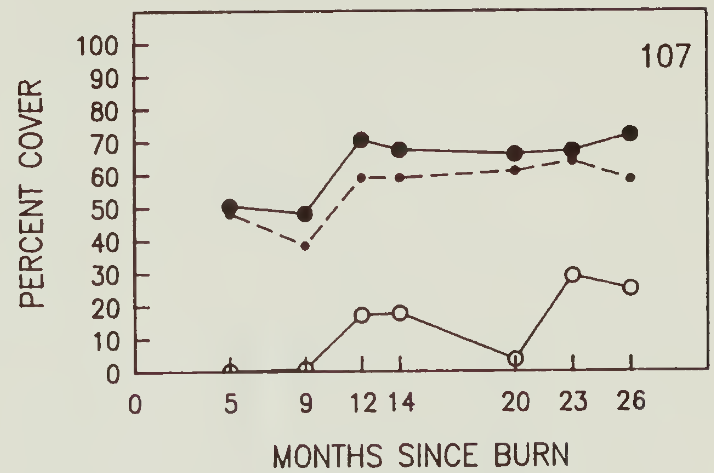
Figure 15. Post-fire regrowth in mesic hardwoods.

Total herb cover

Total shrub cover

Serenoa repens cover


105
PERCENT COVER
100
90
80
70
60
50
40
30
20
10
0
0
5
9
12 14
20
23
26
MONTHS SINCE BURN


107
PERCENT COVER
100
90
80
70
60
50
40
30
20
10
0
0
5
9
12 14
20
23
26
MONTHS SINCE BURN

and 144 extended along an area affected by deep pine litter burn. Regrowth was very limited near this large pine, but was more dense and dominated by Serenoa further into the plot as was typical in this forest type. Herbaceous regrowth was limited, composed mainly of Panicum species and Pteridium aquilinum. Herbs regrowth in plot 107 was very similar to that of plots 145 and 147. Eupatorium capillifolium, Phytolacca americana, and Senecio vulgaris formed tall stalks between the Serenoa. The latter two species were much less common in the second year when Eupatorium was codominant with Panicum.

Oak Scrub Fire Boundary Transect

Soil and tree data followed similar patterns across the transect pairs. The fire boundary extended diagonally across the transect line such that more of the plots on the north side of the line (plots 11-19) were severely burned scrub than were those south of the line (plots 1-9). Another factor which may have affected the data was the location of the plots relative to the road and the saltmarsh. The northern edge of plots 11-19 was about 50 meters away from the saltmarsh, and the southern edge of plots 1-9 was about 30 meters away from Candler Road.

Soil data from the transects were considerably more consistent than data from the seasonal plots, probably due to the finer separaton of soil layers. The top soil layer of 0-7 cm indicated a distinct transition between plots 4 and 5, and similarly between plots 16 and 17 as shown in Table 10. At the transition in both transects, pH values dropped from 4.0-4.1 to 3.5-3.7. P and Ca values were higher in plots 1-4 and 11-16 than in the plots across the transition zone, while the pattern of K and Mg values was less distinct. Data from the two lower

TABLE 10. Soil pH, buffer pH, (pH B), and macronutrient (Kg ha^{-1}) values of the 0-20 cm depth samples from the oak scrub fire boundary transects.

Transect nearest road							Transect nearest saltmarsh						
PLOT	pH	pH B	P	K	Ca	Mg	PLOT	pH	pH B	P	K	Ca	Mg
1	4.1	6.90	40	90	1232	241	11	4.1	7.70	95	125	1644	351
2	4.0	6.75	48	117	1488	318	12	4.0	7.80	38	109	834	254
3	4.1	6.80	101	123	1384	333	13	4.1	6.70	13	119	1489	347
4	4.0	6.35	32	153	1440	400	14	4.0	7.00	40	91	802	233
5	3.6	6.05	17	210	1021	379	15	4.4	7.25	97	145	1584	288
6		lost sample					16	4.1	6.95	15	104	1234	319
7	3.6	6.95	16	166	795	236	17	3.7	7.45	17	153	1042	334
8	3.5	7.25	11	117	374	148	18	3.5	7.75	17	304	694	250
9	3.7	7.45	8	75	342	75	19	3.5	7.20	9	91	345	110

layers at 7-15 and 15-23 cm soil depth showed less variation, but generally followed the pattern of the 0-7 cm layer. Macronutrient values of the deeper soils were lower than those of the shallow samples, and generally had higher pH values and lower pH buffer values. The transition of pH, phosphorus, and calcium occurred in the plots where crown fire became ground fire as it entered the larger oaks.

Tree survivorship also indicated a transition between plots 4-7 and 15-18 as shown in Table 11. At the middle of both transects a strip of larger oaks occurred in plots 5 and 15. Successive plots contained at least twelve individuals of _Quercus virginiana_ which were larger than 13 cm dbh. The most apparent trend across the transect from the completely burned scrub to the lightly burned forest was this increasing number of large oaks. A comparison of the basal area of _Quercus virginiana_ in the plots to the basal area survival within the plot is given in Table 12. Percent basal area survival falls off rapidly between 13 and 12 m^2/Ha _Quercus virginiana_. However, the transition plots 5 and 15 suffered high mortality regardless of the high basal area of oak along this strip.

Community Ordination

The principal components community ordination of the plots within the South-Cut site is presented in Figure 15. Six community groupings were formed within the scatter diagram which differed from the original community designations in two ways. Plots 153 and 155 which had been designated as pine/oak forest fell into the hardwood forest group and was most closely related to the mesic hardwood plot 107. Plots 109 and 111 which had been designated as oak scrub were found to be a unique

TABLE 11. Survival of trees (numbers per 400 m2 plot) compared to the number of oaks, Quercus virginiana individuals larger than 13.0 cm dbh in south (plots 1-9) and north (plots 11-19) transects across a fire boundary.

Plot	Total Number trees	Number oaks > 13cm	Number Root killed	Number sprouting	Number alive	Percent alive
1	179	5	17	161	1	0.5
2	198	11	29	169	0	0
3	171	5	27	144	0	0
4	150	14	11	132	7	5
5	199	25	21	110	68	34
6	162	17	2	42	118	73
7	217	17	12	4	191	88
8	149	16	1	2	146	98
9	152	21	1	13	138	91
11	110	9	17	93	0	0
12	92	6	21	71	0	0
13	41	5	1	40	0	0
14	69	5	5	64	0	0
15	125	30	7	116	2	1.6
16	197	15	20	174	3	1.5
17	176	14	31	121	24	14
18	179	12	10	44	125	70
19	157	19	0	4	153	97

TABLE 12. Survival of basal area (M^2 Ha^{-1}) compared to the amount of oak, Quercus virginiana, along two transects across a fire boundary.

Plot	Total Basal Area	Basal Area of oak	Basal Area of trees alive after fire	Percent Basal Area Survival
1	16.19	9.15	1.61	10
2	18.89	9.41	0	0
3	20.80	6.62	0	0
4	18.45	9.97	4.54	25
5	32.79	18.78	5.41	17
6	22.36	12.71	11.07	50
7	23.82	13.12	17.54	74
8	19.82	12.23	19.66	99
9	24.86	15.11	22.65	91
11	13.89	8.98	0	0
12	14.61	6.15	0	0
13	7.98	6.27	0	0
14	8.63	4.45	0	0
15	31.16	16.69	1.73	5
16	20.61	10.65	.67	3
17	22.23	12.10	1.34	6
18	22.58	12.62	11.24	50
19	26.72	18.79	18.79	97

