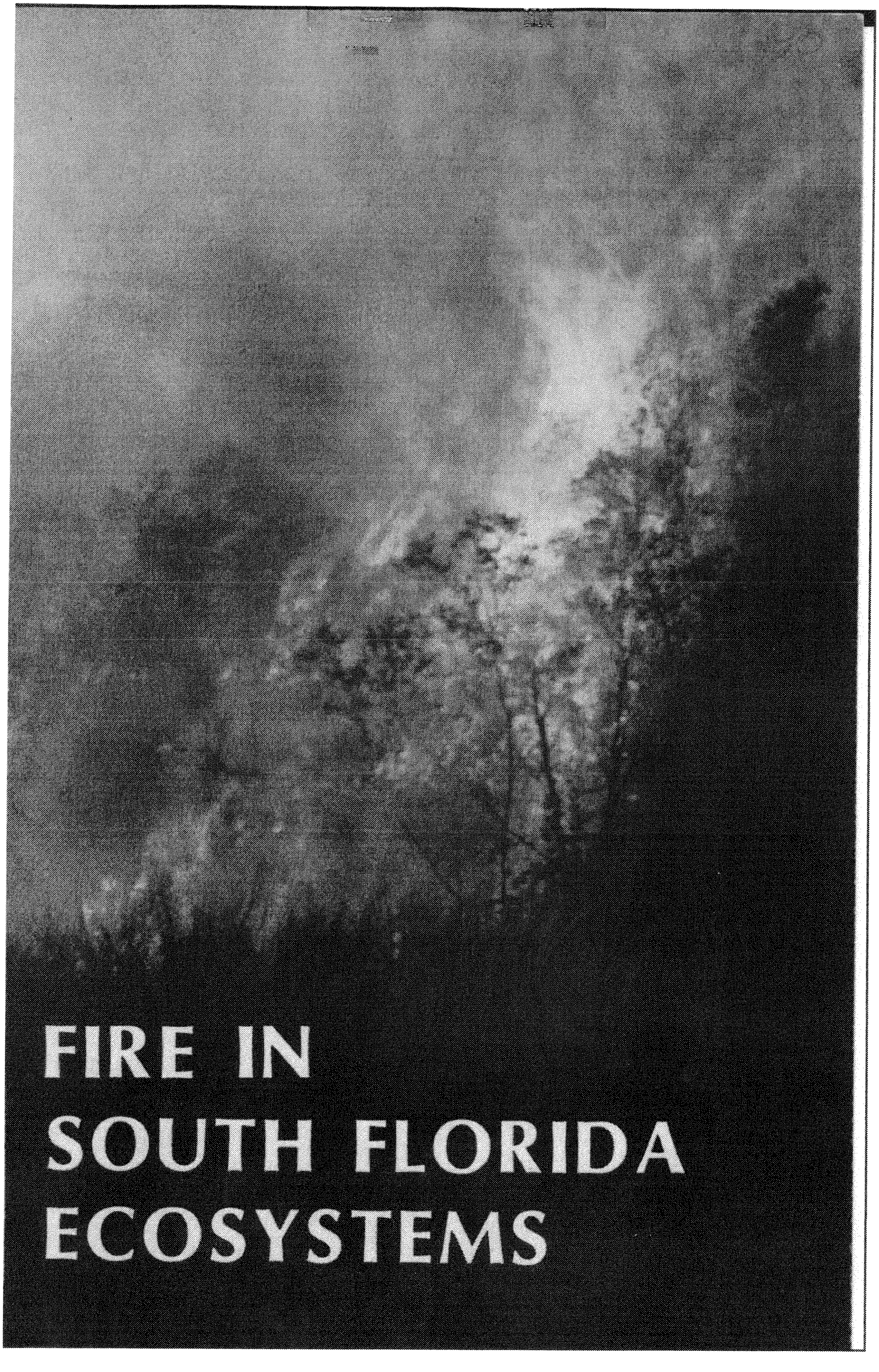

FIRE IN SOUTH FLORIDA ECOSYSTEMS

U.S. Department of Agriculture
Forest Service General Technical Report S E- I7

Cover Photo. — A rare phenomenon: Fire crowning into a stand of mangrove after a killing frost, hut prior to leaf fall. The small mounds in the foreground are cordgrass tussocks. Broad River Marsh, Everglades National Park, February 1977.

March 1980

Southeastern Forest Experiment Station
Asheville, North Carolina

FIRE IN SOUTH FLORIDA ECOSYSTEMS

by

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ABSTRACT. — This compendium of tire information for selected south Florida vegetative communities will help resource managers and policymakers to better predict the consequences of their fire management decisions. Included is a brief history of fire in south Florida, along with some associated damages and benefits. Certain natural functions fulfilled by tire are outlined. Fire is rated against other specified threats to south Florida's remaining wildlands, and the impact of ongoing vegetative changes upon fire management in the near future is assessed. The effect of tire on attainment of resource management objectives and the necessity of integrating fire planning into the land management planning process are explained. Available information about fire effects is presented for each of the major vegetative types in south Florida, and tire's relationship with certain exotic species is discussed.

Keywords: Fire management, fire effects, prescribed burning, wildfire, water levels.

FOREWORD

Our Smoke Management Research and Development Program was asked to help with a smoke problem on the south Florida "Gold Coast" late in the winter of 1974. Smoke was being blamed for numerous hospital admissions and for blocking out the sun many people paid highly to enjoy. There was a genuine concern that this smoke would interact with urban emissions — such as automobile exhaust — and result in an increased health hazard. The smoke came from the Everglades, from the agricultural lands adjacent to Lake Okeechobee, and from way off in the Big Cypress Swamp. Some came from fires on nearby lands soon to be subdivided.

On a fact-finding trip to the areas, we heard once more about the natural role of fire, and for the first time heard the term "benign fire." We heard, on the one hand, that the Florida Division of Forestry was letting too many fires get too big, but, on the other hand, that more should be let burn. We were told of strong pressures to let most of the fires we saw continue burning — "to a point." To a point where someone became alarmed about a threat to improvements, alarmed about the size of the fire, or alarmed about the smoke. But delaying control action often resulted in tires so large that suppression costs were next to impossible to meet!

From the air we saw many intentional "sets" beyond fire suppression lines, we saw glade-buggy and airboat tracks leading from these "sets," and we saw miles of continuous fuel that pointed to the enormous tactical, logistical, and detection jobs that face south Florida fire managers. We saw the entire Big Cypress Seminole Indian Reservation blanketed with a thick smoke that hugged the ground for days. Here and there, the fires were spreading across water.

Perhaps most important, there was an odor not at all like that from the sweet-smelling grass fires known elsewhere. This disagreeable odor was said to come from fires that were burning deep into the dried muck and peat underlying the sawgrass. A nagging question began to bother us. If peat takes hundreds of years to form, how can peat consuming fires be regarded as a natural part of the ecosystem?

Shortly after, State Forester John Bethea invited other agencies and the interested public to take part in a South Florida Fire Management Open Forum. In discussions at that landmark meeting, we learned that others, too, believed that properly used fire was needed in south Florida. Yet these same people feared that too many fires, set by too many well-meaning people, were not what the area needed. As we progressed, more and more references were made to unknowns and changed ecosystems, and a list of research needs was compiled.

To help meet these needs, the Forest Service initiated a new research effort, the Lowlands Fire Management Alternatives Work Unit. Their first goal was: TO GAIN NEW KNOWLEDGE AND SYNTHESIZE WHAT IS KNOWN ABOUT THE EFFECTS OF FIRE ON SOUTH FLORIDA

ECOSYSTEMS, TRANSLATING THESE TO IMPLICATIONS FOR FIRE MANAGEMENT WHERE POSSIBLE.

The authors of this report have satisfied these objectives. A rigorous technical review of their findings assures that the best knowledge available is contained in the pages to follow.

We still have a long way to go. The strange-smelling smoke is just now being characterized. Photochemical reactions and other phenomena are being studied. The best smoke management practices in south Florida are thus only partially set forth. Final guidelines for when fire is really needed must await a merger of land management objectives, resource evaluations, and other research. Here, though, is a determined first step forward!

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Program Manager
Southern Forest Fire Laboratory
USDA Forest Service
August 4, 1979

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PREFACE

On the following pages, we have attempted to define the historical effects of fire on evolving south Florida ecosystems and to describe the responses of selected plant communities to changes in the frequency and intensity of fire under current conditions.

Our intent was neither to produce a burning manual nor to leave the reader with the idea that fire is the sole means of achieving all resource-management goals; other treatments do exist. Instead, our objective is to add to and synthesize available information regarding fire effects in south Florida. We think this report will help policymakers and land managers support decisions concerning fire management.

A reader might well conclude, on the basis of this report, that prescribed fires can help achieve certain management objectives. In that case, a burning manual might prove helpful. "A Guide for Prescribed Fire in Southern Forests" (Mobley and others 1977)[1] provides a good basic discussion of prescribed fire, but it does not relate specifically to south Florida conditions. Another sourcebook that the potential prescribed burner should be aware of is the "Southern Forestry Smoke Management Guidebook" (USDA FS 1976a), available from the same address. We recommend that anyone contemplating the use of fire become familiar with these two publications and then contact the nearest Florida Division of Forestry (FDOF) office.

The FDOF is the best source of information about south Florida fuel types and burning prescriptions. Moreover, it helps individual landowners to plan and execute prescribed burns. Regardless of one's proficiency with fire, Florida law requires that a prescribed burning authorization be obtained from the FDOF before a fire is set. Other pertinent Florida statutes involving fire are briefly summarized in a separate section entitled "Relevant Florida Statutes," at the end of this report.

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[1]Available free from U.S. Dep. Agric. For. Serv., South. For. Fire Lab., P.O. Box 5106, Macon, Ga. 31208.

FIRE IN SOUTH FLORIDA ECOSYSTEMS

INTRODUCTION

Florida's population increased 35 percent between 1960 and 1970.[1] The seven counties south of Lake Okeechobee (fig. 1) reported a 49 percent increase during the same time period. Since 1970, people have been migrating to Florida at an estimated rate of over 5,000 per week. The southeast Florida coast contains the fastest growing population center in the United States. Lee County's population increased 64 percent between 1970 and 1977, and Fort Myers was the fastest growing city in the Nation from 1970 through 1974. The population of Collier County rose 89 percent between 1970 and 1977. As the population of south Florida continues to soar, so do demands upon its natural resources. Aquifers are being depleted as water-use rates exceed recharge rates. Saltwater intrusion is all too common during the dry season. The water table has dropped more than 6 feet in the northern Everglades. The hydroperiod has been drastically shortened throughout south Florida, and the potential for large destructive wildfires has increased. Stephens (1974) estimated that 88 percent of the volume of peat present in 1912 would be gone by the turn of the century.

Changes in land use, and attitudes of people, have increased the risk of fire and have resulted in severe conflicts of ideas and fire management objectives. These fires can eliminate tire-adapted species and consume vast amounts of the underlying organic soil.

No wonder dramatic vegetative responses are taking place. The natural system cannot be expected to support itself indefinitely under these pressures. Aggressive exotics are colonizing large areas at the expense of native vegetation. The situation has become critical. Decisions must be made; realistic goals for resource protection and use have to be set. Planners must determine the compatibility of fire management alternatives with resource options. But this cannot be done until land managers and policymakers are able to predict ecosystem responses to their fire-related decisions. Researchers are being asked to assist in this process. Research results, however, have been slow to accumulate, and available findings often have not been related to the fire problems that exist.

To the extent that knowledge can help, this publication should aid in the decisionmaking process. It summarizes available information on the effects of fire in south Florida ecosystems. It reviews some of the damages and benefits as well as some of the natural ecological functions of tire in the area. Next, for each major vegetative type in south Florida, fire effects are described in detail. We hope that our efforts will help with the needed task of integrating fire planning into land management planning.

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[1]The following population-growth statistics are from various articles that appeared in the Miami Herald and Fort Myers News-Press. [Clippings on file at the South. For. Fire Lab., Macon, Ga.]

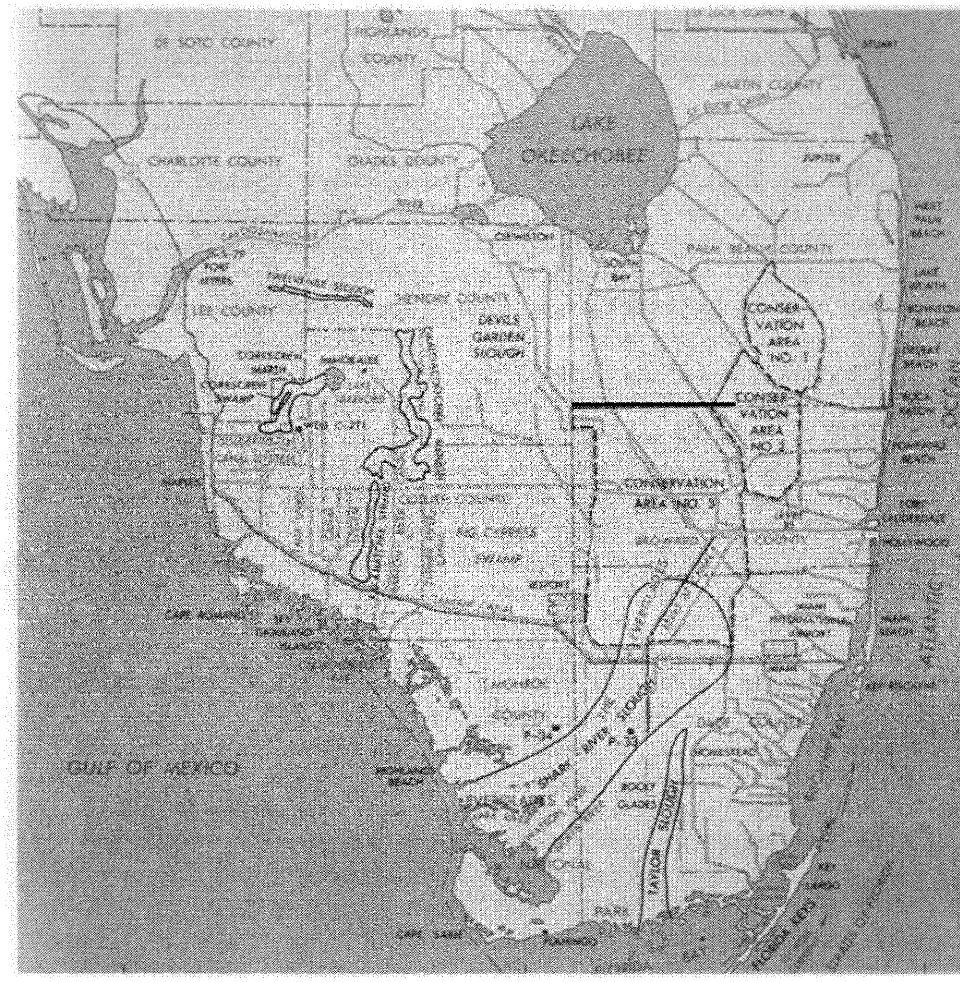
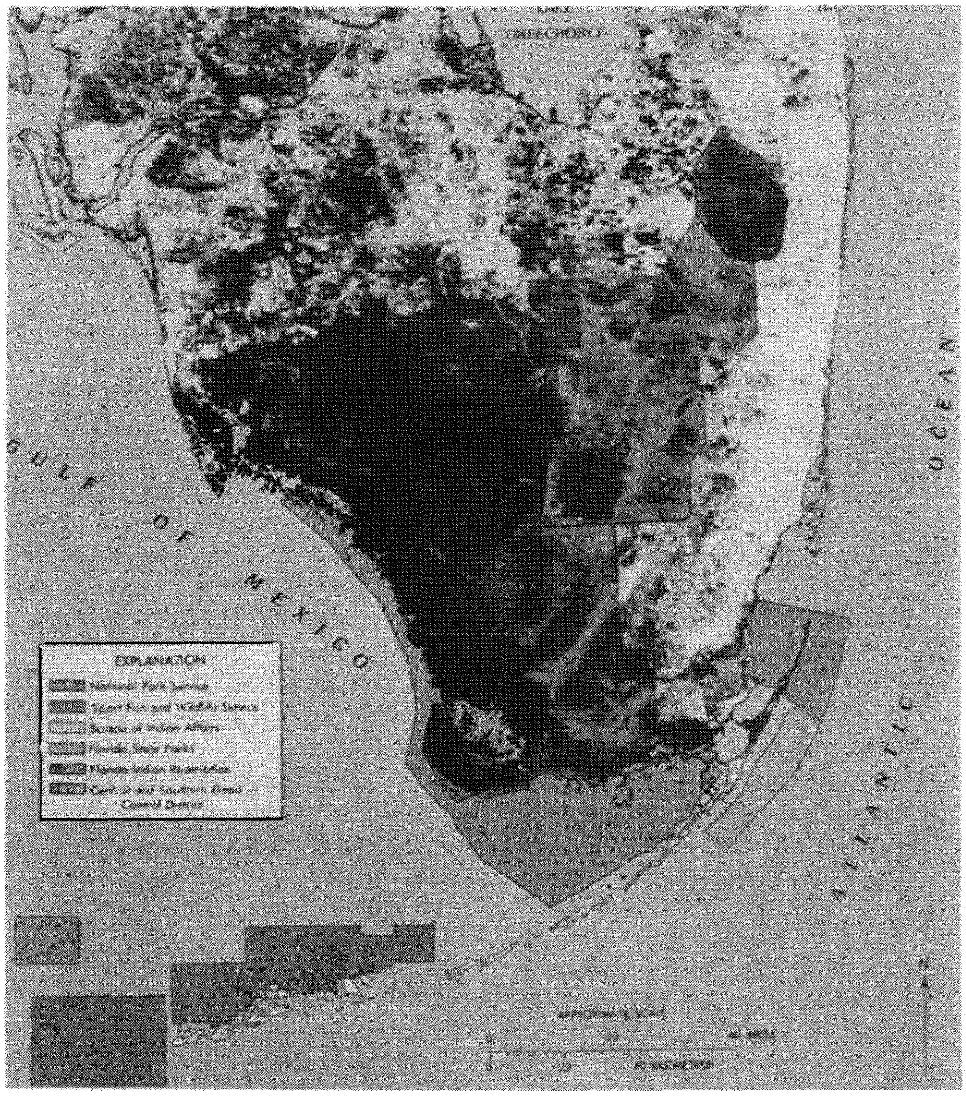


Figure 1.— Map of south Florida showing: A, the major road and canal network; B, selected large ownership. (Adapted from McPherson and others 1976.)