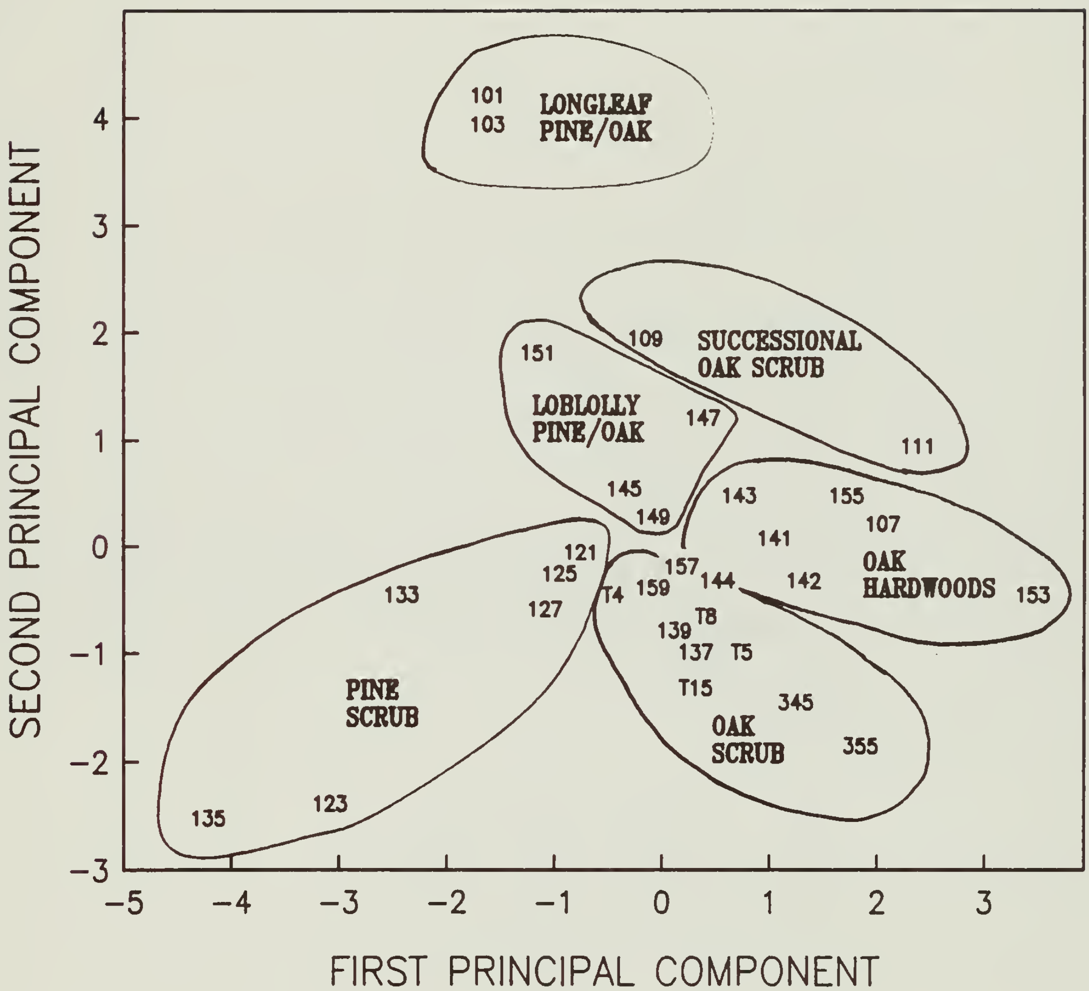
type. Further scrutiny of the basal area data of these plots indicated that the cause of this separation was relatively large basal areas of *Ilex opaca* and *Persea borbonia* among the more typical scrub species. Although small individuals of *Persea* were often encountered in scrub, large trees were uncommon. Seedlings of *Ilex* had been found in scrub, but large holly trees were very uncommon in scrub. *Ilex* was more characteristic of mature forests and was found to be intolerant to fire in any severity. Where large *Ilex* trees were found in the burn plots, the thin bark around the base of the trees was often peeled back. These girdled trees died shortly after the fire. These observations and the adjacent location of these plots to mesic hardwood suggested that these plots were successional from scrub to hardwood, and had probably been missed by the last destructive fire.

Percent basal area removal by fire was compared to the plot scatter diagram presented in Figure 16. Plots in which there was a large degree of survival were clumped together in a group characterized by a large amount of *Quercus virginiana* as shown in Figure 17. Plots which had large amounts of pine were characterized by low survival of fire.

The effect of *Quercus virginiana* on stand survival is depicted in Figure 18, which plots the basal area of live oak against percent basal area survival for every stand in which this species occurred. With the exception of six plots, stand survival is high (90-100%) in areas which contain 13 m^2 ha^{-1} live oak. Below this figure, stand survival falls off rapidly. The regression fitted to points with x-axis values below 15 was:

$$y = 46.4778 - 19.0272\,x + 1.67859\,x^2$$

Figure 16. Principal components ordination of arboreal species by pre-fire basal area within plots of the South-Cut site. Points are represented by plot number.



LONGLEAF
PINE/OAK
101
103
SUCCESSIONAL
OAK SCRUB
109
111
LOBLOLLY
PINE/OAK
151
147
145
149
OAK
HARDWOODS
143
155
107
141
142
153
157
144
PINE
SCRUB
121
125
127
133
135
123
OAK
SCRUB
T4
159
T8
139
137
T5
T15
345
355
SECOND PRINCIPAL COMPONENT
FIRST PRINCIPAL COMPONENT
4
3
2
1
0
−1
−2
−3
−5
−4
−3
−2
−1
0
1
2
3

Figure 17. Comparison of relative amounts of fire-killed trees to the principal components ordination of plots within the South-Cut site.

● > 50% basal area removed

◐ 10-50% basal area removed

○ 0-10% basal area removed

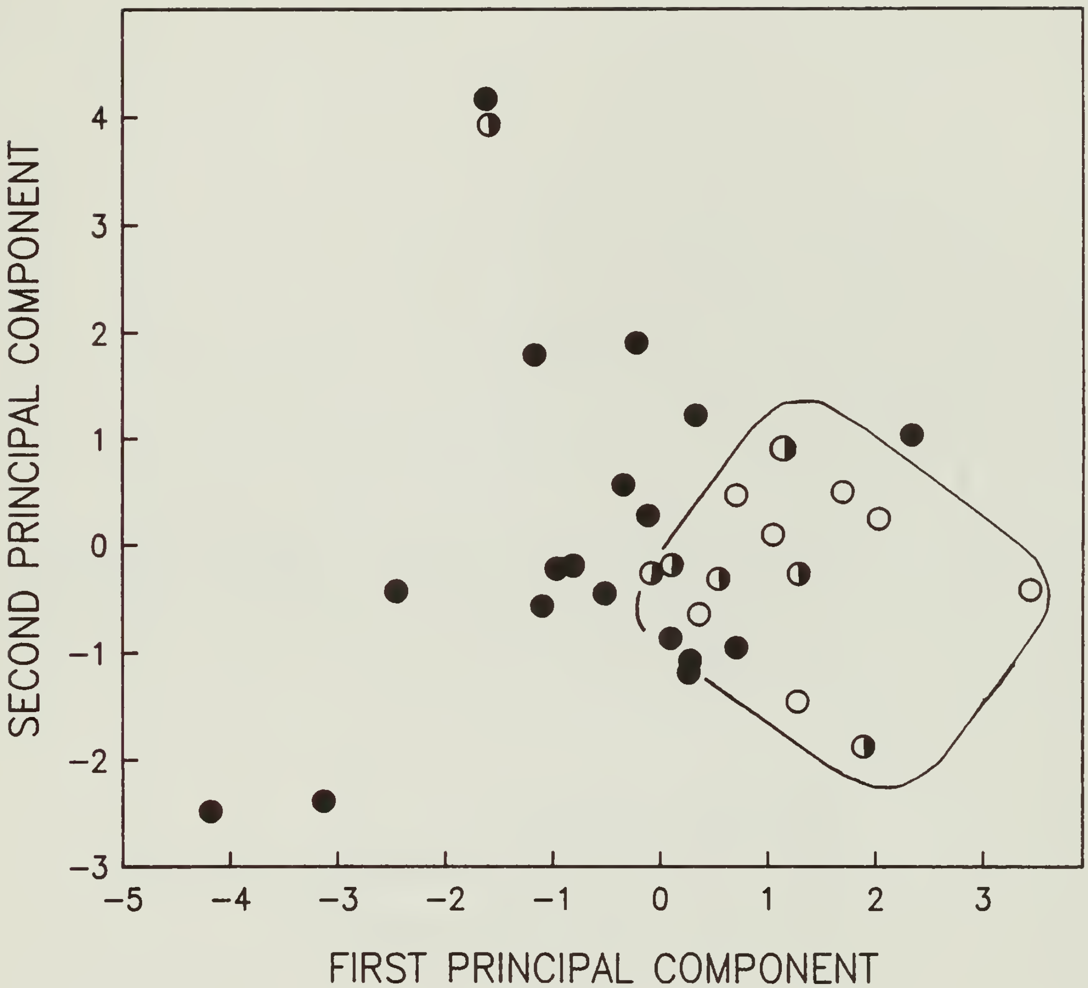
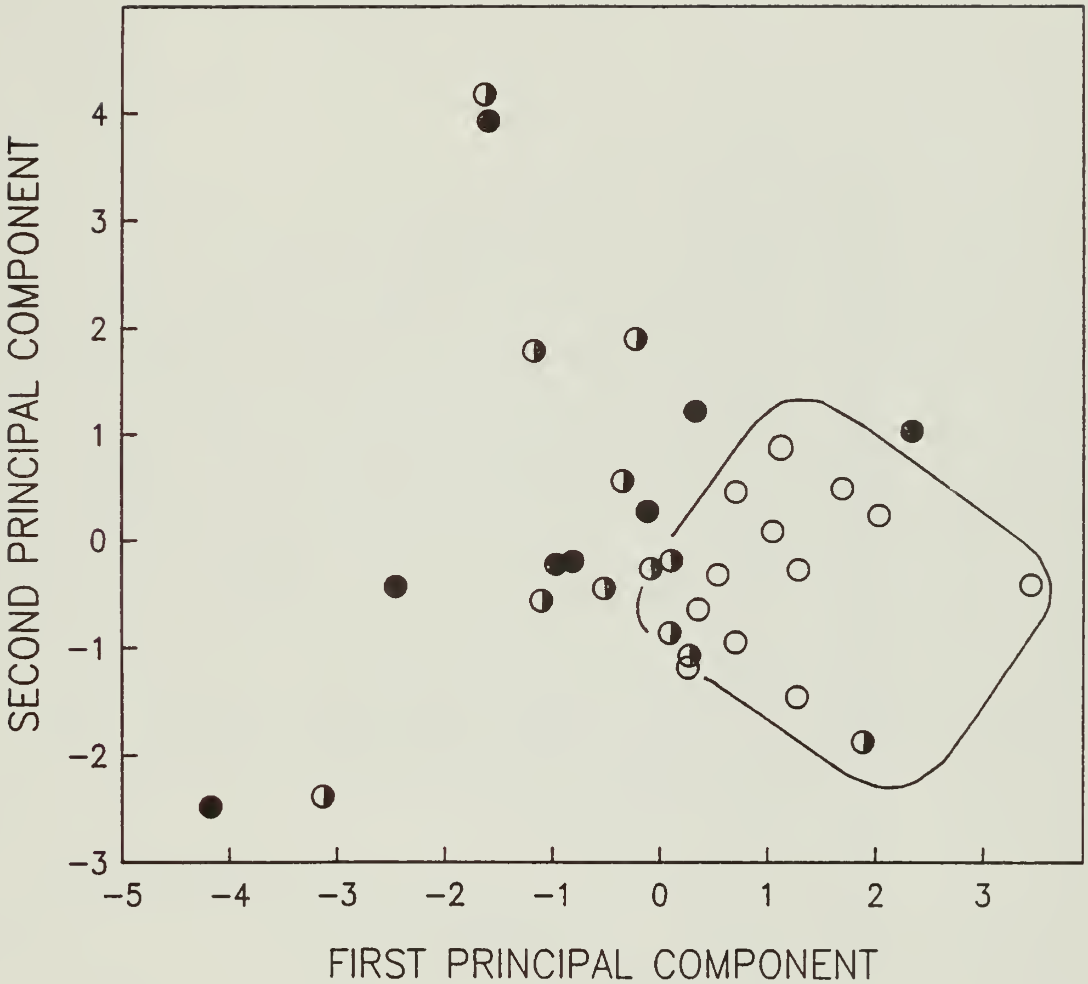