BACKGROUND

The Florida Peninsula extends almost to the Tropic of Cancer. In fact, Miami is closer to Havana, Cuba, than to Orlando or Tampa. Thus, south Florida in many respects has more in common with the West Indies than with central Florida.

In this discussion, south Florida includes the counties of Broward, Collier, Dade, Hendry, Lee, Monroe, and Palm Beach (see figure 1). These seven counties lie south of Lake Okeechobee and have a total area of 7,448,000 acres (3,014,200 hectares) (Alleger 1974). Our discussion is limited to the mainland, but it should be applicable to the Keys and offshore islands wherever the same vegetative associations exist.



During ancient ice ages, the land mass of south Florida was much greater. As the glaciers began receding about 17,000 years ago, sea level increased. Alexander (1974); Scholl, Craighead, and Stuiver (1969); and Scholl and Stuiver (1967) present evidence that this increase is continuing in south Florida. Concurrent with this slow submergence, however, has been the land-building action along the coastal mangrove fringe (Craighead 1964). This process has resulted in formation of nearly one-fifth of the present land surface of Dade, Monroe, and Collier Counties within the last 4,000 to 5,000 years (Craighead 1971). Parker and others (1955) reported that Everglades organic soils began accumulating approximately 5,500 years ago. Long (1974a) estimated the south Florida flora to be 3,000 to

5,000 years old at most. The earliest dated south Florida archeological materials are about 3,500 years old (Griffin 1974), although human remains dating back over 10,000 years have been found at Warm Mineral Springs in Sarasota County (Clausen and others 1975).

The climate is subtropical with alternating wet and dry seasons. Average annual precipitation is between 45 and 65 inches (114 to 165 cm), depending upon location (Thomas 1974), and is characterized by wide annual fluctuations — from less than 30 to over 105 inches (76 to 267 cm) (Leach and others 1972). Between 70 and 80 percent of the rain generally falls during the May-to-October wet season. Average annual temperature is between 71° and 75° (22° to 24° C) (Thomas 1974), but below-freezing temperatures can be expected several times a year in the low-elevation interior glades. Frost can be expected in all south Florida counties about once every other year, but severe cold snaps — such as the one of January 19-20, 1977, when the temperature remained below freezing for more than 12 hours over much of the area — are very unusual and have an immediate and profound effect on the composition of plant and animal communities.[1]

The topography is flat; virtually all land is less than 25 feet (7.6 meters) above mean sea level. Slope averages about 0.2 ft/mile (0.038 m/km) from north to south. Historically, elevation changes of several inches made the difference between being flooded during the summer wet-season and being flooded throughout the year. In general, the soils occupying relatively high ground are sands or exposed limestone, while those submerged several months or more are peats, mucks, marls, or muds.

The process of lumping related vegetative associations for ease of discussion proved to be no easy task. The flora of south Florida is comprised of approximately 1,650 indigenous and naturalized species, of which about 60 percent are of tropical origin (Long and Lakela 1971). About 4 percent of this flora is endemic to south Florida. This percentage is rather small, compared to that of West Indian islands such as Cuba (50 percent endemism) and Jamaica (27 percent endemism).[2] According to Long (1974a), 75 south Florida plant communities have been described. Two commonly used classifications (Davis 1943a and Craighead 1971) each delineate more than 60 plant associations. Of the thousands of species of ferns and flowering plants that have been introduced, over 170 have naturalized in southeastern Florida alone (Austin 1978). According to Long (1974b), almost 16 percent of the flora of Collier, Dade, and Monroe Counties is exotic. Several of these species are becoming major components of various communities, or are forming pure stands. Thus, exotics considerably increase the number of associations present. Because fire is so common in south Florida, virtually all terrestrial plant associations have been affected by it. The effects of fire

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[1] For more detailed descriptions of the physiographic and environmental factors that influence vegetative succession in south Florida, see Alexander and Crook 1973; Craighead 1971; Gleason 1974; and Robertson 1953, 1955.

[2] Avery, G., and L. Loope. 1978 [Data on file at Everglades Natl. Park, Homestead, Fla.]

on many of these communities, however, are unknown. Moreover, it would probably be impossible to find examples of a majority of these plant associations that are not responding to other pressures, such as hydroperiod changes. Thus, that portion of the total response attributable to fire could not be separated out.

The process of combining or eliminating communities to reach a more manageable number ended with our selection of 10 broad vegetative associations that: (1) reflect the physiographic features of the area, and (2) are easily recognizable by their structure and prominent indicator species. They are: sawgrass; wet prairie and slough; marsh and marl prairies; saltmarsh; pine flatwoods; Miami Rock Ridge pineland; tree islands, including Miami Rock Ridge hammocks; cypress; mixed-hardwood swamps; and mangroves. Long and Lakela (1971) recognize five major physiographic provinces in south Florida into which our 10 vegetative communities can be rather conveniently grouped: (1) the Everglades which contain our sawgrass, wet prairie and slough, tree island, and marsh and marl prairie associations, (2) the Sandy Flatlands which are the equivalent of our pine flatwoods association, (3) the Big Cypress Swamp which includes our cypress, and mixed-hardwood swamp associations along with some pine, wet prairie, and marsh vegetation, (4) the Atlantic Coastal Ridge, the southern part of which corresponds to our Miami Rock Ridge pine association (we have excluded the northern portion of the Atlantic Coastal Ridge from our discussion.), (5) the Coastal Marshes and Mangrove Swamps which contain our saltmarsh and mangrove plant communities. These physiographic areas are outlined in figure 2.

Other physiographic breakdowns exist. Craighead (1971), for example, divides south Florida into nine provinces — only one of which (the Big Cypress Swamp) has the same name in both systems. There is an acute need for natural science workers in south Florida to adopt a standard nomenclature for the physiographic areas of this region, so that future researchers will not have to contend with conflicts in terminology.

Although the range of longleaf pine (*Pinus palustris*)[1] extends into Lee County and an isolated pocket of sand pine (*P. clausa*) occurs in Collier County, both species are excluded from discussion. Neither do we include the coastal strand and dune vegetative type, although Richardson (1977) suggests that tire helps determine successional patterns there. We have also omitted the Atlantic Coastal Ridge from Miami north because it is now primarily urban. The vegetation of this area is described by Alexander and Crook (1975); Austin and others (1977); and Richardson (1977). Virtually nothing is said about the hammocks in the Big Cypress or farther west because information is not available.

Exotics such as melaleuca (***Melaleuca quinquenervia***), Brazilian pepper (***Schinus terebinthifolius***), and Australian pine (***Casuarina*** spp.) are now principal components of the arborescent vegetation in many locations. Lit-

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[1]Taxa primarily from Long and Lakela (1971) and updated through review by George Avery, Everglades Natl. Park.

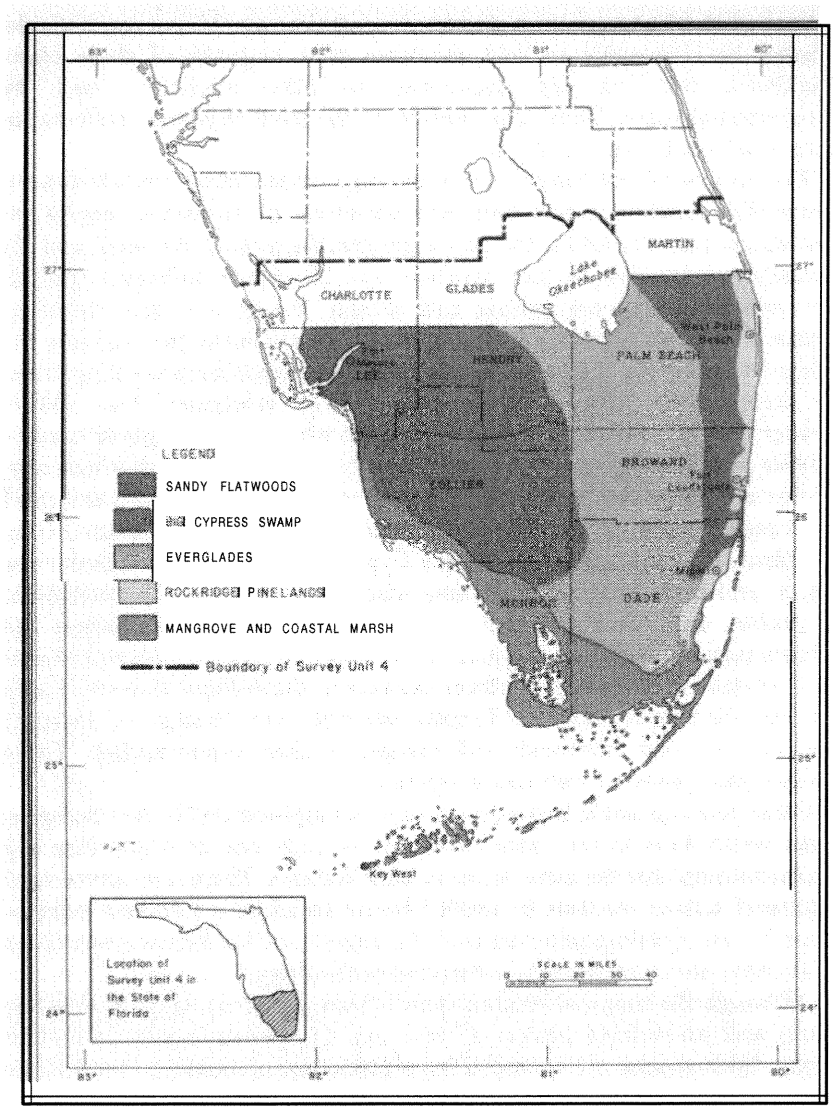

Figure 2. — Physiographic provinces of south Florida (after Parker 1974).

tle information concerning their management is available, however, and many purported facts are contradictory. Research by Egler (1952), Ewel and others (1976), Hofstetter (1976), Meskimen (1962), Myers (1975), and Woodall (1978) is beginning to provide reliable data on these species in south Florida. We do not consider these introduced species as separate communities in this paper. Instead, we discuss what is known about them as they occur in each of the 10 designated associations. Melaleuca, in particular, is having a major impact on fire management in south Florida. As dense stands of this species develop, south Florida resource managers are being faced, for the first time, with a vegetative type in which crown fires are common. Special safety procedures will be needed near urban areas and new fire prescriptions and control measures in rural areas (fig. 3).

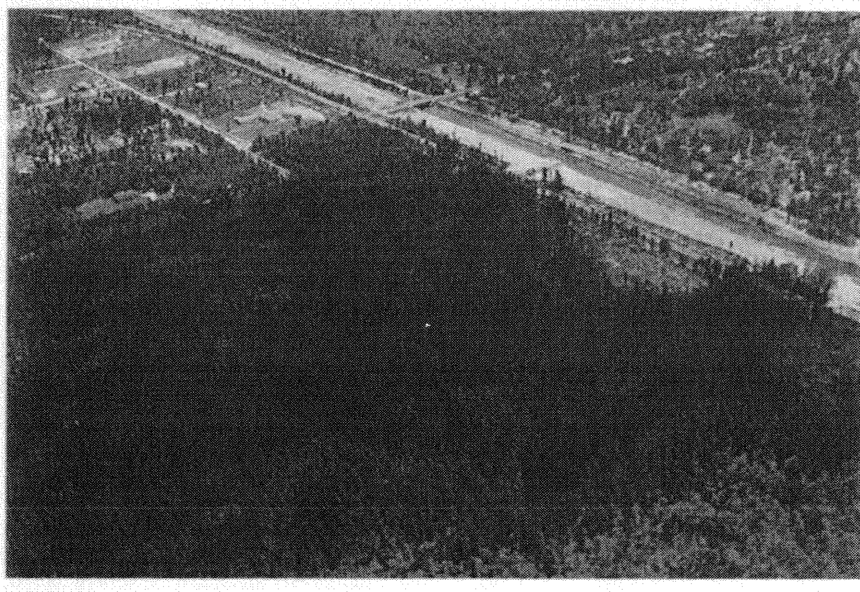

Figure 3. — A 650-acre wildfire in melaleuca adjacent to Ft. Myers, May 1977. The fire crowned through the black area. Note the drainage canal the fire jumped.

The interaction among water, fire, and frost created and maintained the diverse vegetative mosaic that greeted man upon his arrival to south Florida. Layers and pockets of charcoal frequently found in Everglades peat (Cohen 1974) show that drought-year fire has long been part of this system. Craighead (1971) radiocarbon dated these layers back to over 3,000 years. Parker (1974) found ash layers up to 2 inches (5 cm) thick and Davis (1943a) reported the recollections of Everglades District Drainage Engineer F. C. Elliott regarding ash layers 6 or more inches (15 cm) thick, uncovered during drainage canal excavation.

The vegetation itself offers further evidence of the long history of fire in south Florida. According to Robertson (1954), over 70 percent of the approximately 100 herbaceous and low-shrub species endemic to southeast Florida occur in communities now maintained by periodic fire. Robertson goes on to state that because species evolve slowly, some frequently recurring natural disturbance must have maintained suitable conditions for several thousands years. Robertson's observations indicate that most of the 50 or so species in the Miami Rock Ridge pinelands can be shaded out by encroaching hardwoods within 5 or 6 years if fire is excluded. Thus, without periodic tire, these pinelands would have long ago become hardwood hammock.

Adjacent to these pinelands, a vast marsh, commonly referred to as the "Glades," stretched over several thousands square miles. Although many marsh and prairie species were present, the visually dominant plant was sawgrass (*Cladium jamaicensis*). The combination of fire and flooding, occasionally at the same time, inhibited the invasion of woody species. Tree islands speckled the landscape, particularly in the southern portion of this marsh. To the west, sawgrass gave way first to other grasses and stunted cypress, locally called "hatrack" or "bottleneck" cypress, and then to an area interlaced with ponds and sloughs. Here a dense multitiered canopy developed, with cypress and swamp hardwoods forming the overstory except on those slightly higher areas subject to just brief flooding, which are easily identified by their pine overstory (fig. 4). This region was appropriately named "Big Cypress Swamp." The pine islands must have burned off regularly, but fire penetrated the surrounding swamps only during the most prolonged droughts. When fire did enter these low areas, the resistant cypress often survived as long as the underlying organic soil did not burn. On rare occasions when the soil did burn, all vegetation — including the cypress — fell in matchstick fashion as the soil supporting their root systems was consumed (fig. 5). The result was an open body of water within the stand.

North of the Big Cypress as well as to the east of Lake Okeechobee, the pine flatwoods occupied the slightly higher sandy soils and were subjected to

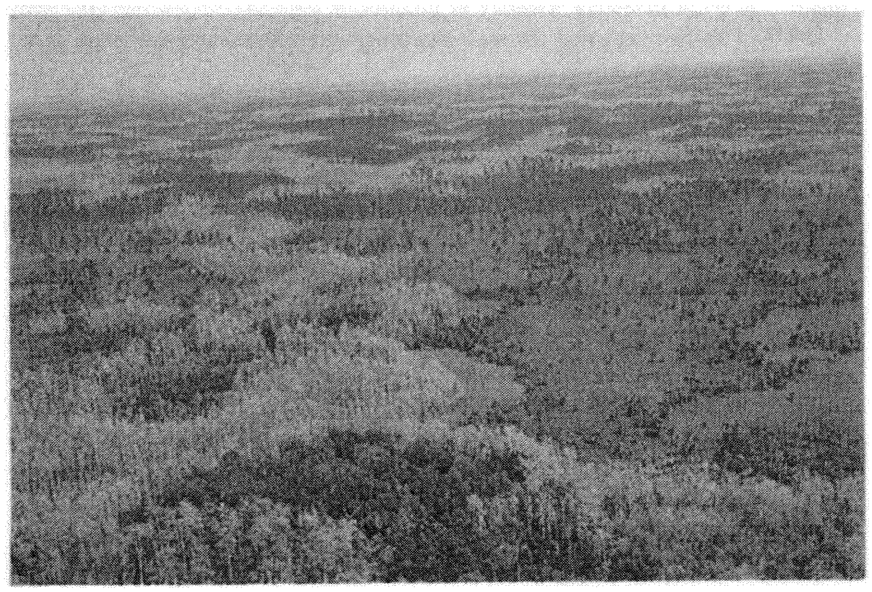

Figure 4. — Big Cypress vegetation. The gray areas are leafless (winter) cypress. Swamp hardwoods are in the center foreground, while pine islands dot the background. Tan-colored areas are prairies. Note the recent fire scars in the pine-cabbage palm savannas. Collier County.

Figure 5. — Aftermath of a summer organic soil fire in cypress. Fire began August 1973 and was extinguished by rain. Photo taken September 1973.

frequent fires. Throughout south Florida the vegetation was in dynamic balance; community boundaries oscillated back and forth, depending upon precipitation, the extent of lightning fires (fig. 6), and frost (fig. 7) during a given year. Many of the soil cores taken by Craighead (1971) had several alternating bands of marl and peat within the top 6 feet (1.8 m), suggesting climatic cycles of 100 years or more. Hurricanes were an additional force, particularly near the coast where they periodically recycled the mangrove forests (fig. 8).

When white people first penetrated south Florida, they found the Indians using fire for a variety of purposes and quickly adopted the practice themselves (Givens 1962; Robertson 1954; Small 1929). Nevertheless, man's presence remained unobtrusive until near the end of the 19th century, when elaborate plans to drain and reclaim the southern part of the State for agricultural development were initiated (see figure 1A). This large-scale drainage of the Everglades and associated vegetative types has produced several side effects. Except during drought years, water levels were historically at or above the ground surface on all but the higher pinelands when the intense thunderstorm activity began each summer (Parker 1974). Now, it is increasingly common to find the organic soil dry enough to burn, well before the beginning of this season of frequent lightning. The increased length and severity of the dry season, along with man's incendiary activities, have resulted in more destructive wildfires and higher fire-control costs. Under these conditions, fires consume vast amounts of organic soil and kill the root systems of most fire-adapted plants -as well as fire-sensitive species (fig. 9).

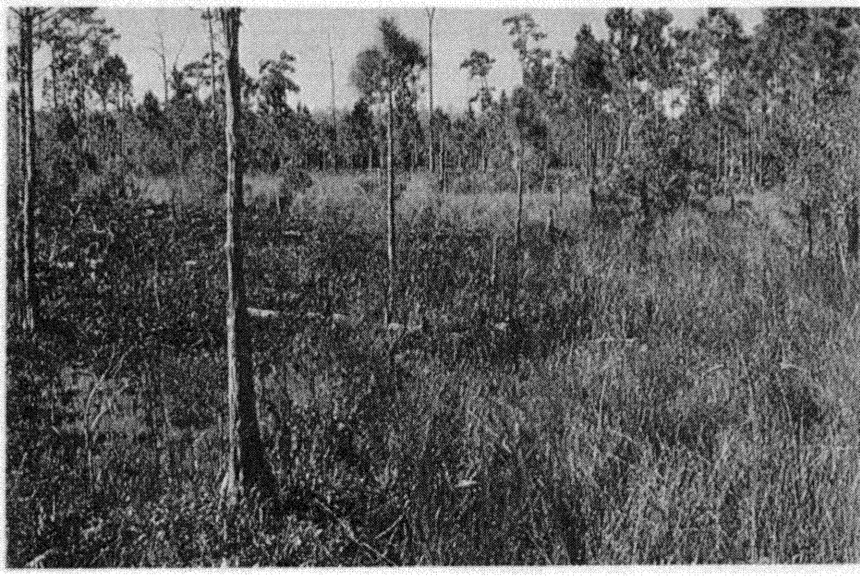

Figure 6. — A wet-season lightning tire in the pine flatwoods that went out because of the lack of dry fuel; much as happened historically. Collier County.

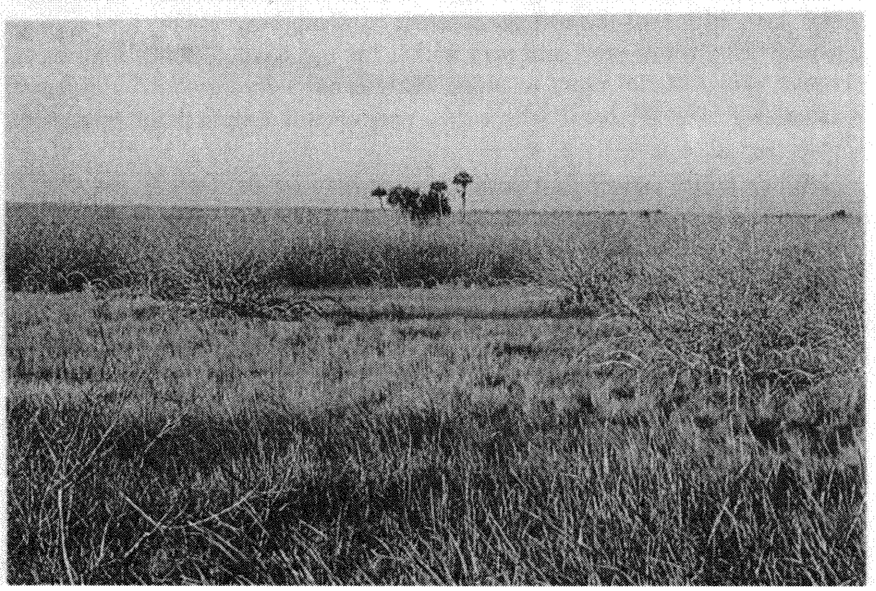

Figure 7. — Red mangrove top-killed by the severe cold snap of January 1977. The cabbage palm were not damaged. Collier County.

Figure 8. — Snags from a past hurricane stand watch over the mangrove regrowth and suggest the destructive potential of these storms. Everglades National Park.

Figure 9. — A burning pine trunk, Ingraham fire, Everglades National Park.

These fires destroy the very resource the land was drained to reclaim. Robertson (1953) reported that widespread and severe fires plagued south Florida during more than one-third of the years between 1900 and 1952.[6] During very dry years, organic-soil fires occasionally burned from one dry season to the next — right through the normally wet summer months (Bender 1943; Dovell 1942; and Small 1921). Based on the 1937 report of the Governor's Commission on the Conservation of Florida's Natural Resources, Hanson (1939) estimated that $40 million worth of land within the Everglades Drainage District was no longer suitable for agriculture because fires had consumed the organic soils. We, however, know of no land that has been removed from agricultural use for this reason. As new roads made the vast interior wilderness more accessible and as drainage progressed (see figure 1), the fire situation continued to worsen (fig. 10). In the seven counties of south Florida, more than 530,000 acres (214,500 hectares) per year burned during 1969 through 1971. This area contained 12 percent of the land burned by wildfire in the United States during that period (USDA FS 1970, 1971, 1972).

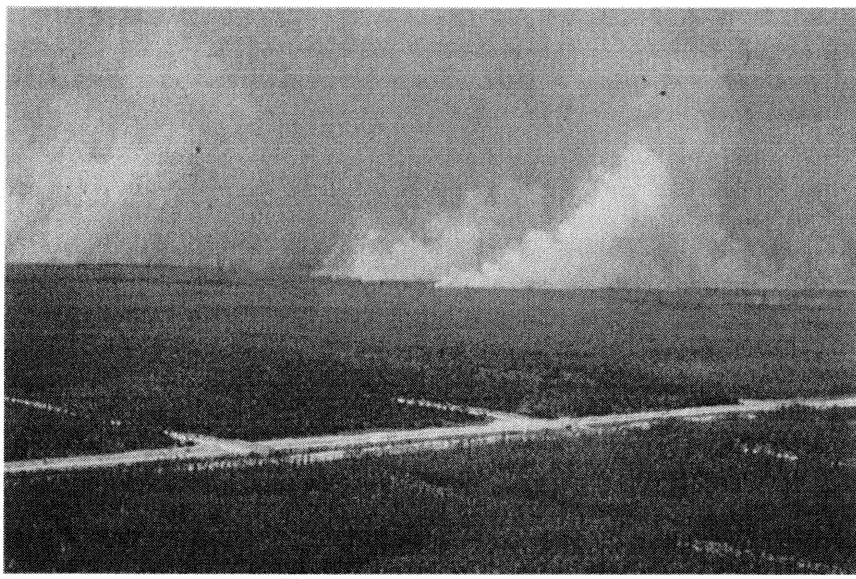

Figure 10. — Drought-year wildfires in Golden Gate Estates, a 200-square mile (518 km²) tract in Collier County that was drained and subdivided by 800 miles (1287 km) of road.

In response to these losses, organized fire protection was extended to all of south Florida in 1971, when the Florida Division of Forestry was given fire-control responsibility for all non-Federal land in Monroe and

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[6] Readers interested in a chronology of fires in southeast Florida between 1900 and 1952 are referred to Robertson (1953, p. 93-99).

Collier Counties. Burned acreages continued to be very high, however, because annual rainfall deficits which began in 1970 continued through 1977. During 1972 through 1976, Florida accounted for 14 percent of the fires in the 13 Southern States but sustained 32 percent of the protected area burned (USDA FS 1973, 1974, 1975, 1976b, 1977). In severe-drought years, fire losses continued to assume national importance. In 1974, 8 percent of all land burned in the United States was south of Lake Okeechobee and in 1975, 9 percent.

These statistics do not imply shortcomings in fire protection. They simply underscore the fact that the climate and the vegetation of south Florida, coupled with the area's elaborate system of drainage ditches and canals, have created one of the highest fire potentials in the United States. Abundant summer rainfall (even during extremely dry years) and warm temperatures from May through October promote a rank buildup of fuel that becomes explosive during the 6- to 8-month dry season.

The suppression workload in these fuels is enormous. There are more days with lightning recorded in south Florida than elsewhere in the Nation. Over 6,000 lightning strikes were recorded in inland south Florida during one 6-hour period in the summer of 1976.[1] Much of the area is relatively inaccessible to fire-suppression equipment (fig. 11). Many of the fuels make excellent short-distance firebrands. The more than 29 million tourists annually hosted by Florida and the increased leisure time of its year-round inhabitants both dramatically increase the risk of ignition.

Figure 11. — An all-terrain vehicle attempting to cross an area of exposed limestone, Dade County.

[1]Maier, Michael. 1978. Personal communication. Natl. Hurricane and Exp. Meteorol. Lab., Coral Gables, Fla.

Moreover, many south Florida residents believe the Everglades must burn for a variety of reasons. They see fire suppression conflicting with their objectives. Arson, the largest single cause of fire in the area, accounted for 58 percent of the 553,000 acres (223,800 hectares) burned during 1972 through 1975.

City dwellers object primarily to the reduction in air quality, associated with these fires; a substantial segment of the population simply wants clear skies (lig. 12). Further, because of the large number of retired people in south Florida, a rather high proportion of the population suffers from respiratory difficulties, many of which are aggravated by smoke. Organic soil smoke is especially noxious, sometimes necessitating evacuating residents of nearby homes. Decreased visibility along highways has caused numerous traffic accidents. Smoke during the 1971 drought drastically reduced aircraft operations at Palm Beach International Airport (Williams 1972).

Figure 12. — Smoke pall from Gotcha wildfire near Pinecrest about 40 miles west of Miami, April 1971.

Other detrimental fire effects include consumption of organic soil, damage to vegetation, impact on esthetics, damage to wildlife and wildlife habitat, creation of site conditions favorable for invasion of exotic species, long-term scars and changes in drainage resulting from certain tire-suppression tactics, and destruction of homes and other improvements. The Florida Division of Forestry estimated that fire damage to vehicles, equipment, buildings, and other improvements in south Florida exceeded $960,000 during the 1974 drought year and averaged about $380,000 the following 2 years. Fire-suppression costs are not included in these figures.

Although fire can be very destructive, it is also a natural process with many vital functions. The following list, based on one given by Wright and Heinselman (1973), was modified to make it more relevant to south Florida:

A. Fire influences the physical-chemical environment by:
   1. Directly releasing mineral elements as ash
   2. Indirectly releasing elements by increasing decomposition rates
   3. Volatilizing some nutrients
   4. Reducing plant cover and thereby increasing insolation
   5. Changing soil temperatures because of increased insolation

B. Fire regulates dry-matter production and accumulation by:
   1. Recycling the stems, foliage, bark, and wood of plants
   2. Consuming litter, humus layers, and occasionally increments of organic soil
   3. Creating a large reservoir of dead organic matter by killing but not consuming vegetation
   4. Usually stimulating increased net primary production

C. Fire controls plant species and communities by:
   1. Triggering the release of seeds
   2. Altering seedbeds
   3. Temporarily eliminating or reducing competition for moisture, nutrients, heat, and light
   4. Stimulating vegetative reproduction of top-killed plants
   5. Stimulating the flowering and fruiting of many shrubs and herbs
   6. Selectively eliminating components of a plant community
   7. Influencing community composition and successional stage through its frequency and/or intensity

D. Fire determines wildlife habitat patterns and populations by:
   1. Usually increasing the amount, availability, and palatability of foods for herbivores
   2. Regulating yields of nut and berry-producing plants, such as runner oak
   3. Regulating insect populations which are important food sources for many birds
   4. Controlling the scale of the total vegetative mosaic through fire size, intensity, and frequency
   5. Regulating macrovertebrate and small-fish populations.

E. Fire influences insects, parasites, fungi, etc., by:
   1. Regulating the total vegetative mosaic and the age structure of individual stands within it
   2. Sanitizing plants against pathogens such as brownspot on longleaf pine
   3. Producing charcoal which can stimulate ectomycorrhizae

Fire also regulates the numbers and kinds of soil organisms; affects evapotranspiration patterns and surface waterflow; changes the accessibility through, and esthetic appeal of, an area; and releases combustion products into the atmosphere.

Many of these processes and functions can be influenced by regulating the intensity and timing of a fire. Fires can be set at specified intervals during particular physiological stages of plant growth under selected fuel and weather conditions.

In many areas of the world, including the Southeastern United States, resource managers have found that the benefits from the judicious use of prescribed fire far outweigh any disadvantages. In fact, fire is believed to be the only practical method of achieving some resource management objectives. Prescribed fire was authorized for silvicultural and range-management purposes on over 390,000 acres (157,800 hectares) per year in the seven south Florida counties between 1975 and 1977.

The large acreage burned by prescription does not mean that this tool is easy to use, nor does it imply that there are no deleterious side effects. It does, however, suggest that prescribed burning is economical in comparison to other alternatives. Figures from the Everglades National Park and the National Forests in Florida indicate that the current cost of prescription burns in south Florida seldom exceeds $2 per acre ($5/ha). Often, the cost is only a fraction of this amount. For example, the State burned 13,000 acres of high-hazard fuels, by prescription, in Collier County during the 1977-78 dry season for less than 50¢ per acre (Wade and Long 1979).

In the future, the justifications to use fire, and the prescriptions to carry out this burning, will be more fully scrutinized. Renewed interest is being focused on the remaining wild lands in south Florida. Increased emphasis on the quality of the environment and changes in the relative value assigned various management alternatives are shifting priorities. These developments necessitate a reevaluation of resource management objectives and the techniques used to achieve them. The probability of unplanned events such as wildfire, and their potential impact upon resource management plans, must be an integral part of this reevaluation.

From a fire standpoint, managers have four basic alternatives: (1) use prescribed fire to achieve one or more clearly defined objectives and attempt to control all unwanted fires, (2) let all fires burn with the chance combination of an ignition source and a receptive fuel complex determining the time, place, and intensity of the resulting fire, (3) attempt to exclude all fire, or (4) some combination of choices 1 through 3.

These four alternatives must be carefully evaluated under a variety of circumstances. A large percentage of the fires in south Florida are caused by arsonists and lightning. There is no reason to expect a long-term decrease in the number of fires from either of these causes under alternatives 2 or 3. To the contrary, an increase in ignition from both sources is anticipated. Vegetation growing on wet sites is relatively safe from damaging fires except during droughts, but it is at precisely this time that fire-suppression forces are most likely to be overextended and thus least able to mount a successful intitial attack.

A different problem exists in most plant communities that have been burned at frequent intervals before an attempt is made to exclude fire. Here suppression is very effective at first because of the lack of fuel. But, over time, fuels accumulate and fires that do start will burn hotter and require more effort to stop. This accumulation will continue until an equilibrium is reached between production and decomposition. Thus, more money will have to be allocated to fire suppression each year to ensure that the capabilities of the fire-control organization keep pace with the increasingly hazardous fuel conditions. If unchecked, costs may eventually reach the point where they exceed the values at risk. If protection costs are held constant, the level of protection provided will decrease as the probability of a destructive fire increases. The costs of providing the same degree of protection over time for an ecosystem depend upon several factors. In *Muhlenbergia* prairie, the balance between fuel accumulation and decomposition can be reached in as little as 3 years,[1] but in the majority of communities, fuel continues to increase far longer, particularly as species composition changes. In many communities, especially mixed-hardwood and cypress swamps, protection costs are less in wet years than in dry years. Although fewer acres generally burn during wet years, the additional precipitation accelerates growth, increasing the fuel loads that have to be contended with when the area does dry.

The resource manager's dilemma in plant communities that develop and survive because of periodic fire is that species composition will change in the absence of fire. Furthermore,- if fire is excluded until fuel concentrations are very high, even fire-adapted species are likely to be killed by an intense wildfire. The resulting changes in vegetation and wildlife habitat may not be in keeping with stated resource management objectives.

The next section is devoted to clarifying what is known about fire effects in 10 major south Florida vegetative communities. But, even before considering management objectives, one needs to determine if existing plant associations will be present in the near future. Assessment of an ecosystem's ability to cope with current and predicted alteration of its environment should help in reaching a decision. Egler (1952, p. 227) contended that "the herbaceous Everglades and the surrounding pinelands were born in fires; that they can survive only with fires; that they are dying today because of fires." Alexander and Crook (1973, 1975, p. 824) reported vegetative changes over the last 16 to 30 years on 100 mile-square quadrats located throughout south Florida. They found changes were variable, but that fire, with severity related to drainage, was responsible for the more drastic changes. They concluded, "Unless a way is found to return and properly distribute more water to the wild habitats, control exotic plants and animals, and manage fire in some meaningful way, the natural ecosystem will con-

[1] Werner, Harold W. 1979. Personal correspondence. U.S. Dep. Inter., Natl. Park Serv., Carlsbad Natl. Park. On file at Southern Forest Fire Lab., Macon, Ga.

tinue to lose its diversity and ability to maintain itself in any resemblance to the pre-1940 condition."