SECOND PRINCIPAL COMPONENT
FIRST PRINCIPAL COMPONENT
4
3
2
1
0
−1
−2
−3
−5
−4
−3
−2
−1
0
1
2
3

Figure 18. Comparison of relative amounts of *Quercus virginiana* to the principal components ordination of plots within the South-Cut site.

● *Quercus virginiana* not present

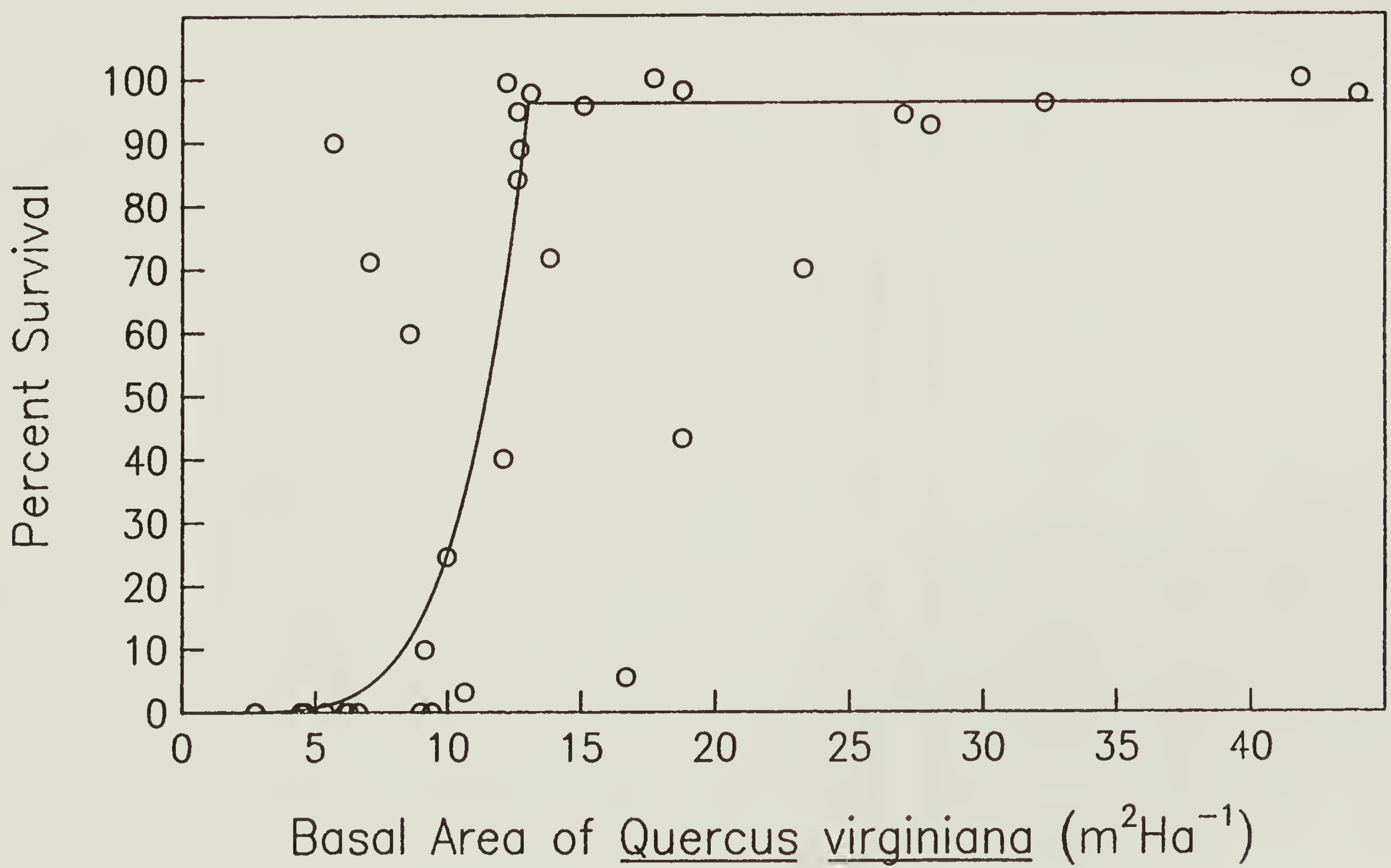
◐ $< 10.0\ m^2H^{-1}$ *Quercus virginiana*, but present

○ $> 10.0\ m^2Ha^{-1}$ *Quercus virginiana*



SECOND PRINCIPAL COMPONENT
FIRST PRINCIPAL COMPONENT
4
3
2
1
0
−1
−2
−3
−5
−4
−3
−2
−1
0
1
2
3

Figure 19. Comparison of the amount of _Quercus virginiana_ to the relative survival of total pre-fire basal area.



Percent Survival
0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
20
25
30
35
40
Basal Area of Quercus virginiana (m2Ha-1)

This regression had a 91% goodness of fit, although it provided y values below zero for x values less than or equal to 5 which were not included. The six exceptional plots fall into two groups: 1) plots which bordered highly flammable vegetation, or had a large component of diseased oak prior to the burn, and 2) areas which had a low oak component, but in which weather conditions kept fire from becoming destructive. The first group included plots 5 and 15 from the transect study and plot 143. Plots 157, 159 and 355 comprised the second group all of which were scrub oak plots in which prevailing winds were in the opposite direction of fire. This "backfire" remained low and resulting survival was high.

DISCUSSION

Each of the communities studied had distinct relationships with fire. The dominant vegetation of a given community heavily influenced fire severity, and thereby mortality and response. Prefire vegetation fire also influenced regrowth to a great extent. Sprouts from pre-existing species represented the largest part of post-fire regrowth. Characteristic responses indicated some preadaptation of this vegetation to a phenomenon of recurring fire which has probably existed for millenia.