Exotic species, urban expansion, nutrient enrichment, changed fire frequency or intensity, and water table/hydroperiod modification are all agents of vegetative change. Both the likelihood that one of these "threats" will occur over an extensive area of a vegetative type and the severity of impact are ranked by vegetative type (table 1). Changes in one factor can produce changes in another, often resulting in a synergistic effect. Examination of this table shows that the freshwater hydroperiod is expected to decrease throughout the wetlands of south Florida. This reduction will trigger changes both in plant community boundaries and in species composition. In some plant associations, such as the Everglades Tree Island vegetative type, these consequences will be secondary to the effects of other threats, such as increasing fire frequency as the hydroperiod is decreased.
It can be seen, however, that the most disastrous impacts are from increased fire intensity. Intensity is increased by consuming more fuel per unit of time which, in turn, is one of the characteristics of those fires that burn in areas managed under a fire-exclusion policy.

The utility of a fire management plan will be greatly enhanced if it reflects anticipated ecosystem changes. For example, there is little value in formulating a detailed fire plan designed to perpetuate a plant community that is vanishing because of other, overriding circumstances. Conversely, lack of an adequate fire management plan, or implementation of one based on ignorance or misinformation, can lead directly to the rapid demise of a vegetative association which the resource manager wanted to perpetuate.

In a fire climate such as south Florida's, the importance of integrating fire planning into the land management planning process cannot be overemphasized. Ultimate attainment of resource management objectives is dependent upon the success of the fire management system. If fire policy is in conflict with these overall goals, their fulfillment is likely to be impossible.

Table 1. — Rank and severity of various change-elements upon major south Florida vegetative types

Vegetative type	Changed land use		Exotic species invasion		Wildfire increased periodicity		Wildfire increased intensity (drought conditions)		Hydroperiod reduction		Nutrient enrichment	
	Rank	Severity	Rank	Severity	Rank	Severity	Rank	Severity	Rank	Severity	Rank	Severity
Sawgrass	3	2	3	2	4	3	2	1	1	1	4	3
Wet prairies and sloughs	4	2	3	3	3	3	3	3	1	2	3	3
Freshwater marsh and marl prairies	1	1	2	2	4	3	2	2	1	2	5	3
Saltmarsh	5	2	5	3	3	3	5	3	2	2	5	?
Mangrove	5	3	5	3	5	1	5	1	5	3	5	?
Mixed-hardwood swamps	4	2	4	2	2	1	2	1	1	2	4	?
Cypress:												
Strands/domes	4	2	2	1	2	2	1	1	1	2	4	?
Dwarf	3	2	3	3	2	3	2	1	1	2	5	?
Tree islands:												
Bayheads	3	2	3	3	2	2	1	1	3	3	NA	NA
Rock Ridge hammocks	1	2	3	3	3	2	3	1	NA	NA	NA	NA
Pine flatwoods	1	2	2	2	4	3	3	2	NA	NA	NA	NA
Miami Rock Ridge pineland	1	1	3	3	3	3	3	2	NA	NA	NA	NA

Rank: The likeihood of the change occurring, with 1 being most and 5 least likely.
Severity: The severity of the change if it does occur, with 1 being most and 3 least severe.
NA: Not applicable.

SAWGRASS

Sawgrass *(Cladium jamaicensis)*,[9] a member of the sedge family and not a true grass, is the dominant plant in the Everglades. It once covered approximately 2 million acres (0.8 million hectares) (Stephens 1974) and accounted for about two-thirds of the total plant cover in the region (Loveless 1959a).

Sawgrass attains its best development on deep organic soils with long hydroperiods in the central Everglades. Under such conditions it can form pure, dense stands more than 10 feet (3 meters) tall, with a standing crop in excess of 25,000 lbs (dry weight) per acre (28,000 kg/ha) (Hofstetter and Parsons 1975; Hofstetter 1976).

More extensive than these pure, dense stands, however, are vast areas occupied by sawgrass growing with other plants, such as arrowhead *(Sagittaria lancifolia)* and maidencane *(Panicum hemitomon)*. In areas where the surface water is a little deeper and the hydroperiod longer, wet prairie and slough species dominate with pure sawgrass confined to isolated strands. The transition between these communities is usually abrupt (fig. 13). Sawgrass is often a major component of the drier marsh prairies on marl soils as well as of brackish water marshes. A band of sawgrass commonly encircles tree islands throughout the Everglades (fig. 14). In the lower Everglades, tails of the numerous teardrop-shaped tree islands are usually accentuated by robust sawgrass stands intermixed with species such

Figure 13. — Typical-sharp transition between a sawgrass and wet prairie community of spike rush and pickerelweed. Everglades National Park.

[9]Formerly called *Caldium effium* and *Mariscus jamaicensis.*

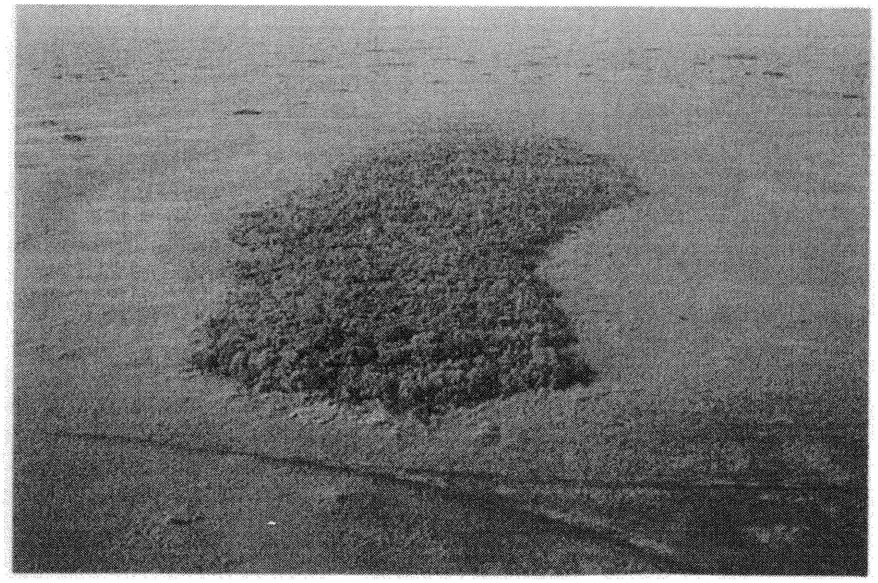

Figure 14. — Sawgrass margin and tail surrounding a tree island. A hardwood hammock can be seen at the upstream end of the island just behind the exposed limestone and airboat trails. Everglades National Park.

as willow (*Salix* ***caroliniana),*** buttonbush ***(Cephalanthus occidentalis),*** red bay (*Persea* ***borbonia),*** elderberry ***(Sambucus simpsonii),*** and royal fern ***(Osmunda regalis).*** In fact, because sawgrass can tolerate a wide range of edaphic and hydrologic conditions, it can be found in virtually every plant community in southern Florida, albeit in many cases simply as a remnant of past stands that once occupied the site.

What are some of the characteristics of sawgrass which enable it to so effectively dominate the vegetation over such a large portion of south Florida? It can tolerate very prolonged flooding in nutrient-poor and oxygen-poor waters. Unlike most plants, sawgrass does not have mycorrhizal fungi associated with its roots. These fungi are necessary for nutrient uptake in many species, and plants which have them may have a competitive advantage over those which do not. However, mycorrhizal fungi require oxygen, so they are seldom found in poorly aerated soils, such as those of the Everglades. Sawgrass compensates for its nonmycorrhizal handicap by having exceptionally low nutrient requirements (Steward and Ornes 1975b) plus the ability to accumulate P and K far in excess of its own needs (Alexander 1971; Steward and Ornes 1973, 1975b). Thus, it reduces the amounts available to competing plants. Even though it is nonmycorrhizal, its roots require oxygen, which is transported to the roots through airspaces in both the living and dead leaves (Conway 1936, 1937; Forthman 1973; Parsons 1977). Sawgrass can survive complete submergence for about 6 weeks

(Lynch 1942). Florida Game and Fresh Water Fish Commission personnel[19] burned sawgrass plots weekly on a rising water table during the summer of 1978. The minimum submergence time of 8 weeks that they encountered did, in fact, result in 100 percent kill.

The sites occupied by sawgrass are not always flooded however. In addition to being well adapted to flooded soils, any plant which dominates in the Everglades must also tolerate a second extremely important natural environment variable: fire. Sawgrass fills the bill. Except when flowering, the growing points (meristems) of its leaves and upright stems (culms) are buried in the top of the horizontal stem (rhizome) and are surrounded by tightly overlapping leaf bases, with the youngest toward the center (fig. 15). These meristems are usually at or just above the soil surface. As long as the soil surface is damp, the attached dead leaves act as wicks, keeping the bases of the culms damp and protecting the meristems from the heat of a fire. If the soil is flooded, burning stops several inches above the water surface. The outer leaves tend to burn somewhat lower, forming a cone that tapers upward to a point (fig. 16). The lower the surface water or the drier the soil, the less unburned portion of the plant remains and the greater the

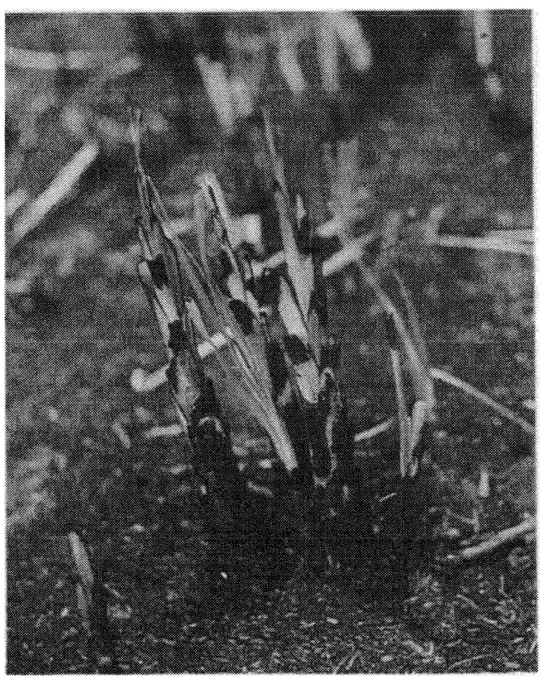

Figure 15. — Sawgrass culms 1 week after a May 1977 tire showing leaf bases, regrowth, and some heat-killed meristems. Hendry County.

[19]Schortemeyer, James. 1979. Personal conversation. Fla. Game and Fresh Water Fish Comm., Dist. Off., Ft. Lauderdale, Fla.

Figure 16. — Sawgrass culms and unburned litter after a headfire swept the area, March 1975. The metal sampling frame encompasses a quarter milacre. Conservation Area 3A.

chance of the meristem being killed by heat (Forthman 1973; Hofstetter and Parsons 1975; Werner 1975). When the soil surface is exposed, the heat from a fire will occasionally kill some meristems even though the older protecting leaf bases are not all consumed (see figure 15).

Sawgrass regrowth after a burn is very fast, in part because it can tap the food reserves of the rhizome rather than depending upon slower and more precarious reproduction from seed. This rapid recovery enables it to recapture a site quickly, shading out other pioneer species which might germinate. This fast growth rate also helps sawgrass to keep pace with any rise in surface-water levels. Forthman (1973), for example, measured a IO-inch (25 cm) rise in surface-water level within 3 weeks after burning, but noted that sawgrass regrowth was even faster.

Sawgrass not only tolerates fire, it thrives on it. Mutch (1970) hypothesized that natural selection has favored the development of survival mechanisms that make species which evolved in the presence of repeated fire more flammable and thus preconditioned to burn more often than others. Sawgrass tits these criteria well (fig. 17). It is easy to ignite and burns hot, even with a foot or more of water overthesoilsurface(see figure 12) and within hours after a rain. Sawgrass leaves have a high surface-area-to-volume ratio, which means their moisture content quickly responds to changes in atmospheric relative humidity. Its leaf arrangement is like that of kindling on a campfire-leaves are close enough together to heat each other rapidly and conduct flames from leaf to leaf, yet not so close as to inhibit good airflow. The leaves die from the tip back, curling over and ac-

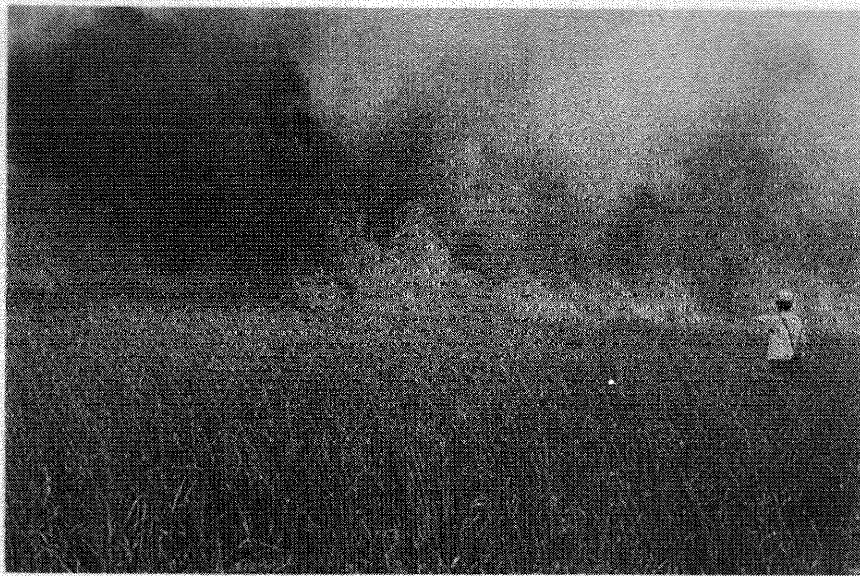

Figure 17. — Prescribed fire in sawgrass at the begining of the dry season. Note the flame length and intensity of the fire and the surface water in the foreground. Everglades National Park.

cumulating in a loosely tangled mass intermixed with the live leaves. The leaves have a high percentage of aerenchyma (tissue with large intercellular airspaces), which enhances combustion. Moreover, the chemical composition of sawgrass is conducive to rapid burning. Lindenmuth and Davis (1973) found that PO, concentrations of less than 0.235 percent in tissue appreciably increase rate of fire spread-sawgrass values are lower by at least a factor of 7.

Thus, sawgrass possesses almost unique characteristics which adapt it to sites which are nutrient poor, flooded for long periods (and, therefore, poor in oxygen), and subjected to frequent fires. These are the conditions which prevail over vast areas in the Everglades and account for the success and importance of sawgrass in south Florida.

RECENT SAWGRASS DECLINE

Although sawgrass is still the most extensive plant community in south Florida, it occupies substantially less area than it did 100 years ago. This decline primarily reflects human manipulation of water levels and fire (Craighead 1971). In some cases, sawgrass has declined because water levels have been dropped by draining and diking, which are often associated with increased frequency and intensity of fire. In other cases, sawgrass has suffered because hydroperiods have been artificially extended and/or water levels have been increased. Finally, there are many cases-especially noticeable in the 1970's—in which sawgrass has declined markedly, for unknown reasons (fig. 18).

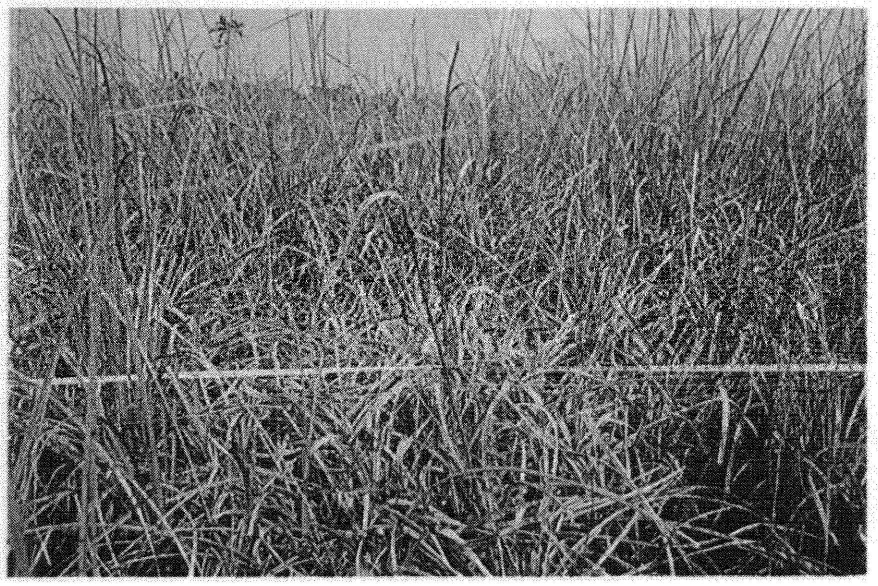

Figure 18. — Decadent sawgrass, Shark River Slough, Everglades National Park.

Considerable acreage of sawgrass has been lost on the higher elevations in what are now the Conservation Areas because of reduced water levels and shortened hydroperiods (Egler 1952; Craighead 1971; Alexander and Crook 1973, 1975). There, sawgrass has been replaced by drier-site species such as wax myrtle (*Myrica* ***ceriferu***), saltbush (*Baccharis* spp.), plume grass ***(Erianthus giganteus)*** muhly grass (***Muhlenbergia*** spp.), marsh fleabane (***Pluchea*** spp.), fennels (***Eupatorium*** spp.), and hemp vine (*Mikania* spp.) (fig. 19).

In the early 1950's, muhly grass was rare in Taylor Slough, Everglades National Park, but it has steadily replaced sawgrass in response to the lowered water table until it is now probably the most common plant there.