Each community burned in a particular manner, according to the physiognomy of the dominant species. The dominant types of physiognomy (grasses, shrubs, pine trees, and mature hardwood trees) represented basic fuel types. Fuel types differ in flammability by virtue of their structural and chemical composition. Fuels which have a high surface to volume ratio combust rapidly as oxygen is readily available. These fuels, being well-aerated, are also subject to rapid decreases in moisture content which increases their flammability. Dense fuels retain moisture, require high ignition temperatures and combust slowly. Many species produce volatile substances in foliage and bark that ignite at temperatures lower than those required for ignition of lignin and cellulose. Volatile substances may also cause fuels to burn at higher temperatures once ignited. Plants that produce high concentrations of such volatile substances include some of the dominant species of fire-prone scrubs such as Serenoa repens and Ilex glabra. Pines contain terpenes in foliage, bark and sap among other flammable compounds (Rundel, 1981). A recent study found that temperatures under burning Pinus palustris exceeded those under nearby hardwoods. Pines survived their own fire better than surrounding hardwoods. Higher burning temperature was suggested to be a selective advantage of pine over oaks. Fire fueled by pine arrested succession by removing small hardwoods, and produced conditions favorable to establishment of pine seedlings (Williamson and Black, 1981). Pyrolisis of plant material may also be affected by mineral content. Foliage deficient in P was found to be more flammable than foliage with normal levels of this element. This may be an important feedback in nutrient poor ecosystems. Changes in vegetation nutrient composition may increase the probability of fire, which recycles minerals locked up in litter and dead foliage (Pilpot, 1970).

The mature hardwood forest exhibited many fire resistant traits. The canopy of this forest enclosed a more humid microclimate than within the open scrub, marsh and pine communities. The foliage of the dominant tree, Quercus virginiana, is concave which as litter holds moisture to the ground. Although there was a layer of flammable Serenoa under the canopy, a spacial disjunction of vegetation existed between the foliage of the canopy and that of the understory. This was contrasted to the scrub which presented a continuous vertical ladder of fuel. Fire which had ignited the lower shrubs was easily carried through the entire height of the scrub. Scrub oaks, also within the species group of Quercus virginiana, were differentiated from the mature hardwoods by physiognomy. These oaks were of smaller, more twisted stature, and were never taller than eleven meters.

Approximately 70% of the area burned in the South-Cut Fire was of pine and oak scrub, and it was there that the ignition source was located. The scrub acreage was continuous, not divided into isolated patches as were the pine oak stands. Nearly the entire area previously mapped as scrub burned. Roads and trails were not effective fire breaks for the severe fire that swept through this area during the first fourteen hours of the fire. Fire severity was low or moderate in scrub only where the fire spread was in the opposite direction of the prevailing winds. Mature hardwood forests formed a natural firebreak around the scrub. The large oaks bordering scrub suffered high mortality, but checked the spread of destructive fire where roads and manmade firebreaks were ineffective.

Periodic destructive fire has been described as characteristic of Florida scrubs (Mulvania, 1931; Webber, 1935; Veno, 1976). The South-Cut scrub has burned at least three times since 1900. A destructive fire passed through this area in 1956 according to natives of the island. The United States Geological Survey map dated 1958 indicated a large sparsely vegetated area with boundaries very similar to those of the South-Cut Fire that was assumed to be the boundary of the scrub fire. Another large scrub fire occurred in this area in 1934. These three major fires in the north end scrub (1981, 1956, and 1934) occurred in years of marked low rainfall (Turner, in press). Burning in scrub usually depends upon moisture content of the living tissue and litter. Scrub typically does not burn well unless under drought stress (Webber, 1935). When fire occurs during drought, it is easily swept into the upper branches, causing a hot fire and destroying all aboveground vegetation.

Recycling of nutrients may be one of the most important roles of fire, especially in scrubs. Soils sampled from unburned scrub were the most sterile encountered in this study. Scrub soils sampled nine months after the fire were significantly higher in exchangeable bases; Ca and Mg by 2-5 times and K by 1.5-2 times over amounts found in unburned soils. There was no significant difference in the amounts of P between burned and unburned soils. Burned soils from the fire boundary transect sampled sixteen months after the burn were also significantly more fertile than soils from the unburned end of the transect. The fertilizing effect of fire on soil is well known and has been used in agricultural and range management for hundreds of years (Harper, 1962; Prunty, 1965; Aschmann, 1977). Burned soils contain greater amounts of exchangeable bases and are less acidic due to additions from ash (Woodmansee and Wallach, 1981). Although N is volatilized at high temperatures, burned soils are not typically lacking in this element. Shifts in pH and greater availability of exchangeable bases often increases activity of soil microflora, including the nitrifiers (Ahlgren, 1974; Woodmansee and Wallach, 1981). A recent study of soil nutrient balance before and after low intensity burns in slash pine/palmetto/gallberry found annual and biennial burns increased macronutrient concentration in the soil surface layer. A loss of 110 kg ha^{-1} of N was measured after burning. However, there was 160 kg ha^{-1} of N remaining in the ash and residue, and about 700 kg ha^{-1} of N in the upper 10 cm of the soil profile (Hough, 1981). These soils were analyzed immediately after the fire was extinguished and were not a measure of soil microflora activity, but of relative losses and gains due to burning. N losses probably increase with increasing fire severity and organic soil consumption.

Plants capable of symbiotic N fixation were a significant part of the post-fire growth in both pine and oak scrubs. Galactia elliottii, a viny legume, was very common throughout the scrubs and flowered particularly well in the first year. Myrica cerifera was a ubiquitous species throughout the South-Cut site, encountered in at least one seasonal sample of all burned plots except those within Cladium marsh. Myrica was a faithful component of pine scrub and was frequently found in the other communities, burned and unburned. It is one of the first woody species to colonize secondary dunes and beach meadow. Myrica is associated with an actinomycete and there are reports of its N fixation rates exceeding those of legumes (Edmisten, 1963). Symbiotic N fixation may be a selective advantage to establishment in a substrate fertile in all other aspects. Edmisten hypothesized that the N inputs from Myrica enrich soils for species with higher nutrient demands, an integral part of succession to hardwood forest.

Scrubs are also described as characteristically stable communities relative to species composition. After fire, scrub replaces scrub (Webber, 1935). Veno (1976) found little change in species composition in unburned scrub over a 21 year period. Post-fire growth on Cumberland was also very stable. Species represented in the first few samples were in the same proportions of the prefire species, and this composition remained stable throughout the two year sampling period.

It is not likely that the large scrub comprising the majority of the South-Cut site will ever succeed to hardwood forest. The fire history of this area, stability, and rapid regeneration after fire suggest that this community is a pyric disclimax. Similar scrubs in Florida have been described as not fire dependent, but revitalized by fire (Abrahamson, 1984). In contrast, the fire prone manzanita chaparral (Arctostaphylos glandulosa) of California was found to be dependent upon the revitalization of fire for long term survival. Chaparral which had not burned for 40 years was degenerate. A devastating fire removed all vegetation from this site. All but the largest shrubs were consummed down to the root crowns due to the high amount of litter fuel which had accumulated in the years since the last fire. Revegetation of this area was predominantly by seed, and proceeded at a much slower rate than that recorded for sprout revegetation which normally follows fire in this community. Soil properties were changed by additions of large amounts of ash and charcoal which further discouraged establishment of post-fire vegetation (Vogl and Schorr, 1972). Hypothetically, this pattern of degeneration could occur in scrub vegetation of the SECP. There was no record encountered, however, describing scrub which had not burned on at least thirty year rotations. The typical rotation period between scrub fires is 10-20 years (Komarek, 1974; Christensen, 1981). The ready availability of ignition sources in lightning has ensured that most scrubs burn as often as the fuel will support a fire. This period of time is too short for the hardwoods to attain the height and size which would permit canopy survival of even a moderately severe burn. Litter accumulating during long fire-free intervals almost ensures severe fires. Thus, scrub vegetation is perpetuated through periodic destructive fires which will not permit further succession. Reduction of fuels near the mature hardwoods by prescription burning could be used to stop this cycle and perpetuate the mature forests.

The three marsh types studied responded to fire in the same manner. Marshes burned intensely; tree and shrub borders in every case suffered high mortality regardless of species. Grass blades presented a fine, loosely packed continuous fuel. Once ignited, the marshes burned completely to fire breaks of water, roads or adjacent vegetation. One hundred percent cover was attained by vegetation in all but one of the saltmarshes during the first year, and regrowth was predominantly herbaceous. All woody seedlings that sprouted while the freshwater marshes were still dry disappeared as the water level rose; persistent woody vegetation was limited to the one or two aquatic species that sprouted from pre-existing rootstocks. Species diversity was highest for all burned marsh plots in the June and September samples of 1982, higher than that of unburned marshes. Diversity declined during the second year as the dominant graminoid closed the open area. The hummocked or clumped growth form was common to all the dominant graminoids, and was probably responsible for the survival of these plants. Meristems were insulated by densely packed blades at the center of the clumps, and did not burn. The hummocks remained after the fire and put out new growth almost immediately.

As the water level rose in the two years after the fire, open water was more abundant in the burned freshwater marshes which may have been due to the lack of absorbent peat. Prescribed fire has been used in many freshwater systems to make water resources more readily available. The Sweetwater Marsh complex was burned frequently by caretakers of the Carnegie estates prior to park establishment. During this frequent (annual or biennial) fire regime, there was enough open water to canoe down the entire length of the complex. These marshes are presently impassible by any manner of boat, as they are choked with peat and emergent vegetation (Turner, in press). Water availability was the main reason for reintroduction of fire to the Everglades. Fire was used successfully to slow an unnaturally accelerated succession. This reduced water loss from evapotranspiration, and decreased water absorption and thereby evaporation by reducing accumulated organic matter (Stottlemeyer, 1981). Prescribed fire was also used at Cape Hatteras National Seashore in North Carolina to impede artifically accelerated marsh succession. Roads constructed on that barrier island imposed an artificial stabilization preventing marine overwash. Ponds which had been popular habitat for freshwater birds were dried up over a short ten year period. Fire successfully reestablished the ponds with species typical for such habitats (Stottlemeyer, 1981).

The freshwater cordgrass marshes scattered across the island probably shared mixed origins. Most of these occurred along ancient dune/slough depressions left by old shore lines. Some of the marshes occurred in areas adjacent to roads elevated above the high water level of the wet season. These marshes were most likely remnants of borrow pits from road construction. Penfound (1952) stated that cordgrass marshes in Louisiana were evidence of logging disturbance in hardwood swamps, and were perpetuated by fire. The latter was observed in the South-Cut marshes. Pond pines which had been invading the drier cordgrass marshes were entirely killed; pine seedlings found in the first two seasonal samples did not survive inundation. Thus, fire effectively removed woody invasion from the freshwater cordgrass marshes, perpetuating the herb species.

Vegetation cover in the burned Cladium marsh plots had not reached that observed in the unburned plots by the end of the second year.

This was due in part to two factors. Standing dead blades of grasses and sedges were difficult to separate from living blades and were therefore included in the cover estimates. The unburned Cladium was thick with dead blades, all of which had been removed from the burned plots. The second factor was the deep peat burn which removed structural support from around the bases of Cladium clumps. As new growth appeared many of such unsupported clumps became top-heavy and fell over. The roots of Cladium apparently were not anchored in sand as were those of the cordgrasses. Cladium flowered in the second year after fire. Wade, et al. (1980) reported that Cladium thrived on an annual burn cycle in the Everglades, growing rapidly and flowering during the first year after fire. Cladium grew so rapidly that there was enough fuel to carry fire again only three months after a burn, although this regime did not benefit the plant. It is possible that the long period since the last burn followed by fire in the droughted marsh adversely affected Cladium regrowth in the South-Cut site.

Response patterns in saltmeadow cordgrass were very similar to those of freshwater cordgrass. There was no evidence that this marsh burns any more frequently than the forest vegetation surrounding it, and there was no reference to fire in this type of marsh in the literature. There was also no evidence that the high saltmarsh dominated by short Spartina alterniflora and Distichlis spicata burned to any great extent in the South-Cut fire. This vegetation is sparse, heavily grazed by horses and is inundated daily with the tides. These factors make fire unlikely in saltmarsh.

Fire affected pine/oak communities on all vegetative strata: herb, shrub, and canopy. The patterns were the same for both loblolly pine/oak and longleaf pine/oak although the species were different. Herb diversity and cover were considerably higher in the burned sites. Herbs such as *Eupatorium capillifolium* and *Senecio vulgaris* were represented heavily in the first year, and became less common during the second year. Perennial species common to the fire sites, especially *Pteridium aquilinum* and *Panicum* spp. increased cover during both years. Lemon (1949) found increased herb diversity under *Pinus palustris* in the first year after fire due to a combination of high survival of perennial grasses and an increase in "fire followers". This was a large group of species adapted to rapid migration and aggregation on open ground cleared by fire. The fire followers decreased significantly during the next two years, and dropped out of the area over the next eight years. A similar occurrence was observed among herbs under longleaf pine during the first two years after fire in this study.

There was evidence that fire in pine stands was usually very hot. Hardwood shrubs surrounded by pine litter were killed completely, not many sprouted. Pine trees bore high scorch marks usually exceeding 3 meters. Oaks in the same stand which grew at least three meters away from the nearest pine bore scorch marks shorter than one meter and were not killed by fire. The fire selectively removed mature individuals of loblolly and longleaf pines and left mature oaks. This may have accelerated succession of these communities toward a closed canopy hardwood forest. Artificial thinning of mature pines accelerates succession toward establishment of mature hardwood forest (Peet and Christensen, 1981). Fire may be acting in this manner on Cumberland Island.

Mortality of Pinus elliottii differed from the patterns observed among the other pine species. Slash pine occurred in the South-Cut site as scattered large individuals within mesic oak forests, often at the edge or just within oak scrub. This pine species survived fire in every burn plot in which it was encountered, except for one individual in the scrub oak transect. No slash pine sampled in the South-Cut or Table Point fire sites was smaller than 13 cm dbh, and most were larger than 40 cm dbh. The large size of the trees sampled may have been a factor in their survival. This sample may not have been representative for the species as a whole, as slash pine stands did occur elsewhere on the island. Two of these sampled in unburned sites were found to contain smaller individuals of 8 and 9 cm dbh. Slash pine/oak plots were classified with hardwood forests by the principal components analysis. This is believed to be a reflection of the large oak component and the fact that this pine species occurred in relatively mesic, fertile sites. Because of these characteristics, allied more closely to hardwood than pine forest this type was determined to be a part of the mesic hardwood forest.

In contrast to the pine/oak forests, the hardwood forests were only minorly affected by fire. This forest was found to be resistant to fire. Mortality of canopy trees depended upon proximity to scrub or pine. Large hardwood trees within three meters of this more flammable vegetation suffered high mortality, especially if the flames reached the crown foliage. However, these trees did not carry crown fire into the mature oak forest. Fire entered this forest fueled by Serenoa and remained low. Canopy species generally survived if damage to the crown was not extensive: less than half the crown foliage removed. Shrubs, small trees and vines suffered high mortality, especially if surrounded by Serenoa. These were quickly replaced by rootsprouts.

The critical difference between survival of scrub oaks and mature oaks was the size of the individuals. Trees smaller than 8 cm did not survive fire well. This phenomenon is well documented in literature for prescribed burning. Prescribed fire is effective in killing hardwoods 7.5 cm dbh and smaller (Mobley et al., 1978). Total basal area of oak within a stand gives a gross measurement of this which effectively described survivorship patterns over many different forest types. Although weather factors also influence the manner in which vegetation burns, general patterns were very clear. Trees in hardwood forests with live oak basal areas greater than 13 m^2/ha survived fire. The presence of large live oaks was highly correlated not only to their own survival of fire, but to the survival of all the individuals in the stand.

Many of the vegetation patterns of Cumberland Island were the direct consequences of man's activities. Succession of old fields to pine has scattered a considerable fuel source throughout the island's present woodlands. Road building created fire breaks and numerous small marshes in the borrow pits. Logging of pine was evidenced by many stumps within the study site. This practice probably has encouraged growth of hardwoods now intermixed with mature pines. The large population sizes of horses and deer were indirectly due to man's interference. Horses were introduced to the island and have no natural predators. There were over 150 horses counted in the last census and there was evidence that this population will continue to grow (Ambrose, et al., 1983b). Amounts of grass in the pine oak forests, meadows and saltmarshes are greatly reduced by these grazers (Ambrose et al., 1983a). Natural predators of deer have long been removed (Hillestad et al., 1975). Annual hunts, disease and lack of food check this population. Evidence of the latter was most apparent in the winter months when nearly all woody sprouts except Myrica were browsed to the soil surface in mature hardwood and pine forests. Fire interacted with each of these impacts creating unique vegetation patterns.

SUMMARY

The vegetation of the South-Cut site exhibited many fire-adaptive traits and was generally tolerant or resistant. Although the above-ground vegetation was destroyed within the scrub acreage which comprised 70% of the burned acreage, post-fire regrowth was vigorous and represented all prefire species. Marshes burned intensely, down to sand within the cordgrass. The hummocked grasses survived and replaced foliage lost to the fire very rapidly. Species diversity was higher in burned marshes than within the unburned control plots during the first year, and decreased to control levels during the second year after fire. All pine species except *Pinus elliottii* experienced high mortality, and were not well represented in the post-fire regrowth. Mature hardwoods in the same areas as pines which were fire-killed suffered considerably less mortality. By thinning mature pines, the fire may have accelerated succession toward closed mature hardwood forest. Mature hardwoods suffered high mortality only where trees were in close proximity to more flammable vegetation such as scrub or pine. The interior of the hardwood forests did not burn extensively. This resistance was highly correlated to the basal area of *Quercus virginiana* within a stand. This correlation was also significant in scrub vegetation. The death of large hardwoods bordering scrub following destructive fires fueled by the latter may be causing expansion of scrub.