The shortened hydroperiod increases in the time when muck and peat are exposed to ground fires that also consume sawgrass rhizomes and roots (fig. 20). Thus, sawgrass has to reinvade these areas by vegetative propagation or seeding, both of which are slow processes. Numerous seedlings can become established on these sites when the soil is damp, but they die during the ensuing dry season unless it is unusually wet (Craighead 1971). If an area stays wet, sawgrass can again form rank stands within 4 or 5 years.[11] Shallow-burning ground fires result in sawgrass replacement by weedy annuals and perennials such as fennel, primrose willow ***(Ludwigia peruviana)***, water hemp (*Amaranthus cannabinus*), cattail (*Typha* spp.), willow, elderberry, alligator flag ***(Thalia*** *geniculata*), and buttonbush (fig. 21). Deep-burning organic soil fires have exposed the underlying bedrock or marl soil

[11] Schortemeyer, James. 1979. Personal conversation. Fla. Game and Fresh Water Comm., Dist. Off., Ft. Lauderdale, Fla.

Figure 19. — Sawgrass communities being displaced by Andropogon, south end of L-31 canal, Everglades National Park.

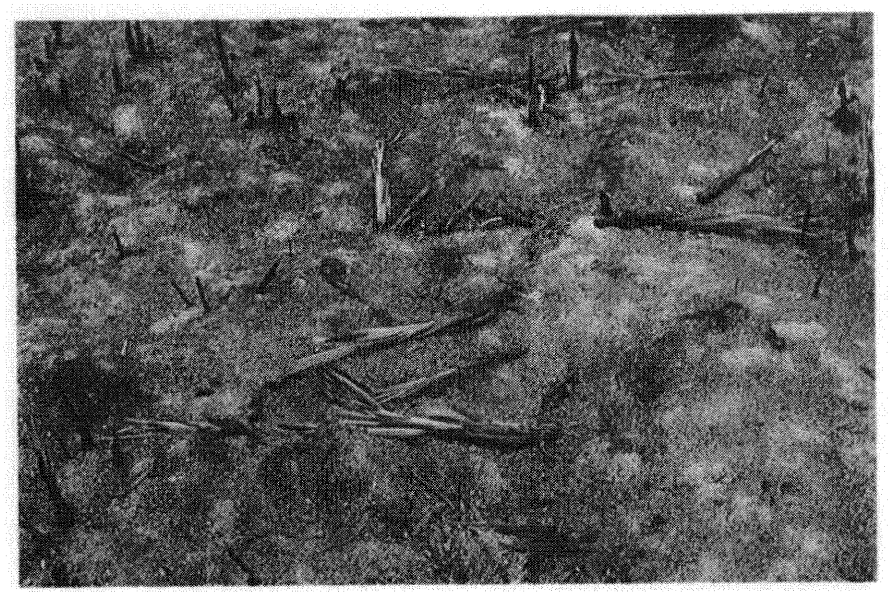

Figure 20. — Fire-killed sawgrass on a shallow peat burn, Everglades National Park, May 1974.

in numerous locations, creating wet-season ponds that fill with aquatic plants.

Figure 21. — Fennel and golden ragwort *(Senecio glabellus)* invading a former sawgrass community following an organic soil fire.

The slowly rising sea level (Scholl and Stuiver 1967), combined with reduced freshwater flow and head, has allowed salt and brackish water to move farther inland, especially during the dry season. This process has decreased sawgrass stature and area at the southern end of the Everglades. Here, the sawgrass is being replaced by saltmarsh species and mangroves (Alexander and Crook 1975; Craighead 1971; Egler 1952) (fig. 22).

Where the water table has been artificially held at a higher level for longer periods of time, such as the downstream ends of the Conservation Areas, sawgrass, beak rush ***(Rhynchospora*** spp.), and maidencane have given way to other wet prairie and slough species. The hardwood components of tree islands in these areas are dying and being replaced by sawgrass, but overall the sawgrass is suffering a net loss in area occupied.

Where surface waters are deep and annual fluctuations of the water table are not great, sawgrass develops structures called tussocks (cylindrical mounds of undecayed leaf bases), roots, and rhizomes (fig. 23). The meristematic zone is on top of this mound and is well above the soil surface (Yates 1974). If tussocks are present, their meristems are likely to be damaged by fire because of their increased exposure.

Between 1972 and 1977, the stature and density of sawgrass mysteriously deteriorated throughout the Everglades, especially in once-vigorous pure stands. Some sawgrass stands that in 197 1 were so dense and tall that penetration on foot was laborious, and seeing over them was impossible, could be traversed with little difficulty in 1976, and visibility was unimpeded. Patches of previously robust sawgrass became open water or

Figure 22. — Sawgrass being invaded by buttonwood along Flamingo road. Everglades National Park.

Figure 23. — Sawgrass tussocks, Everglades National Park.

exposed bare peat, with only decaying sawgrass stubble reflecting the past vegetation (fig. 24). Werner (1975) noted entire strands in the Shark River Slough system that had died in less than 2 years except for a narrow fringe around the edge.

Discussions with long-time users and researchers failed to turn up any recollections of similar conditions prior to 1972, nor was any reference found in the historical literature. Several possible explanations have been suggested however. Craighead (197 1) attributed the decline of sawgrass in wet prairies to burning of the deep peat, upon which sawgrass grows best. Just as too much of the wrong kind of fire may be detrimental to sawgrass, so might too little fire. Forthman (1973) suggested that sawgrass decadence may simply be the result of an excessive accumulation of its own litter, such as occurs in many grass communities (Launchbaugh 1973; Old 1969; Van Rensburg 1972). Werner (1975) studied the effects of fire on decadent sawgrass strands in the Shark River Valley. He found that burning stimulated the recovery of these strands, resulting in a general (although not significant) increase in sawgrass propagation (fig. 25). He burned each month from October through April and found the best regrowth occurred after his January and February fires.

Insect attack is another possibility. Valentine (1964, in Yates 1974, p. 112) reported an extensive sawgrass dieback in Louisiana which was caused by insects, but there is no strong evidence of such depredation in the Everglades.

The extremely wet years of 1968, 1969, and spring 1970, followed by the severe drought that began in the summer of 1970 and continued through 1971, may also have been a major contributor to this widespread sawgrass decadence.

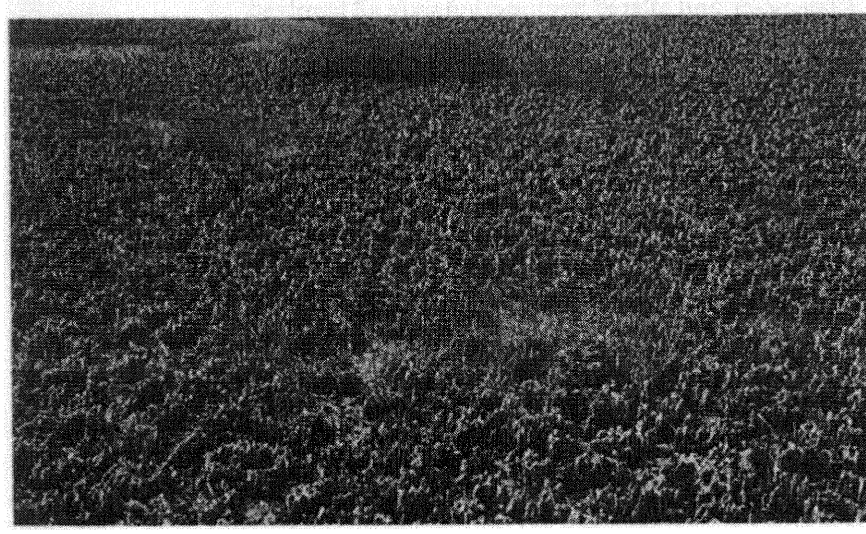

Figure 24. — Dead sawgrass and suspended algal mat during the dry season, northeast corner of Conservation Area 3A.

Figure 25. — Prescribed burning decadent sawgrass in Shark River Slough, Everglades National Park, February 1973. The dense black smoke is characteristic of fire in decadent sawgrass. Ignition by personnel on foot without the safety of a fireline is not generally recommended.

It is most likely that the recent decline of Everglades sawgrass resulted from the interaction of several factors. Hofstetter and Parsons (1975), and Hofstetter (1976), for example, believe that insect damage, nutritional deficiencies, and altered hydroperiod were all involved.

Whatever the reasons, this situation seems now to be reversing itself; observations since 1977 suggest sawgrass is again gaining in stature and density.

MELALEUCA THREAT TO SAWGRASS

While the coverage of sawgrass has been decreasing in south Florida, that of melaleuca (Melaleuca *quinquenervia)* has been increasing dramatically. Also called cajeput or punk tree, this exotic was introduced into the area early in this century. Melaleuca has become established in a wide variety of south Florida ecosystems, and its range continues to expand yearly. One estimate of its potential range in south Florida, based on the assumption of continuation of present trends, is shown in figure 26. Because it is an exotic and highly visible plant, it is considered to be undesirable by many who fear that it will eventually eliminate native south Florida vegetation. In addition, both melaleuca and Brazilian pepper *(Schinus terebinthifolius)* cause contact dermatitis and respiratory problems (Finegold 1975, in Austin 1978, p. 28; Morton 1971). Therefore, management practices which might encourage or discourage melaleuca are of great interest, not only in sawgrass but also in other south Florida plant communities.

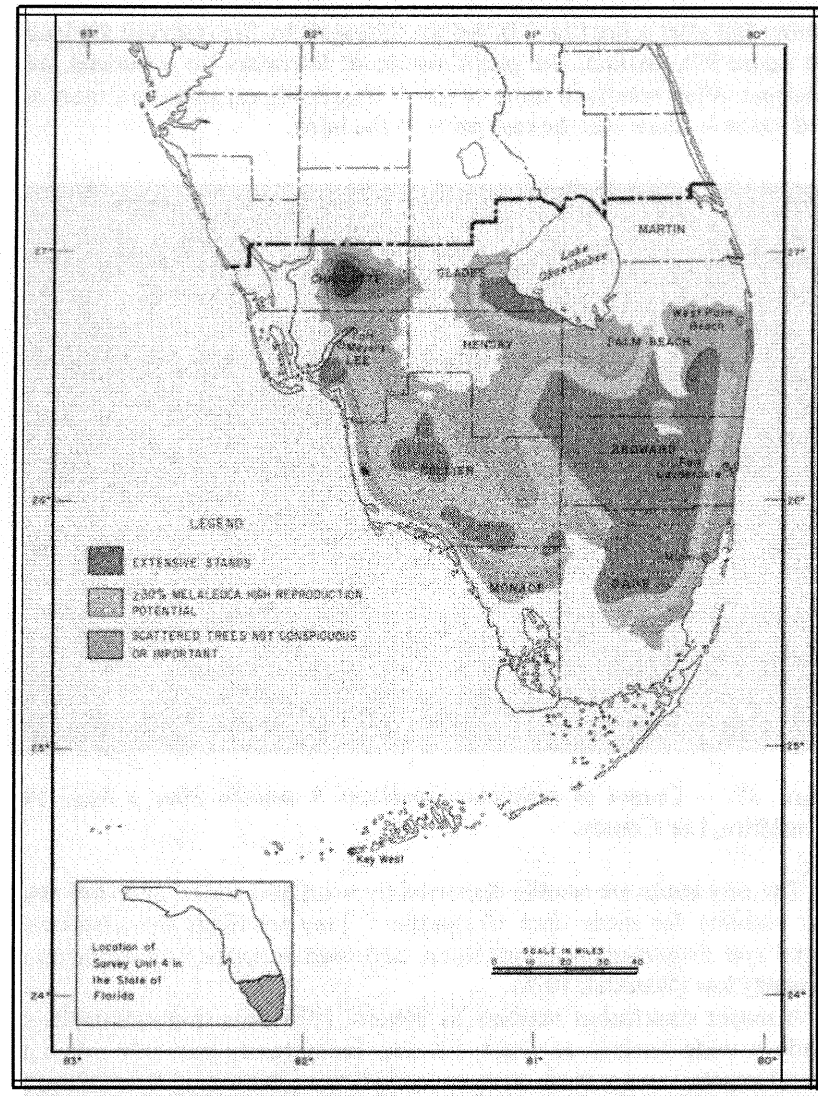

Figure 26. — Projected distribution of melaleuca in south Florida by the year 2000 under 1976 conditions.

Most of the available information regarding melaleuca in south Florida is the result of work by Meskimen (1962); Myers (1975); and Woodall (1978). The following description of melaleuca's ecological characteristics is based on the work of these three authors. One important characteristic of melaleuca is its incredibly high reproductive potential. Each tree produces millions of tiny seeds each year, and these are held in capsules on the tree, sometimes for many years. The capsules open when the twig to which they are attached is killed, either through natural mortality or fire. Because of natural twig dieback, some seeds are continually released, but a tremendous number fall after a fire (fig. 27). Adults damaged by tire resprout vigorously (see figure 99). In fact, the proliferation of branches on a burned, adult melaleuca often results in more twigs — thus more capsules and more seed production — than was the case prior to the burn.

Figure 27. — Carpet of melaleuca seedlings 3 months after a May 1977 wildfire, Lee County.

The tiny seeds are readily dispersed by wind and water, and they retain their viability for more than 10 months.* Tiny seedlings can also be uprooted and dispersed by floodwaters, and their nutrient requirements are extremely low (Woodall 1978).

A major conclusion reached by Myers (1975) was that melaleuca can invade a wide variety of south Florida ecosystems, but only when the natural vegetation on these ecosystems had been disturbed. Sometimes the disturbance that facilitates melaleuca invasion is wildfire, sometimes drainage, sometimes land clearing, and most often some combination of impacts. Other workers, however (e.g., R. Hofstetter and S. Woodall) have observed it on apparently undisturbed sites. Once established, melaleuca is extremely difficult to eliminate, primarily because it resprouts vigorously after tire or cutting, and anything which damages a seed-laden adult usually results in the dispersal of a vast amount of seed onto the site. Because of its tenacity once established, it would seem to be far more preferable to prevent initial establishment of melaleuca than to attempt to eliminate it after it has successfully colonized a site. Perhaps the best way to exclude

[12] Woodall, S. 1978. Personal conversation. U.S. Dep. Agric. For. Serv., Southeast. For. Exp. Stn., Lehigh Acres, Fla.

melaleuca is to manage south Florida landscapes in ways that maintain the vigor of the native vegetation. If resource managers keep the natural vegetation happy, it, in turn, will help contain the spread of melaleuca.

There is a possibility (as yet untried) that fire may be useful for controlling melaleuca on some sites where it is already established. Ewel and others (1976) suggested that very young seedlings might be killed by prescribed burning. However, an abundance of tiny melaleuca seedlings usually means that there was an earlier fire-induced seed release, and the earlier fire would probably have consumed most available fuel, thus precluding a second burn which might be used to kill the seedlings. But, if the adult melaleuca were killed by below-freezing temperatures, fire might be an excellent method of eliminating any subsequent seedlings. A second possible use of fire (suggested by Myers' work) would be to induce a melaleuca seed release at a time when germinating seeds would be killed by drought or flooding. This approach would require accurate prediction of water level changes and merits additional research before definite recommendation can be made.

Another approach to melaleuca containment is a direct attack on individual trees. Woodall (1978) has concluded that massive elimination of dense stands is not ecologically nor economically feasible, but he does suggest that additional expansion of melaleuca into presently uncolonized ecosystems might be slowed or stopped by manual removal of the scattered individuals which serve as seed sources. Fire must be used with great care on such areas to prevent inadvertent seed release.

FIRE AND SAWGRASS

Successful sawgrass management depends, to a large degree, on the fire regime. Sawgrass has evolved with fire; it apparently needs fire to maintain its dominance and, even if man-caused fires could be eliminated, lightning fires would continue. These often occur in the dry season and, if the upper layer of organic soil is dry enough to ignite (moisture content [m.c.] <65 percent ovendry weight) when the surface fuels burn, these smoldering ground fires can dry out and burn progressively wetter layers (at least 150 percent m.c.) until the water table is approached or bedrock is reached. Such fires will kill virtually all vegetation on the site.

When sawgrass remains unburned for 3 to 5 years, the amount of dead material usually surpasses the live biomass. Eventually several feet of litter accumulate, particularly in the central Everglades where sawgrass achieves its best growth. However, in the Shark River Slough, Werner (1975) found most of this dead material disappears each wet season rather than accumulating, as it does in the Conservation Areas. These differences are partially due to the different hydroperiods, which affect decomposition rates, and different waterflow rates, which determine how much of the dead material is flushed from the system. Sawgrass survival can be assured by prescribed burning when surface water still covers some of the litter or, if tussocks are present, when most of the meristems are just submerged by the dropping surface water. To reduce the threat of fire during the peak of the dry season, however, prescribed burning has to remove much of the accumulated litter. If the sawgrass is burned when the water table is too high, it may reburn later in the dry season when the water table is lower. Some sawgrass communities burned three times in 4 months during the spring of 1971, the last burn being an extensive ground fire. Similar events occured during the 1973-1974 season (Zipprer 1977).

Sawgrass regrowth after burning is prompt and rapid if the meristems are undamaged (fig. 28). Tilmant (1975) recorded average sawgrass regrowth heights of 2.5 feet (0.75 m) 2 weeks after a March prescribed burn when the water table was just below the soil surface and 3.9 feet (1.2 m) 8 weeks after the fire. Forthman (1973) found new shoots 1 inch (2.5 cm) high the day after a prescribed burn. Regrowth averaged 8 to 16 inches (20 to 40 cm) at the end of 2 weeks. She found these growth rates were much higher than those on unburned control plots and that the new sawgrass leaves differed from those on control plots. New leaves on culms in the burned areas were rather limp, a brighter green, and had fewer teeth. The rigid, toothed leaves from which sawgrass derives its name were not produced until 1 to 2 months after burning, when growth rates slowed to normal. As Forthman (1973) pointed out, it would be advantageous for any defoliated plant to produce new leaves as quickly as possible so it could resume photosynthesis and thus not deplete its stored food reserves. Sawgrass does just this after a fire; it produces new leaf area at the expense of secondary thickening of cell-wall tissue. Many grasses do the same; following the tire an increase in the ratio of cellulose to lignin (which in indigestible) is often noted (Daubenmire 1968; Halls and others 1952, 1964; West 1965).