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APPENDIX I

TABLE 13. Comparison of burned and unburned soil pH, buffer pH, (pH-B), and macronutrient ($Kg\ Ha^{-1}$) values at two depths, arranged according to community type.

	0-20 cm Depth						30-60 cm Depth					
PLOT	pH	pH-b	P	K	Ca	Mg	pH	pH-b	P	K	Ca	Mg
Freshwater cordgrass marsh, nine months after burn												
113	4.2	7.40	4	27	429	204	4.7	7.90	2	10	47	12
115	4.4	7.55	2	10	413	147	4.7	7.95	2	8	63	26
129	3.6	7.30	16	19	185	36	4.4	7.85	6	11	50	4
131	3.9	7.60	13	25	102	18	4.3	7.80	3	25	26	0
Freshwater cordgrass marsh, five years after burn												
211	4.1	7.20	9	112	1610	177	4.5	7.60	8	19	108	9
213	3.8	7.00	22	22	197	58	4.5	7.20	20	21	100	25
Freshwater cordgrass marsh, unburned												
321	4.1	7.45	29	35	217	54	4.8	7.20	25	20	111	53
323	4.2	7.45	11	31	260	66	4.5	7.35	25	9	156	54
Freshwater sawgrass marsh, unburned												
317	4.3	7.95	115	43	578	162	NO DATA					
319	4.4	7.45	64	48	345	86						
Saltmeadow, nine months after burn												
149	5.0	7.50	30	134	733	369	4.3	7.80	7	49	96	71
151	5.1	7.55	47	186	727	545	4.9	7.60	38	90	134	129
Saltmeadow, unburned												
301	4.9	7.40	10	103	243	204	5.1	7.90	1	37	52	34
303	4.8	7.45	9	196	449	408	4.8	7.90	2	55	87	76
Pine Scrub, nine months after burn												
121	4.1	7.30	24	95	362	271	4.2	7.75	22	26	21	8
123	4.1	7.30	10	81	530	168	4.5	7.95	4	21	50	10
125	4.1	7.45	9	71	343	164	4.2	7.90	2	19	81	20
127	4.6	7.50	8	153	634	193	4.7	7.95	1	15	19	7
133	5.1	7.65	85	118	1044	251	4.8	7.90	6	26	73	13
135	4.5	7.60	21	65	263	83	4.1	7.70	6	43	87	38

Appendix 1, continued.

	0-20 cm Depth						30-60 cm Depth					
PLOT	pH	pH-b	P	K	Ca	Mg	pH	pH-b	P	K	Ca	Mg
Pine Scrub, five years after burn												
203	4.1	7.40	19	41	525	194	4.1	7.90	2	15	38	17
205	4.1	7.30	18	47	536	166	4.2	7.80	8	27	75	40
Pine scrub, four months after burn on Sapelo Island												
501	4.2	7.20	16	92	875	212	NO DATA					
503	3.9	7.05	21	123	466	203						
Oak Scrub, nine months after burn												
109	4.1	7.65	32	147	952	326	4.2	7.75	9	39	188	64
111	4.1	7.80	12	121	828	213	4.3	7.90	1	15	50	17
137	4.6	7.45	16	54	325	47	5.1	7.65	16	15	71	8
139	4.3	7.40	11	80	407	117	4.6	7.90	1	19	55	9
157	4.2	7.40	10	122	328	122	4.3	7.80	6	43	90	29
159	4.5	7.40	15	101	428	217	4.3	7.90	11	43	36	20
345	3.8	7.20	28	108	356	140	4.9	7.60	57	12	29	6
355	4.3	7.60	12	52	141	49	4.7	7.60	76	18	31	11
Oak Scrub, five years after burn												
207	3.9	7.35	18	175	864	301	4.7	7.90	3	12	83	31
209	4.1	7.80	13	76	1320	254	4.4	7.90	1	11	18	2
Oak Scrub, unburned												
347	4.0	7.70	15	44	78	27	4.9	7.65	26	17	12	1
349	4.5	7.45	18	73	125	67	4.6	7.65	114	18	27	1
Pine/Oak, nine months after burn												
101	5.4	7.55	127	31	1268	112	6.3	---	125	11	436	35
103	5.3	7.55	115	32	893	65	6.2	---	145	11	1007	38
145	4.7	7.35	17	95	359	202	4.3	7.75	8	35	85	47
147	3.9	7.15	36	138	790	168	4.9	7.60	48	45	140	35
153	4.5	7.40	10	53	936	110	4.7	7.70	4	16	375	63
155	4.7	7.45	74	35	379	62	5.4	7.65	119	17	229	39

Appendix 1, continued.

	0-20 cm Depth						30-60 cm Depth					
PLOT	pH	pH-b	P	K	Ca	Mg	pH	pH-b	P	K	Ca	Mg
Pine/Oak, five years after burn												
215	3.8	7.05	24	62	412	136	4.2	7.85	8	34	101	24
Pine/Oak, three years after burn												
217	4.0	7.05	20	19	564	164	4.0	7.75	8	27	193	47
Pine/Oak, burned												
313	5.3	7.50	63	46	152	37	5.0	7.60	67	19	89	20
315	4.7	7.45	63	39	85	30	5.0	7.70	68	13	53	8
325	5.0	7.60	71	31	1281	99	5.4	7.90	69	6	380	19
327	4.9	7.65	20	20	1872	72	5.9	7.95	2	9	240	6
333	4.9	7.70	55	26	202	22	4.9	7.80	141	15	36	2
335	4.6	7.60	56	11	80	24	5.5	7.80	71	13	58	18
Oak hardwood, burned												
141	4.2	7.30	11	129	448	149	4.0	7.45	3	29	111	86
142	4.0	7.30	10	74	334	111	4.6	7.85	2	19	17	10
143	3.6	7.35	11	140	388	404	4.3	7.90	1	7	21	16
144	3.8	7.89	31	143	424	239	4.7	7.90	2	10	28	11
Mesic hardwoods, burned												
105	4.0	7.85	15	62	2338	267	5.6	7.70	6	12	1349	55
107	4.5	7.45	54	74	1841	177	4.7	7.60	10	26	771	63
Mesic hardwoods, unburned												
351	4.7	7.40	17	41	1723	190	6.0	---	11	8	1811	71
353	4.0	7.80	24	74	1659	244	5.4	7.60	24	10	1867	86

APPENDIX II

Herb and Shrub Percent Cover Data According to Community Types

Table 14. Freshwater cordgrass marsh herb and shrub cover in seasonal and comparison plots.

	SOUTH CUT (1 and 2 years after burn)								TABLE POINT (5 years after burn)		TABLE POINT (unburned)	
PLOT	113		115		129		131		211	213	321	323
Date of sample	9/82	9/83	9/82	9/83	9/82	9/83	9/82	9/83	4/82	4/82	5/82	5/82
Spartina bakerii	96.5	144.0	96.0	139.5	65.0	99.2	14.5	33.5	165.5	195.0	31.5	137.5
Panicum spp.	32.0		27.5		37.0	8.0	61.5	17.4		0.4	1.7	5.0
Panicum hemitomon					0.5	1.0	1.6	1.2			22.5	6.6
Andropogon virginicus							0.7	0.6	1.4		48.5	2.0
Other grasses		0.5			0.5				19.0			
Pluchea spp.	0.9				8.5	4.3	2.6	7.9			0.5	1.3
Proserpinica pectinata	1.0				0.1	1.6		0.3				0.4
Eupatorium capillifolium	2.2		0.1		2.2		2.1		5.1	0.1	2.5	4.6
Eleocharis spp.	1.7		4.5		26.0	11.8		8.2		0.2		
Xyris spp.	5.3		0.2		0.6	1.3	1.9	6.8				
Juncus spp.	0.5				4.3	6.0	10.2	24.0				
Cyperus spp.	1.2		0.3					1.5				
Limnobium spongia	0.9	11.5	2.9	17.0								
Polygonom hydropiperoides	2.0		3.3	0.5								
Sagittaria graminifolia		1.5		2.0								
Utricularia purpurea		0.5		2.6								
Utricularia fibrosa				1.5								
Spirodela oligorrhiza				0.2								
Ludwigia linaris			0.2									
Woodwardia virginica			1.0									
Fimbristylis spadicea	0.5											
Mecardonia acuminata					0.6	0.9	3.0	3.6				
Hypericum cistifolia					2.2		1.3					
Drosera rotundifolia						0.2						
Elephantopus nudatus									0.2	0.3		
Mikania scandens									0.4	0.1		
Centella asiatica									0.6			
Eupatorium aromaticum									0.1			
Lysimachia terrestris											0.5	0.2
TOTAL HERB COVER	144.6	158.0	136.0	163.3	147.5	134.3	99.4	105.2	195.9	196.1	107.7	157.6
Number of species	12	5	10	7	12	10	10	11	8	6	7	8
Decodon verticilatus	7.4	0	16.0	2.0								
Pinus serotina					0.3	0				0.1		
Myrica cerifera					0.1	0	0.1	0		0.2		
Serenoa repens										3.0		
Lyonia lucida										4.5		
Ilex opaca									0.1	0.4		
TOTAL SHRUB COVER	7.4	0	16.0	2.0	0.4	0	0.1	0	0.1	8.2	0	0
Number of species	1	0	1	1	2	0	1	0	1	5	0	0

Table 15. Freshwater sawgrass marsh herb cover in seasonal and comparison plots.

	SOUTH CUT 1 & 2 years after burn						Unburned	
PLOT		117			119		317	319
Date of Sample	7/82	9/82	9/83	7/82	9/82	9/83	5/82	5/82
Cladium jamaicense	63.0	81.0	101.0	112.0	80.5	94.0	167.5	137.0
Polygonum hydropiperoides	18.8	25.5	1.7	14.3	23.0	1.1	18.6	0.5
Pluchea spp.		0.5					0.5	
Eupatorium capillifolium	0.1	0.2		0.3				0.5
Ludwigia linaris	1.5	0.7	0.5		1.0	0.4		
Utricularia purpurea			1.0			14.0		
Woodwardia virginica	40.5	13.5		9.6	9.2			
Cyperus spp.		4.5	0.4					
Nymphoides aquatica			0.5					
Limnobium spongia				3.5				
Lemna spp.				0.2				
Pteridium aquilinum							4.3	0.5
Osmunda regalis							3.0	
Senecio vulgaris							1.0	1.4
Spartina bakerii								40.0
TOTAL HERB COVER	123.9	125.9	105.1	139.9	113.7	109.5	194.9	179.9
number of species	5	7	6	6	4	4	6	6

Table 16. Saltmeadow cordgrass marsh herb and shrub cover in seasonal and comparison plots.

	SOUTH CUT 1 & 2 years after burn				Unburned	
PLOT	149		151		301	303
Date of Sample	9/82	9/83	9/82	9/83	5/83	5/83
Spartina patens	29.5	96.0	38.5	31.5	85.5	134.0
Distichlis spicata	8.5	14.5	8.5	13.5	0.3	6.5
Juncus roemerianus	2.5	7.0	4.3	3.0	47.7	16.2
Cynodon palustris	2.1	0.2	3.0	0.9		0.2
Juncus tenuis						0.5
Muhlenbergia capillaris					2.7	4.5
Fimbristylis spadicea	13.5	15.5	33.0	40.0		
Cyperus spp.	16.5	-	5.0	-		
Eupatorium capillifolium	5.0	-	5.0	-		
Pluchea spp.	5.6	1.1	1.8	1.5		
Bacharis hamilifolia	0.6	-	3.0	1.8		
Senecio vulgaris	0.5	-	-	0.5		
Samolus parviflora	0.5	-	0.5	-		
Sessuvium portulascastrum	0.2	-	0.5	-		
Setaria spp.			-	1.0		
Eleocharis spp.	0.5	-				
TOTAL HERB COVER	85.5	134.3	103.1	93.7	136.2	161.9
number of species	13	6	11	9	4	6
Serenoa repens	0.2	0.5				2.0
Myrica cerifera	0.2	0.0	1.0	1.3	0.8	
Iva frutescens	0.6	1.2	8.6	23.9		
Rubus trivialis					1.4	
Smilax spp.					0.2	
Vitis rotundifolia					0.1	
Opuntia drummundii					0.1	
TOTAL SHRUB COVER	1.0	1.7	9.6	25.2	2.6	2.0
number of species	3	3	2	2	5	1

Table 17. Pine scrub herb cover in seasonal and comparison plots.

Date of sample PLOT	135	133	121	125	127	123	203	205	501	503	509	511	505	507
Panicum spp.														
Andropogon virginicus	7.7	.3			.7	2.4			.1		2.1	9.7		
Other grasses	11.9	2.3			.5		7.0	1.5						
Pteridium aquilinum									1.2	.2	6.0	7.0	2.8	7.4
Woodwardia virginica			2.8		1.2	4.6	1.2		2.6	2.8	8.2	1.7	12.0	26.5
Eupatorium aromaticum	1.6	.1						3.7						
Eupatorium compositfolium							32.0	14.5						
Eupatorium capillifolium							1.7	6.2						
Pluchea spp.	13.0	45.6												
Senecio vulgaris	2.3	4.3			.5									
Cyperus spp.		.2												
Juncus spp.	11.6	2.6							1.0					
Eleocharis spp.	11.8													
Hypericum cistifolium	.5				.2									
Mecardonia acuminata	5.5													
Pterocaulon pyenanthemum	.2													
Xyris spp.	5.5													
Helianthemum corymbosum	.2													
											1.0	2.5	.3	
											.1	8.6		
									1.0					
TOTAL HERB COVER	66.5	55.4	2.8	0	3.1	7.0	41.9	25.9	4.9	3.0	17.4	29.5	15.1	33.9
Number of species	10	7	1	0	5	2	4	4	4	2	5	5	3	2

Table 18. Pine scrub shrub cover in seasonal and comparison plots.

	SOUTH-CUT Two Years After Burn						TABLE POINT 5 Years After Burn			SAPELO ISLAND 6 Months After Burn			No Burn		
date of sample		September 1983					July 1983			June & July 1982			May 1982		
PLOT	133	135	121	125	123	127	203	205	501	503	509	511	505	507	
Serenoa repens		5.0	12.0	38.0	10.7	35.5	38.5		29.5	8.5	10.0	25.7	21.7	45.0	37.0
Myrica cerifera	5.4	5.3	1.8		1.6	1.7	147.0	79.5	9.2	6.2	6.8	3.0	7.0	8.6	
Galactia elliottii	0.3	13.0	1.4	0.4	1.9	1.8		0.5	5.4	12.5	16.5	23.6	5.9	16.0	
Pinus serotina		0.5	1.8	7.2	4.5	0.1		1.0		0.1	0.2	0.1		1.5	
Lyonia ferruginea	1.2	0.2	2.8	1.8	6.5	7.2			2.9	2.8	1.0	4.8			
Lyonia lucida	4.0		29.5	59.5	10.9	7.0	5.8	9.9							
Ilex glabra	2.1	12.3	28.0	12.5	5.1	9.7									
Befaria racemosa			3.2	0.5	1.6	2.7									
Vaccinium arboreum			0.2			0.3	0.2		6.0	4.6	3.0	1.8	4.1	1.0	
Vaccinium myrsinites			2.7	1.2	0.8	8.2			20.2	11.5	8.4	26.0	7.6	12.5	
Gaylussacia frondosa							0.7			9.6	4.0	0.6		12.7	8.8
Quercus virginiana					3.0	1.9			8.7	6.9	2.5	6.0	23.0	14.2	
Quercus myrtifolia						4.8			3.0	6.9			7.0	3.5	
Rhus copallina			0.2		0.3			0.1		0.3			1.1		
Smilax spp.						0.2			0.1				0.5		
Vitis spp.							1.0	1.7							
Persea borbonia			0.2				2.5								
Sorbus arbutifolia				0.1											
Juniperus silicicola									0.2						
Rhus radicans								1.4							
Ilex opaca						0.2									
TOTAL SHRUB COVER	18.0	43.3	109.8	93.9	71.7	84.8	156.7	123.8	73.6	65.8	64.7	87.0	113.9	103.1	
Number of species	6	6	12	9	11	14	6	9	10	11	9	8	10	9	

Table 19. Oak scrub herb cover in seasonal and comparison plots.

Date of sample PLOT	109	111	137	139	157	159	345	355	207	209	347	349
Panicum spp.												
Andropogon virginicus	3.5	31.0	19.9	.5	-	1.8	-	-	2.8	3.8	.1	
Other grasses	.2								9.5	.9		
Pteridium aquilinum												.2
Woodwardia virginica	1.0											
Eupatorium aromaticum												
Eupatorium compositfolium								1.5	1.8			
Eupatorium capillifolium	.2	.1						1.2				
Pluchea spp.	28.2	2.6										
Senecio vulgaris	1.2											
Cyperus spp.	.8	.6										
Juncus spp.												
Eleocharis spp.												
Hypericum cistifolium												
Mecardonia acuminata												
Pterocaulon pyenanthemum												
Xyris spp.												
Helianthemum corymbosum												
TOTAL HERB COVER	35.1	34.3	19.9	.5	0	1.8	0	0	24.8	7.7	.1	.2
Number of species	7	4	1	1	0	1	0	0	5	3	1	1

Table 20. Oak scrub shrub cover in seasonal and comparison plots.