Figure 28.—Sawgrass regrowth 3 weeks after a lightning fire, July 1973. Note the tire-killed seed stalks in foreground and the line of Casuarina along canal berm in the background. North boundary, Everglades National Park.

Thus, even though fire generally removes most of the vegetative cover, sawgrass recovers its preburn stature. This process takes 1 to 2 years (Loveless 1959a). Forthman (1973) reported the sawgrass on her plots had regained about 70 percent of its preburn height and standing crop weight the first year, which agrees with the first-year-height recovery reported by Yates (1974). Although Tilmant (1975) did not take any measurements before burning, he reported sawgrass regrowth 5 months after a late December burn over standing water to be 5.75 feet (1.75 m), while regrowth after an early March prescribed burn, when the water table was just below the surface, was 4.9 feet (1.5 m). If fire damages the meristems, regrowth is, of course, much slower. For example, Steward and Ornes (1975b) reported the standing crop was only 38 percent of its preburn weight 18 months after a wildfire in May 1971 — an extreme drought year.

To produce the best growth of both tropical and temperate zone grasses, burning at the end of the dry season is usually recommended (Hughes 1975; Rose Innes 1972; Van Rensburg 1972). Furthermore, Forthman (1973) found that the growth rate of sawgrass increased in the spring (April through June), which she interpreted as a response to increased solar radiation and temperature. The largest acreage of sawgrass has probably always burned in the spring, and this is usually the best time to burn if soil moisture is adequate. This can easily be determined before burning. Seek out the highest elevation on the site; if standing water is present or the soil surface is damp (>65 percent m.c. ovendry weight), proceed; if the soil surface feels dry (<65 percent m.c.), do not burn!

To perpetuate sawgrass in the Shark River Valley, the Everglades National Park fire management plan (Bancroft 1977a) calls for prescribed burning between December and March with winds 10 to 20 mph out of the North, Northeast, East, Southeast, or South (to carry smoke away from the populated east coast). Relative humidity (RH) should be less than 60 percent; standing water should be present but on a falling water table; and Drought Index should be between 400 and 600 (see Keetch and Bryam 1968).

The Florida Division of Forestry uses the following criteria for prescription burning of sawgrass to reduce wildfire hazard and damage on the Conservation Areas (Zipprer 1977): a falling water table with surface levels 3 to 6 inches, wind east to south at 10 to 15 mph, RH less than 60 percent, and the stagnation index under 10 (for good smoke dispersion). They try to maintain less than a 2 to 1 ratio of dead to live fuel; to do so requires a burning interval of 3 to 5 years. In areas where dead fuel buildup is slower, the interval between burns can be extended. The historical sawgrass fire rotation can only be estimated; Hendrickson (1972) gives a hypothetical fire frequency from 3 to 25 years, which is wide enough to encompass most estimates. However, sawgrass can apparently withstand, at least occasionally, more frequent burns (fig. 29). One of Forthman's (1973) study plots had burned the previous year as well, yet these two successive spring fires had no detrimental effect on the sawgrass regrowth. Neither did she find any differences in sawgrass density (culms/m^2) with burning.

Figure 29. — Several weeks after a wildfire in l-year-old sawgrass regrowth, September 1972, Everglades National Park. .

A hazard-reduction burn when surface water levels are high obviously will not meet its objective, nor will a burn over 2 to 3 inches of water completely eliminate the threat of a wildfire later in the dry season as the water table continues to drop. However, if a wildfire does start on such an area, its rate of spread will be less, it will not burn as hot, and it will, therefore, be easier to extinguish. Sawgrass can safely be precribed burned as long as the soil is wet, but it is usually burned when several inches of surface water are present, in part to allow the use of airboats during the burn.

We recommend that headfires or spotfires be used whenever possible. Pushed by the wind, they will cross areas of sparse fuels that a backfire is unable to cross. They are fast moving and thus less likely to dry out and ignite any elevated areas of organic soil. Werner (1975) found a strong positive correlation between sawgrass recovery and fire-spread rate, undoubtedly because headfires consume the dry fuels quicker and move on before the moisture can be driven from the sawgrass culms and rhizomes causing heat damage to these plant parts. Moreover, a headfire will burn a given area quicker than a backfire and is therefore more economical.

Containment should not be a problem because any area of sparse fuels more than a few feet wide should stop a prescribed fire. Fire will sometimes jump these natural breaks, but the spots can be stopped by simply circling them a time or two with an airboat to push down and wet the fuels ahead of the fire (fig. 30). Occasionally, the nighttime increases in humidity and fine fuel moisture are relied upon. In general, control is not a problem until the soils begin to dry out.

Figure 30. — An airboat was used to knock down the sawgrass on the first pass. The line was then backfired on the return pass. Conservation Area 3A.

Because most sawgrass burning is done over water and an airboat is usually present in case it is needed for control, these craft are also commonly used for ignition (fig. 31). However, ignition from a helicopter is generally much more efficient and safer. Travel time to the site is less, ignition is quicker, and the person doing the igniting has an overview of, as well as complete access to, the burn area so he can better place the igniters and can more easily access fire behavior and regulate it by changing his ignition pattern. An aerial igniter was specifically developed for south Florida conditions by the U.S. Forest Service (Sackett 1975) and further refined by L. Bancroft of Everglades National Park. Instead of starting a continuous line of fire, these aerial igniters, like lightning strikes, start spot fires that spread in all directions (fig. 32). The result is a mosaic of burned and unburned areas (fig. 33) which is desirable for wildlife. The unburned areas act as refugia for many animals during the fire and then provide cover for them in subsequent months. The burned areas, on the other hand, soon contain new plant growth that is tender and high in nutrient value, and thus a preferred wildlife food source.

Most animals do not exhibit an innate terror of fire or become unduly alarmed at the first sniff of smoke. We have observed many species of birds feeding on insects and small mammals dislodged by a fire. Snakes are often seen along the flanks and back of a fire, staying just ahead of the flames.

Figure 31. — Prescribed burning sawgrass over surface water, February 1975, Everglades National Park. The airboat is used for both ignition and control. Note the abrupt transition between the robust sawgrass and wet prairie, which will not carry a backfire under these conditions.

Figure 32.— A helicopter was used for ignition. Note the airboat standing by. The gray areas ahead of the fires are decadent sawgrass; the green areas, healthy sawgrass or tree islands; the tan areas, wet prairie; and the open water in the foreground, slough communities. The spot fires are unable to back under these conditions. Note the airboat trail that follows the sawgrass-wet prairie interface. Everglades National Park.

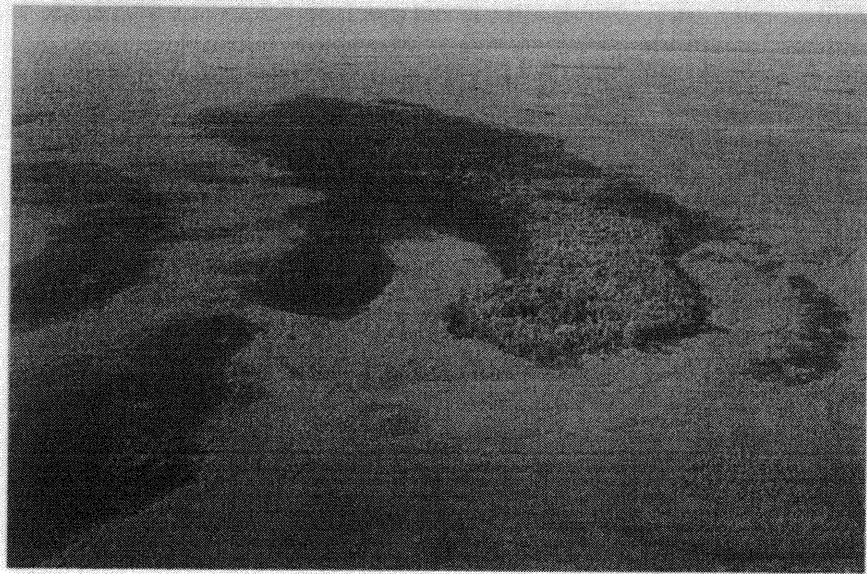

Figure 33. — Mosaic of burned and unburned marsh after a February 1974 prescribed fire, in selected sawgrass strands, to reduce the chances of a dry-season fire reaching the large tree island. Note the airboat trails. Everglades National Park, February 1974.

Dineen (1972) observed that red-shouldered hawks changed their feeding habits and raised their young right through the severe drought-year tires of 1971.

Few studies have been specifically designated to assess the relationship between Everglades fauna and fire, but many first-hand observations have been reported in the literature. Robertson (1953, p. 83) encountered enough fire-killed cotton rats and marsh rabbits to conclude that wildfires in sawgrass "may exert considerable influence on the rodent populations of the glades." He also mentions having seen small alligators, opossums, raccoons, and several species of snakes, frogs, and turtles killed by wildfires in sawgrass. These observations were made during 1951 and 1952, which Robertson (1953, p. 18) states "were abnormally dry years, at least by all previous standards." Babbitt and Babbitt (1951) reported large numbers of frogs, snakes, lizards, anoles, and turtles killed by fire during February through April 1949. Robertson (1953, p. 99) quotes the chief of the Everglades Fire Control District on March 15, 1949, as saying it was the "driest in 14 years." Ligas (1960) believes severe sawgrass fires can set back the frog population by 5 years; but if we can assume that severe fires mean drought-year fires, Ligas' statement must be tempered by that of Viosca (1928, p. 224) who states "frogs are very scarce for 1 to 2 years following every drought sufficient to dry our swamps." Robertson and Kushlan (1974) thought direct tire mortality of birds was limited to nestlings of species that nest on the ground or in low vegetation. Further, springtime bird populations are low except around ponds and sloughs, which are least affected by fire (Robertson 1953). Virtually all the mortality described above occurred during wildfires, many of which were undoubtedly dry-season, organic soil fires. In our experience, turtles are probably the most common victims of fire. Werner (1978) states that it is common to find Florida box turtles ***(Terrupene carolina bauri)*** with up to 70 percent of the carapace scarred by fire. In many cases, the tissue in the bony plates has been destroyed and replaced by new tissue that formed underneath.

Animals may also be killed in prescribed burns, but several factors combine to limit losses. Prescription fires are generally smaller, less intense, slower spreading, occur over standing water, and leave a mosaic of burned and unburned fuels (see figure33). Thus, more animals can outrun the fire, find safety in areas of sparse emergent fuels, or submerge while the fire passes over them (fig. 34). Marsh burning is an integral part of wildlife management on almost all the coastal wildlife refugia in the South (Givens 1962; Perkins 1968; Zontek 1966).

Yates (1974) lists almost two dozen species of birds that utilize sawgrass. Ducks, in particular, are fond of sawgrass seed but are effectively kept from this food source without periodic burning to remove the dense accumulation of plant materials (Givens 1962; Lynch 1941).

In one of the early intensive wildlife studies conducted in south Florida, Loveless (1959a) and Loveless and Ligas (1959) tied the health of the Ever-

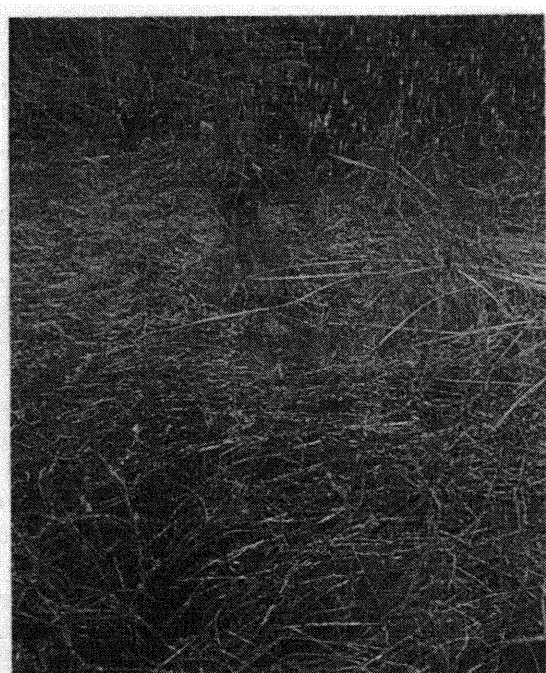

Figure 34. — Alligator on a fresh sawgrass burn, March 1975, Conservation Area 3A.

glades deer herd directly to the periodicity of fire in the Glades. They believe the two most important reasons for burning are that it encourages the establishment of many important deer food plants and that it checks plant succession toward less desirable associations. Deer, like most browsers, tend to congregate on recently burned areas to browse the tender sawgrass regrowth, provided adequate cover is nearby (Klukas 1973; Loveless 1959a).

Cattlemen have long recognized the benefits of burning for range management. Although the slash pine flatwoods provide the principal cattle range in south Florida, postfire marsh regrowth also attracts herbivores (Hughes 1966; Lynch 1941; Van Rensburg 1972; and Wharton 1966).

WET PRAIRIE AND SLOUGH

WET PRAIRIES

The term "wet prairie" has been used in the literature to describe a variety of communities that differ in vegetation, hydroperiod, animal life, and fire history. Wet prairie is used here in the sense of Loveless (1959b) and includes the spike rush marshes and sedge flats of Craighead (1971). Loveless (1959b) identified several subdivisions of wet prairie communities that he called "flats," using as a prefix the Latin name of the dominant plant, e.g., "***Eleocharis*** flats."

Loveless' (1959b) wet prairie communities such as beak rush flats, spike rush flats, and maidencane flats, have different dominant species, but the more common plants in all are: beak rush ***(Rhynchospora*** spp.), spike rush ***(Eleocharis*** spp.), maidencane ***(Panicum hemitomon),*** string lily ***(Crinum americanum),*** spider lily ***(Hymenocallis*** spp.), ludwigia ***(Ludwigia repens)***, arrowhead ***(Sagiitaria latifolia),*** floating hearts ***(Nymphoides aquatica),*** bladderworts ***(Utricularia*** spp.), and pickerelweed ***(Pontederia lanceolata).***

Wet prairies occupy sites where the maximum surface water depth is less than 4 feet (125 cm) and there is, at most, only a short annual dry period (fig. 35). Except during severe drought, the water table does not recede more than about a foot below the soil surface (Loveless 1959b). Wet prairies have a longer hydroperiod than sawgrass communities, according to our usage. However, others in south Florida use the term "wet prairie" to denote vegetative communities between sawgrass and higher ground (fig. 36). This problem in nomenclature can be, at least, partially overcome by becoming familiar with the site requirements of the primary plant species. For example, floating hearts, bladderworts, and ludwigia are indicators of deep water, while maidencane prefers drier sites.

The lowering of the water table and the shortening of the hydroperiod in drained areas have resulted in displacement of wet prairies by species that favor drier conditions (fig. 37). On the other hand, wildfires have burned out the surface layers of peat in many sawgrass communities, and most of these depressions have changed to wet prairie. The raising of the water table, the lengthening of the hydroperiod, and the lack of a dry period (as in the wetter areas of Conservation Areas 1, 2, 3) have resulted in displacement of sawgrass by wet prairies and of wet prairies by slough and cattail communities (Alexander and Crook 1973, 1975; Dineen 1972; Goodrick 1974).

Figure 35. — Wet prairie ecosystem, Conservation Area 3A. Note the sparse fuel load of spike rush and the abrupt transition to sawgrass in the background.

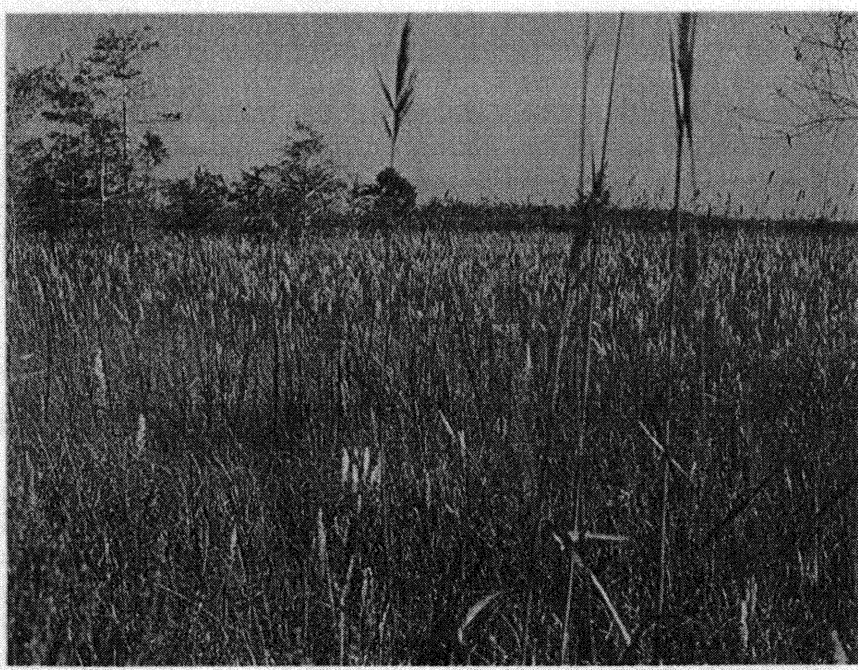

Figure 36. — Wet prairie in the Fahkahatchee, Collier County. Swamp goldenrod is in bloom.