	SOUTH-CUT 2 YEARS AFTER BURN								TABLE POINT 5 YEARS AFTER BURN		UNBURNED	
date of sample	9/83								7/83		5/82	
PLOT	109	111	137	139	157	159	345	355	207	209	347	349
Serenoa repens	60.4	50.2	17.0	32.5	41.0	47.0	15.3	16.7	52.6	65.5	51.7	16.0
Lyonia ferruginea	1.5	6.0	5.5	6.5	15.5	5.4	13.1	12.1	13.0	12.0	4.1	8.2
Quercus virginiana		1.0	2.6	3.2	2.0	13.8	1.4	2.1	0.2	1.8	7.6	1.0
Quercus myrtifolia		2.0	26.7	41.5	2.7		0.5	0.6			0.1	0.6
Myrica cerifera		3.6	1.3	2.0	0.6	3.9	7.8	1.4	5.0	4.7	0.9	2.3
Galactia elliottii	0.2		14.6	0.2	0.1	0.2	0.2		0.4	0.2	0.1	0.2
Vaccinium arboreum			4.5	0.6			0.4	1.7				
Vaccinium mysinites			3.5	2.9	1.6	1.1	5.0	0.6	0.5	0.2	2.0	6.6
Vaccinium stamineum			0.2		0.8			1.8	0.3	0.3		0.2
Persea borbonia	1.0	2.5						2.2			0.2	0.5
Smilax spp.	1.5							0.2			1.5	1.1
Vitis rotundifolia			0.2						0.1		0.1	
Asimina spp.				0.2								
Gaylussacia frondosa				0.1			0.8		0.5		0.1	
Ilex opaca	0.2										0.1	0.8
Ilex glabra									0.1			0.1
Osmanthus americana							0.7	0.2				
Befaria racemosa			2.0						1.1			
Rhus copallina		0.4	1.2									
Symplocus tinctoria					2.0		0.7					
Pinus serotina			1.0									
Quercus chapmanii											1.6	
Rubus cunifolia						3.8						
Rubus trivialis	0.5											
TOTAL SHRUB COVER	65.3	65.7	80.3	89.7	66.3	75.2	45.9	39.6	73.8	83.5	73.3	37.6
Number of species	7	7	13	10	9	7	11	11	11	7	13	12

Table 21. Mixed pine/oak forest herb cover in seasonal and comparison plots.

Date of sample	SOUTH-CUT 2 YEARS AFTER BURN September 1983						TABLE POINT THREE AND FIVE YEARS AFTER BURN July 1983						UNBURNED May 1982					
PLOT	103	101	145	147	153	155	249	251	217	247	215	245	325	327	333	335	313	315
Panicum spp.	.8	3.0	19.0	7.5	.9	3.3	3.6	6.1	1.0	7.7		.3	3.2	2.0	.5	1.4	3.2	1.1
Other grasses	32.5	11.6	3.5										9.1	8.3	44.0	5.8		
Uniola sessiliflora					.5	6.3	9.0	8.3										8.5
Scleria triglomerata						.2	.3	4.1		1.3			8.7	1.5	9.8	2.6		
Galium palustris								.1					.1		.2			
Eupatorium aromaticum	20.1	25.5					5.9	1.7			1.0				4.6	.7		
Eupatorium compositfolium	18.2	8.3					.3	2.0										
Cnidoscolus stimulosum	.2	.2					1.0	3.0							.4			
Helianthemum corymbosum	1.4	11.5					19.0	20.0							.5	5.0		
Helianthemum carolinianum	19.7																	
Lespedesia spp.	.2	.6					.1	12.3							.3	.2		
Stylingia sylvatica	2.7	1.0				.8				.7								.7
Dichondra carolinensis	.2	.4													.4			
Carduus smallii	1.2	.5																
Viola spp.		.5																
Bacharis hamilfolia	.8																	
Diodia teres				.7														
Carex spp.						.3												
Elephantopus tomentosa																.7		
Andropogon virginicus															.4			
Pteridium aquilinum			3.3					2.5		2.0	2.5							
Woodwardia virginica			16.5	25.3					4.5	11.0								
Eupatorium capillifolium			1.5	.5					.3		.7							
Senecio vulgaris		2.2	11.4	45.0					1.0		6.8							
Pluchea spp.			3.1	1.3		.3												
Mecardonia acuminata			1.7															
Phyfolacca americana			.3												.2			
Juncus spp.			7.0															
Mikania scandens			7.0															
Woodwardia areolata				.2														
									.2									
TOTAL HERB COVER	98.0	65.3	74.3	81.7	1.4	11.2	39.2	60.1										
Number of species	12	12	11	7	2	6	8	10										

Table 22. Mixed pine/oak forest shrub cover in seasand comparison plots.

Date of sample	SOUTH-CUT 2 YEARS AFTER BURN September 1983						TABLE POINT THREE AND FIVE YEARS AFTER BURN July 1982						UNBURNED May 1982					
PLOT	103	101	145	147	153	155	249	251	217	247	215	245	325	327	333	335	313	315
Serenoa repens			19.4	10.2	.1	2.0			65.5	53.5	60.7	61.5						6.1
Pinus spp.		.1	.9	.9		.3	.8	.7						.2	.3		.1	
Vitis spp.					.1	.2		.2	.1	.4	.1	.2	.1	.1	.1			
Smilax spp.	.3	.1	.2		.5	.5	.5	.3			.1	.8	.2	.5	.7	.7	1.3	1.4
Quercus virginiana					.5	1.2			2.7				.9	.7	1.1	1.0	.7	.6
Vaccinium arboreum					.2		.4						.9	.3	1.5	.2		.2
Vaccinium myrsinites			.4										.7	.1				
Myrica cerifera			4.2	3.2	.3	1.5	1.3			.1	.2	.3	8.6					8.3
Persea borbonia	.1			1.0	.1				1.7	.5	.1	.1	.2		.1	.1		.1
Ilex opaca	.1						.4	.1	.2	.2	.4			.2	.8	.3		
Rubus trivialis	1.0	.5				1.1	.5	1.9			2.0							
Galactia elliottii				7.5									.2		.1	.4		
Rhus radicans		.4	.5			.2												
Lyonia ferruginea										1.2		5.5	.5					
Prunus serotina			.4															
Vaccinium stamineum								.2										
Asimina spp.					.2	.6											.1	
Quercus laurifolia											2.0							
Parthenocissus quinquefolia									.1									
Quercus nigra		.2																
Anisosticus capreolata		.1														.7	.6	.1
Bumelia tenax																		.2
TOTAL SHRUB COVER	1.8	1.1	26.0	22.8	2.0	7.6	3.9	3.2	70.5	55.9	63.6	70.4	12.3	1.9	5.3	3.1	2.7	17.1
Number of species	6	4	7	5	8	9	6	5	7	6	7	7	9	6	9	8	4	9

Table 23. Hardwood forest herb cover in seasonal and comparison plots.

	SOUTH-CUT, 2 YEARS AFTER BURN						UNBURNED	
Date of Sample	SEPTEMBER 1983						MAY 1982	
PLOT	141	142	143	144	105	107	351	353
Panicum spp.	0	0	0.2	0.4	1.0	0.5	0.5	0
Eupatorium aromaticum					0.2			
Eupatorium capillifolium						24.3		
Senecio vulgaris					0.2			
Woodwardia virginica			1.2			0.2		
Polypodium polypodioides			0.1			0.1		
Pteridium aquilinum				1.1			0.5	
TOTAL HERB SPECIES	0	0	1.5	1.5	1.4	25.1	1.0	0
Number of species	0	0	3	2	3	4	2	0

Table 24. Hardwood forest shrub cover in seasonal and comparison plots.

Date of Sample	SOUTH-CUT, 2 YEARS AFTER BURN SEPTEMBER 1983						UNBURNED MAY 1982	
PLOT	141	142	143	144	105	107	351	353
Serenoa repens	48.5	38.0	9.9	5.8	40.0	58.5	95.0	77.5
Lyonia ferruginea	2.7	3.7	2.6	3.5				
Quercus virginiana	1.2	0.5	0.3	0.4			0.1	
Persea borbonia	3.5	1.2	1.2	0.1	3.1		0.3	0.4
Myrica cerifera			1.4	0.9	0.1	12.2	4.0	0.3
Vaccinium arboreum	0.1		0.2				0.2	
Smilax spp.	0.2	0.2	0.4	0.6	0.2		0.7	0.6
Vitis rotundifolia	0.3	0.5			1.8	0.5	1.0	
Ilex opaca		0.1	0.1	0.1	0.1			
Rubus trivialis						0.7	5.0	
Acer rubrum						0.2		0.1
Rhus radicans					0.1		0.7	
Anisosticus capreolata	0.3							
Galactia elliottii				0.2				
Pinus elliottii				0.4				
Quercus nigra					0.1			
Juniperus silicicola					0.1			
TOTAL SHRUB COVER	56.8	44.2	16.1	12.0	45.6	72.1	107.0	78.9
Number of species	8	7	8	9	9	5	9	5

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