Figure 37. — Wax myrtle encroachment into a wet prairie, Corkscrew Swamp Sanctuary.

Some wet prairies, notably maidencane flats, are becoming more widespread, partially because maidencane prefers drier sites than other wet prairie species and partially because it can tolerate both recurrent fire and widely fluctuating water levels (Loveless 1959b). Goodrick (1974) described wet prairies as one of the marsh communities most sensitive to water conditions.

In general, wet prairies have insufficient fuel to carry a fire when flooded. A well-developed algal mat (periphyton) (figs. 38A, 38B) is frequently present. When this suspended mat and the surface sediments are dry, however, the periphyton will burn, smoldering imperceptibly (fig. 39), often carrying fire through the night and over considerable distances. Maidencane flats are an exception; they burn almost as well as sawgrass and quickly resprout after a fire. Tilmant (1975) considered that vegetative recovery of both species was nearly complete 6 months after a March prescribed burn. The maidencane averaged 3.6 feet (1.1 m) tall and the adjacent sawgrass community averaged 4.9 feet (1.5 m) tall. Average water depths were about 2.8 inches (7.0 cm) greater in the maidencane. Tilmant (1975) thought this difference in water depths was enough to prevent the intermingling of the two species. He also reported that 6 months after a fire, total cover was 77 percent in the maidencane marsh, compared to only 27 percent in the sawgrass strand, which in contrast to the discussion in the sawgrass section, indicates that sawgrass does not always recapture a site rapidly. At about this time, however, the water level rose almost 2 feet (0.6 m) in 2 weeks to 28 inches (72 cm), killing much of the maidencane but apparently not affecting the sawgrass.

Figure 38. — Periphyton in wet prairie during: A, the wet season; B, the dry season. Everglades National Park.

Figure 39. — Smoldering algal mat, Everglades National Park. The light gray is unburned, the dark gray is burned, and the brown is the fire front. Note the lack of smoke.

Maidencane is preferred cattle forage throughout the year (Yarlett 1965) and, along with other wet prairie plants, is an important deer food (Loveless 1959a). These species, therefore, are often burned to improve wildlife habitat and range.

Tilmant (1975) studied the effects of fire on the round-tailed muskrat (*Neofiber alleni*) in Everglades National Park. He found these animals move from wet prairie to sawgrass and back with the annual rise and fall of surface water levels. Fire may force a move to unburned vegetation, depending upon water level at the time of the burn; otherwise, fire has little apparent effect.

Vogl (1973) followed wildlife trends after an intense wet prairie prescribed burn in north Florida, visting the area 63 times in 4 months. He recorded a total of 754 birds on the burned shoreline, but only 236 on an adjacent, comparable unburned shoreline. Thirty of the 35 bird species encountered were seen more often on the burn. Alligators used the burned shore almost exclusively. However, within 4 months after the tire, the animal populations on both areas appeared similar.

Goodrick (1974) points out the general ecological importance of wet prairies: they contain excellent waterfowl food plants, abundant invertebrates and other small aquatic animals, plus the highest density of small-fish populations in any south Florida freshwater vegetative type. All of these are required to maintain the vast wading-bird populations of south Florida.

Van Arman and Goodrick (in press) have just completed a study of the effects of fire in the Kissimmee River marsh which, although north of our south Florida boundary, is considered an integral part of this region by many people. They concluded that maidencane and pickerelweed are fire tolerant and regain preburn biomass within 6 months. But their most important finding was that the total numbers of both animal species and individuals were significantly greater on their burned plots. Thus, for the first time, statistically significant increases in secondary productivity have been tied to the use of fire. One management implication of this discovery is that prescribed burning, in conjunction with the manipulation of water levels, can increase the production of macrovertebrates and small fish which are food for wading birds and larger fish.

SLOUGHS

Sloughs are elongated, often sinuous natural drainage channels that contain water most of the year (figs. 40A, 40B). They are a few inches to a few feet below the adjacent marsh. In the upper Everglades, where the soil is mostly peat or muck, the submerged surface sediment in the sloughs tends to rise and fall with changing water levels.

Emergent plants are usually sparse, while aquatic plants are abundant; sloughs are easy to recognize. The common aquatic plants include white water lily ***(Nymphaea odorata),*** spatterdock ***(Nuphar luteum),*** water hyssop ***(Bacopa caroliniana),*** ludwigia ***(Ludwigia repens),*** bladderworts ***(Utricularia*** spp.), and floating hearts ***(Nymphoides aquatica).*** Spike rush ***(Eleocharis*** spp.), an emergent plant, is common in some areas (see figure 35). Sloughs west of the Everglades generally have a border of overhanging swamp hardwoods and/or cypress (fig. 41).

Because sloughs are wet much of the year and the vegetation is sparse, they have historically acted as nature's firebreaks in south Florida. The communities bordering them are protected from fires approaching from across the slough. When the surface sediments dry out in severe droughts, however, ground fires may develop. Such fires create depressions that later till with water to become ponds. Most alligator holes are found in sloughs; when they occur in other plant communities, they are probably the result of the acids in accumulations of plant litter dissolving the limestone and/or deep-burning muck fires (Loveless 1959b).

Human modification of the hydroperiod throughout the wetlands has altered the distribution and nature of sloughs. Where the hydroperiod has been shortened by drainage, sloughs have been replaced by wet prairies, sawgrass, or even less-water-dependent communities, depending on the extent of reduction. Good examples of these community shifts can be found in Taylor Slough and Shark River Slough. Where the hydroperiod has been lengthened, as by impoundment along the downstream ends of the Conservation Areas, sloughs have been replaced by shallow lake communities of cattails (*Typha* spp.) and/or submerged and floating plants.

Cattails have increased in density and distribution in southern Florida, primarily as a response to human manipulation of the hydrology of the area. Along canals and the wetter southern ends of the Conservation Areas

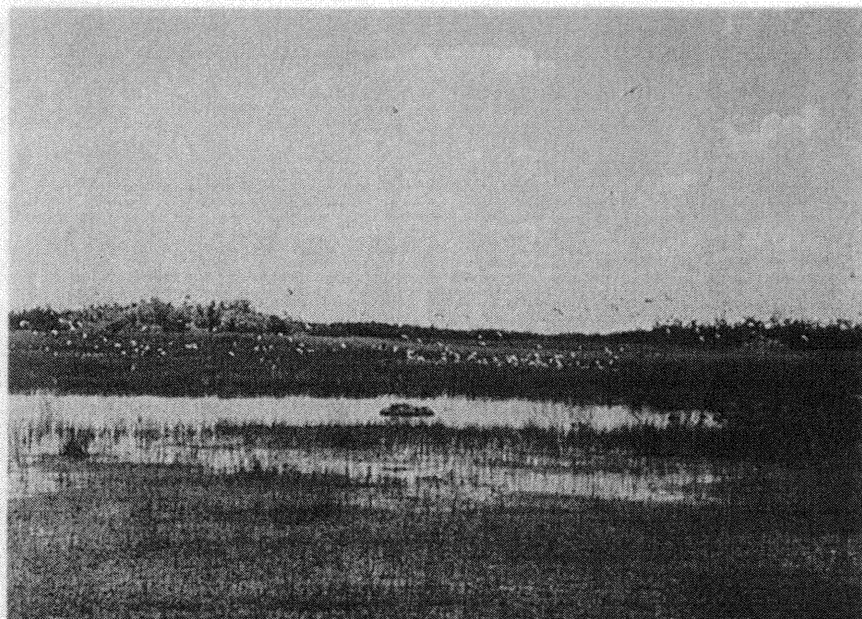

Figure 40. — Slough communities during the wet season: A, Shark River Slough, Everglades National Park; B, slough and adjacent sawgrass communities several weeks after a 1971 drought-season wildfire. The water table was close enough to the surface to prevent ignition of the organic soil. Note the small changes in elevation between communities.

Figure 41. — A pond-apple slough in Corkscrew Swamp Sanctuary.

where surface water is present almost all the time, cattails have displaced other graminoids, especially sawgrass (fig. 42). This succession also may be accelerated by introduction of more nutrient-rich waters from agricultural areas.

Cattail growth declines in the early dry season (i.e., winter), and the large quantity of standing dead material and litter will readily burn when it is dry. Further, cattail shoots cannot tolerate low temperatures, so a cold spell will increase the amount of dead fuel present above that resulting from the annual dieback. The role of fire in cattail marshes of southern Florida is not fully understood, but deep-burning ground fires in freshwater wetlands create conditions favorable for cattail. One hypothesis is that fire in cattail marshes may perpetuate this species by consuming the plant material that would otherwise remain on the site, form peat, and decrease water depths, favoring sawgrass colonization.

FRESHWATER MARSH AND MARL PRAIRIES

These vegetative types are characterized by shallow soils covered with a moderate to well-developed algal mat called periphyton. Where the periphyton is thick, it forms a marl soil high in calcium carbonate. In many places the limestone bedrock protrudes to the surface or has been exposed by past fires that have consumed the thin overtopping layer of peat (fig. 43). The vegetation is sparse to patchy and comprised of graminoids with some

Figure 42. — Cattails invading a spike rush flat in the southern end (deeper water) of Conservation Area 3. Note slough and sawgrass communities in the background.

Figure 43. — Where the limestone outcrops or has been exposed by ground fires, it is called pinnacle rock. Everglades National Park.

forbs intermixed. Species composition varies considerably and may include plants generally associated with sloughs, sawgrass glades, wet prairies, and saltmarshes along with more mesic-site plants, such as white-top sedge ***(Dichromena colorata),*** love grasses ***(Eragrostis*** spp.), muhly grasses ***(Muhlenbergia*** spp.), plume grass ***(Erianthus giganteus),*** and beard grasses ***(Andropogon*** spp.). Included in this section are the Marl Prairies of Harper (1927); the Southern Everglades Marsh Prairies and Southern Coast Marsh Prairies of Davis (1943a); the Southeast Saline Everglades of Egler (1952); and graminoid communities of Craighead's (1971) provinces IV (Freshwater Swamps) and VI (Low Pineland and Sloughs).

While freshwater marsh and marl prairies differ floristically and environmentally (notably, soil type and hydroperiod), they probably share a similar burning history, with periodic fire pruning back invading brush and trees. The irregular vegetative cover generally results in a patchy burn even under severe burning conditions, except on muhly grass prairies where there is adequate fuel to carry fire readily. Although hydroperiods differ within this vegetative complex, they are all fairly short, resulting in dry Surface soils during much of the dry season. At this time, the periphyton will carry a smoldering fire across poorly vegetated areas to unburned patches of fuel (see figure 39). Some researchers (e.g., Craighead) believe the surface soils of these communities historically had a high percentage of organic matter, but that dry-season fires, particularly following drainage, have removed most of it.

This vegetative complex occupies extensive areas in the Big Cypress and once was the characteristic vegetative type from the Miami Rock Ridge southeast to the saltmarsh-mangrove fringe. Marl prairie vegetation has, however, disappeared from much of its original area because of drainage, fire, agriculture, urban expansion, and displacement by exotic plants. Drainage has resulted in a shift to species requiring a drier habitat such as saltbush ***(Baccharis halimifolia),*** wax myrtle ***(Myrica cerifera),*** and swamp fern ***(Blechnum serrulatum).*** With the increasing demands for homesites, the decreasing surface water levels, and the lack of an inexpensive way to control the more aggressive exotic plant species, the loss of these prairies will undoubtedly continue. Richardson (1977) states that the recorded prairie fire cycle of slightly less than 2 years in southeastern Palm Beach County is too short to perpetuate the original prairie community.

Three exotic tree species, known collectively as Australian pine ***(Casuarina*** spp.), are invading the easternmost marl prairies (fig. 44). All three species are very susceptible to fire, but only one, C. ***equisetifolia,*** does not sprout after fire. Thus, periodic fires keep expansion of this species in check and, with herbicide treatment, can be used to kill existing trees. However, fire just prior to seed maturation will prepare a very favorable seedbed for this exotic, promoting it over the graminoid vegetation.

North of Kendall Drive in Miami, melaleuca ***(Melaleuca quinquenervia)*** is the most common exotic invader of these marsh prairies. Melaleuca is rapidly moving westward and eastward from the coastal ridges. Single trees appear first, then scattered dense heads, and finally extensive dense stands

Figure 44. — Casuarina invading a marl prairie south of Miami. Note snags from past fires.

essentially devoid of all other species (figs. 45A, 45B). Melaleuca readily invades disturbed land (Alexander and Crook 1973; Myers 1975), but development in essentially undisturbed communities has also been documented (Woodall 1978). Austin (1976) reports that disturbed "wet prairie" sites are particularly susceptible to invasion by melaleuca. Melaleuca, however, is also spreading south of Miami, displacing the Australian pine with the help of fire.

Brazilian pepper (*Schinus terebinthifolius),* a large shrub or small tree introduced from Brazil, has also invaded areas that once were marsh prairies, but its spread and development are most severe in freshwater buttonwood (*Conocarpus erecta*) forests, and on abandoned farmlands, excessively burned pinelands, and other disturbed land. It is common throughout south Florida and constitutes another major exotic plant threat to the native vegetation. Its fruit is readily eaten by wildlife, but the seeds pass through the digestive tract unharmed. Because wildlife is drawn to fresh burns, this exotic is often a major component of the postburn vegetation (fig. 46). Although fire will kill Brazilian pepper seedlings, it is not effective for the control of this species once it forms thickets because even intense wildfires have difficulty penetrating them, and sprouting almost always occurs. This is at least partially due to the damp conditions and lack of well-distributed dead fine fuels within these thickets (fig. 47). In fact, hedgerows of Brazilian pepper are often used as a firebreak because of this trait.

Figure 45. — Melaleuca invasion of marl prairie: A, clumps developing in Conservation Area 2B; B, closeup of a dense melaleuca sapling stand in Dade County.

Figure 46. — A clump of Brazilian pepper seedlings that germinated in raccoon feces.

Figure 47. — A 36-year-old Brazilian pepper forest, Everglades National Park. Note the lack of dead fuels on the forest floor.

SALTMARSH

Saltmarshes are perhaps the most isolated and least understood plant community in south Florida. Farther north they often extend from high ground directly to the sea, but here they are almost always surrounded by a border of mangrove, or, on the inland edge, by freshwater marsh (fig. 48). Water chemistry of these saltmarshes changes dramatically on several time scales. During much of the year, most saltmarsh areas are covered with freshwater, but as the dry season progresses, brackish water covers them. At the height of the annual dry period, water levels usually drop below the surface. Tidal cycles cause daily low-amplitude salinity changes. Storms, particularly hurricanes, can temporarily alter salinity in two ways. They can push masses of seawater well inland into freshwater wetlands, or the rain from them can increase freshwater discharge and decrease salinity.

Figure 48. — Mangrove lined streams and saltmarsh communities in Everglades National Park. The dead mangrove fringe is the result of a previous fire. Gray areas in the background are black rush.

Saltmarshes are usually dominated by one or more of the following species: black rush ***(Juncus roemerianus),*** salt grass ***(Distichilis spicata),*** and fringe rush ***(Fimbristylis*** spp.). Other species such as cordgrass ***(Spartina*** spp.), sawgrass ***(Cladium jamaicensis),*** cattail ***(Typha*** spp.), and spike rush ***(Eleocharis*** spp.) generally associated with freshwater marshes, are occasionally present and may even dominate some brackish-water areas (fig. 49). Thus, there is a continuum rather than a clear separation between

Figure 49. — Three months after fire in a cordgrass community, Everglades National Park. The lush regrowth on the burned area is rapidly regaining its prefire stature.

saltmarsh and freshwater marsh in southern Florida.

Water (quantity, quality, and duration), frost, and tire are the forces which determine species dominance and succession in this ecosystem. Saltmarshes readily burn, regardless of the height of the water table, when adequate fuel protrudes above the water surface and weather conditions are conducive to fire spread. These fires kill any encroaching mangrove, ensuring continued graminoid dominance (Klukas 1973). When hot tires are stopped by mangrove, the outer fringe of trees is often killed and the marsh temporarily expands (fig. 50). Without frost or fire, trees would probably eventually replace most saltmarsh vegetation.

Little is known about the effects of tire upon saltmarsh communities in south Florida. Most saltmarsh fires are thought to be lightning caused, but some are undoubtedly set by people.

The Everglades National Park initiated a study in 1973 to monitor vegetative changes on two adjacent saltmarshes, one prescribe burned in February 1973 and the other unburned until February 1977. Werner (1977) summarized his observations over the intervening 4 years. The most pronounced changes took place on the unburned marsh, where glasswort (*Saliconia* spp.) expansion resulted in a 75 percent reduction in the area occupied by black rush and a much smaller decrease in the cordgrass area. The salt grass communities remained stable. On the burned marsh, salt grass invaded open areas and patches of sea purslane (*Sesuvium* spp.), while black rush and cordgrass remained relatively stable. The area of glasswort

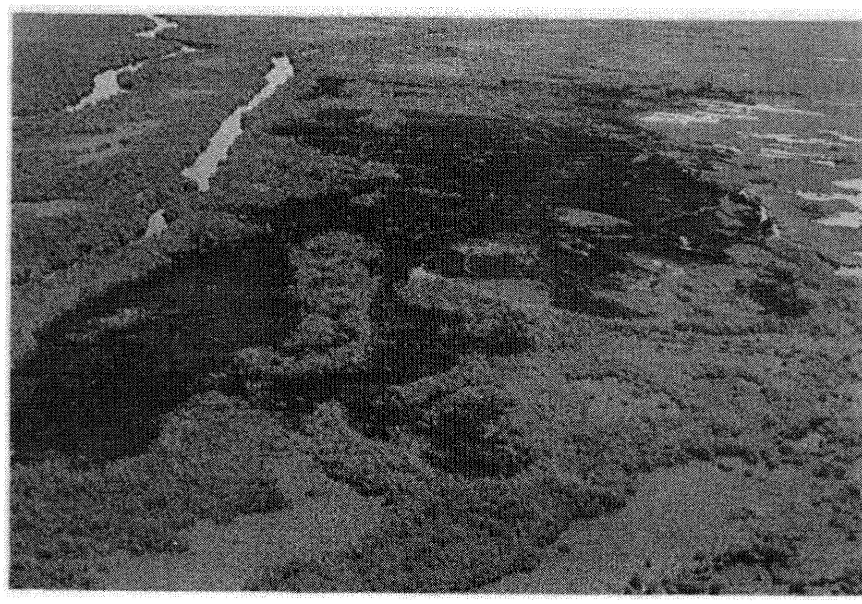

Figure 50. — Repeated fire in saltmarsh perpetuates this vegetation type by killing back encroaching mangrove. Everglades National Park.

also increased slightly on such sites. However, expansion of glasswort, a halophyte, was probably independent of fire and simply a response to higher salinities.[13] Werner (1977) thought the severe frost of January 1977 was more effective than fire in retarding the invasion of mangrove and thus perpetuating these saltmarshes. Saltmarsh species quickly recolonize these areas, but this reprieve may be only temporary because frost-killed mangrove generally resprouts from its roots (fig. 51).[14]

Werner's (1976) detailed study of the endangered Cape Sable sparrow ***(Ammospiza maritima mirabilis)*** shows its plight is due to a loss of suitable habitat. A large colony has recently been found in a freshwater muhly grass (*Mulenbergia* spp.) prairie, where its welfare is tied directly to the fire cycle (Werner 1976). Its existence in the saltmarsh ecosystem may also be related to the fire cycle. Lynch (1941) reported that all species of geese "eagerly sought" the new growth of spartina and salt grass within a week or two after burning Gulf Coast refuges.

There is probably little need to burn these coastal marshes because

[13]Vegetative changes indicating an increase in salinity have been observed in many south Florida coastal ecosystems (Alexander and Crook 1973, 1975; Craighead 1971; Truesdell 1969). Reduced freshwater sheetflow and the slow submergence of this region are thought to be the major reasons for these changes.

[14]There are conflicting opinions regarding the ability of mangrove to resprout after a freeze. Personal correspondence on file at South. For. Fire Lab., Macon, Ga. The January 1977 freeze was reported to be the worst in over 50 years, yet the only mangrove the authors know of that did not sprout was on an area that burned soon after the freeze (see figure 55).

Figure 51. — Mangrove resprouting after being top-killed by the January 1977 freeze. Light-green areas are cordgrass and brown areas are black rush. Photo taken February 1979. Everglades National Park.

lightning fires are common. However, if a decision is made to burn, to slow encroachment of woody plants, for example, the weather conditions should be comparable to those required for burning sawgrass or other graminoid marshes with similar available fuel loads. When burning over standing water, adequate wind to push the fire into unburned fuel is the prime weather requirement. If standing water is not present on the area to be burned, soil moisture should exceed 65 percent on areas underlain by peat to prevent its ignition. Attention should also be paid to the vegetation and soil-moisture content of organic soil on adjacent higher ground. Burning saltmarshes that are surrounded by mangrove is easy because, under normal circumstances, the mangrove border acts as a firebreak. On areas that merge with freshwater marshes, fire can be confined to the saltmarsh by walking the vegetative boundary to knock a swath through the fuels and setting a headfire from that line.

Although coastal prairies are not true saltmarshes, they are sometimes inundated by salt or brackish water and thus are included here. Species composition includes cordgrass ***(Spartina spartinae*** and S. ***bakerii),*** bunchgrass ***(Sporobolus*** spp.), seaside daisy ***(Borrichia frutescens*** and ***B. arborescens),*** and batis ***(Batis maritima).*** The coastal prairies around Flamingo and Cape Sable burned often, perhaps annually, prior to establishment of the Everglades National Park (fig. 52). If fire and hurricanes are kept from these prairies for several decades, they will become buttonwood forests (Craighead 197 1). Encroaching shrubby vegetation is kept off prairies outside the Park because they still burn every year or so.

Figure 52. — Buttonwood killed by fire near Flamingo, probably to clear out the underbrush prior to a charcoal operation before the 1935 hurricane.

MANGROVES

Mangrove forests are found along tropical and subtropical coasts with weak wave action. Although mangroves occasionally become established in other Gulf Coast States, nowhere else in the United States do they form extensive forests, as they do along the southwestern coast of Florida (fig. 53). They make up an unusual and interesting ecosystem that is of particular importance because it links the land and sea.

Four species of mangrove are found in Florida. Red mangrove ***(Rizophora mangle)*** is found primarily along open water channels and has characteristic prop roots (see figure 55). The black mangrove ***(Avicennia germinans)*** is common in areas of high salinity, reduced water movement and low soil oxygen; it is characterized by pencil-like pneumatophores which protrude into the air from the roots. White mangrove ***(Laguncularia racemosa)*** is a colonizing species and thus surrounds many marshes; it frequently is found in mixtures with black and red mangroves. Buttonwood ***(Conocarpus erectaf)*** is most common on the freshwater side of the other mangroves; it generally occurs on dry ground or sites with very short hydroperiods. It was once an important source of charcoal for urban south Florida.

Most of Florida's remaining mangrove forests are located in Everglades National Park and the National Wildlife Refuges in the lower Keys. Outside the Park, mangrove forests have been drastically altered by urban development along the coasts. This loss is unfortunate because mangrove forests form a natural and surprisingly resilient barrier against the sea. Mangrove forests absorb the brunt of many storms.

Figure 53. — Mangrove forests, Everglades National Park. Note the eagle's nest in the large snag.

In addition, mangrove forests produce much of the organic matter that supports the food chains of our coastal waters. Thus, to destroy the mangrove forests is to cut off the food supply of our economically important marine fisheries.

The mangrove belt is also where land building takes place. Craighead (1964) believes this whole zone (one-third of the land area south of the Tamiami Trail) has been deposited in the last 3,000 to 4,000 years.

Lightning is a frequent visitor to mangrove forests (Craighead 1973). From the air, 1/10- to 1-acre (0.04- to 0.4-ha) circular holes of dead and dying mangrove resulting from lightning strikes are obvious (fig. 54). These holes are common, and it has been suggested they might be an important (but as yet unquantified) facet of mangrove ecology.[15] Lightning-started fires in mangrove almost never spread beyond the immediate area of the strike. Fire, however, is an important determinant of how far inland mangroves extend. Mangroves in Florida usually merge into marsh vegetation along the gradient from saltwater to freshwater, and the marshes with which they are contiguous often burn. Because fire readily kills mangrove back to ground line, it excludes mangroves from both salt- and freshwater marshes (Davis 1940; Egler 1952). However, it is perhaps more common for a band of spike rush (***Eleocharis*** spp.), which is too sparse to burn, to separate the mangrove from the more flammable glades.

[15] Robertson, William, Jr. 1978. Personal conversation. U.S. Dep. Inter., Everglades Natl. Park, Homestead, Fla.

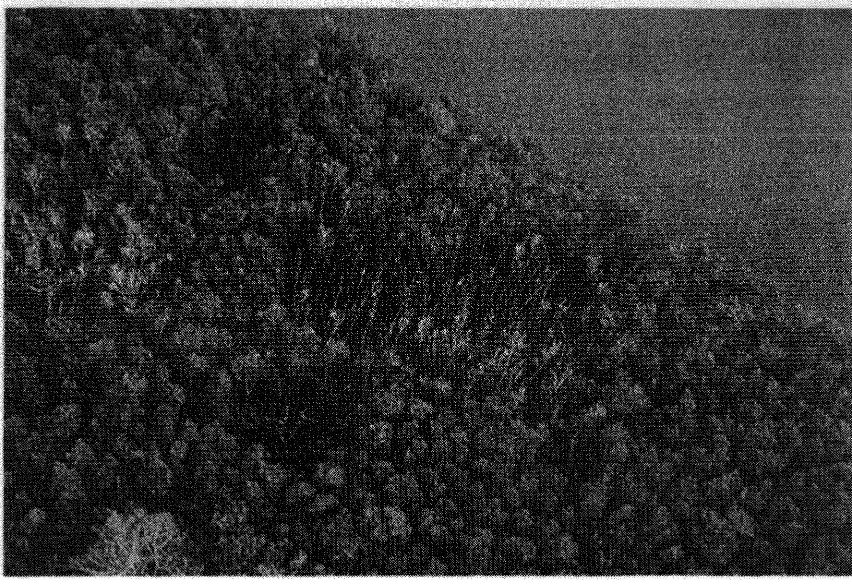

Figure 54. — Circular holes of lightning-killed mangrove. Regrowth is filling the older holes. Mangrove in the fresh strikes have not yet begun to break up. Everglades National Park.

Hurricanes and frost produce considerable amounts of dead fuel and can lead to fire in mangroves. Craighead (1971, 1973) described the fate of extensive areas of mangrove devastated by the hurricanes of 1935, 1960, and 1964 (see figure 8). Frosts occur at least annually along the southwest coast and are the most significant factor in succession along the mangrove-marsh interface (Craighead 1973). Severe cold snaps, such as the one of January 1977, kill back large areas of mangrove forest (see figures 7, 51). Frosts occur during the dry season, so the dead leaves often fall on dry ground, except where influenced by daily tides. These fuel beds are adequate to carry a creeping fire during periods of low humidity. Although mangrove usually recovers from freeze damage, it is extremely sensitive to heat and even very-low-intensity fires will kill it (fig. 55). Fire can crown into mangrove for short distances during the interval between a killing frost and the shedding of the dead leaves (see cover photo), but this is uncommon.

Thus, although a fire may occasionally burn through a mangrove forest that has been frost or hurricane killed, it normally has no role in the management of these ecosystems. Because there is little surface fuel buildup under mangrove forests and what dead fuel is present is usually too wet to burn, fire protection measures are not required. In fact, prescribed fires in the adjoining marshes are generally run against the mangroves because they are such an effective break.

In some of its native habitats in Southeast Asia and Australia, melaleuca forms a band of vegetation in the brackish areas just to the landward side of mangroves (Coaldrake 1961; Coulter 1952; Williams 1967). In Florida this habitat is often occupied by our native buttonwood. Even though Myers (1975) was unable to induce melaleuca establishment in a mixed stand of white and red mangrove in south Florida, the buttonwood zone is susceptible to melaleuca invasion. This substitution of an exotic fire type for a native nonfire type of vegetation is, in fact, apparently taking place on Little Pine Island in Lee County.

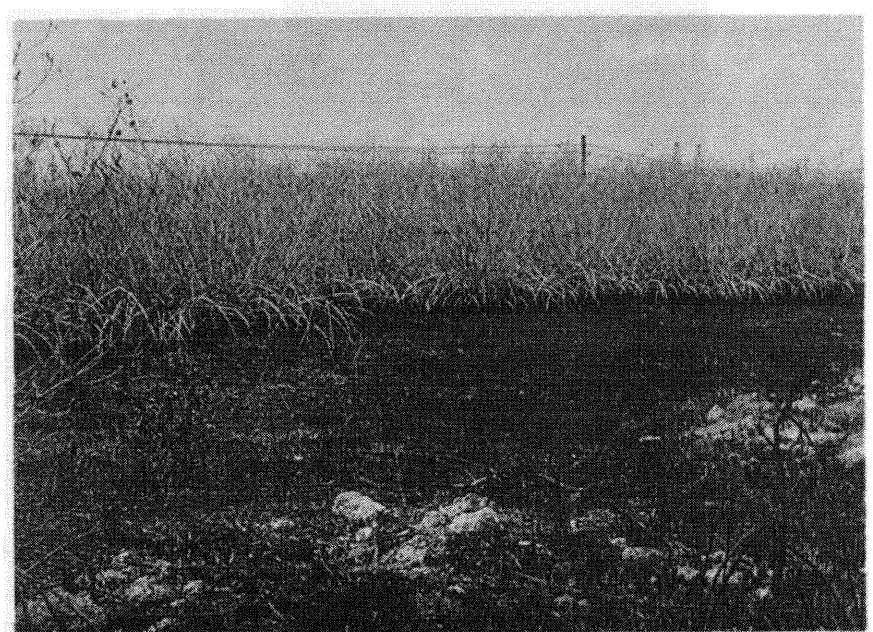

Figure 55. — **Red mangrove vegetation near Carnestown top-killed by the January 1977 frost and subsequently burned. Photo taken April 1977.**

MIXED-HARDWOOD SWAMPS

These forested wetlands constitute one of the most luxuriant and diverse vegetative types in south Florida (fig. 56). They are characterized by numerous species of trees which tolerate wet soil and seasonal flooding. The older successional stages of this forest type are dense and both floristically and structurally complex. They contain abundant epiphytes (including many species of orchids and bromelaids); they serve as either permanent homes or seasonal refugia for a large number of birds, mammals, reptiles, and amphibians; and the knolls within these swamps constitute one of the principal habitats for Florida's rare and endangered royal palm ***(Roystonea elata).***

Mixed-hardwood swamps probably occupy more area today than they

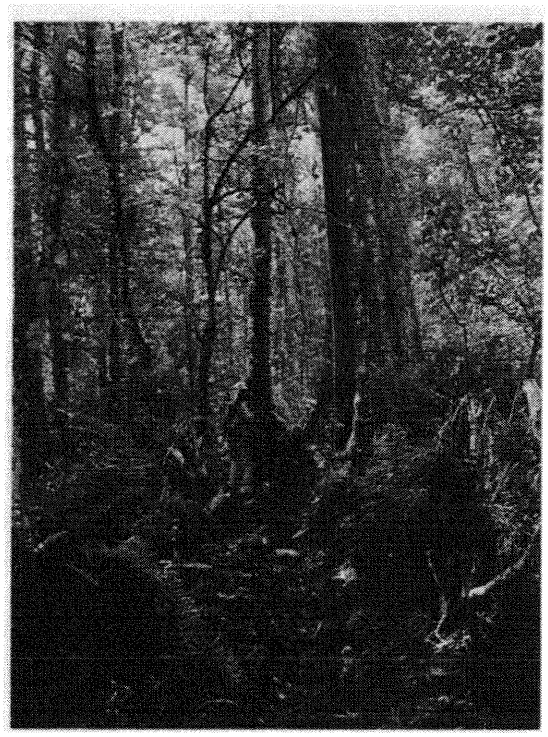

Figure 56. — Fahkahatchee Strand, Collier County, the largest remaining mixed-hardwood swamp in south Florida.

did at the turn of the century because of their successional relationship to cypress forests. The largest and best known mixed-hardwood swamp in south Florida is Fahkahatchee Strand, which covers 180 square miles (460 km^2) in central Collier County and is now owned and managed by the State. Fahkahatchee Strand was logged for baldcypress during the 1940's (Alexander and Crook 1973; Craighead 1971), and the tramways and trestles constructed to extract the logs still form a dense herringbone pattern of dikes which may affect waterflow southward through the strand. Data on floristics, litter dynamics, biomass distribution, and hydrology of the Fahkahatchee Strand are available in the report by Carter and others (1973). There are several other mixed swamp forests in south Florida (primarily in Collier County), but none are as extensive as Fahkahatchee Strand. All of them follow major drainage paths, are generally oriented north-northeast to south-southwest, and have been logged some time in the past.

Mixed swamp forests occupy peats, sands, and rock, as do cypress strands. The hydroperiod is long, often 9 months or more, and in some years the water is above the soil surface throughout the dry season. Since there are no mixed swamp forests in south Florida that have not been affected by drainage or impoundment structures, the presettlement hydrological characteristics of this ecosystem are unknown. In spite of man's activities, Duever, who has been carrying out extensive water-related studies in Corkscrew Swamp for several years, has not been able to document any overall change in the hydrology of the swamp since the area was settled.[19]

The mixed-hardwood swamps of south Florida differ from cypress strands primarily in tree species composition; the sites they occupy are alike in substrate and hydroperiod. The two kinds of forests seem to be closely related, and differences between them probably reflect their ecological histories, including fire and logging. The striking difference between the two kinds of ecosystems is that the cypress strands are dominated by a single species ***(Taxodium distichum),*** with hardwoods constituting a relatively inconspicuous part of the flora. In the mixed swamp forests, on the other hand, *Taxodium* is usually present, but the strand is dominated by a diverse mixture of hardwoods. These commonly include: red maple *(Acer rubrum),* red bay *(Persea* spp.), myrsine *(Myrsine floridana),* dahoon holly *(Ilex* ***cassine),*** pond-apple ***(Annona glabra),*** cabbage palm ***(Sabal palmetto),*** strangler fig *(Ficus aurea),* sweetbay ***(Magnolia virginiana),*** diamond-leaf oak *(Quercus* ***laurifolia),*** and pop ash ***(Fraxinus caroliniana).***

The large baldcypress have been logged out of the mixed swamp forests of south Florida. When no further site disturbance follows logging, hardwoods take over the site, and the result is a hardwood-dominated swamp in which baldcypress are still present but less abundant than before logging. However, cypress appears to be making an impressive comeback in many of these swamps.

In some of the swamps and strands of south Florida, however, logging was followed by fire. Some fires may have resulted from the increased drainage that occurred at about the same time as the logging and some from the construction of tramways that made areas accessible and changed drainage patterns. The logging itself opened the forest and produced large amounts of flammable debris. Many of the postlogging fires were severe enough to consume at least part of the organic soil (Alexander and Crook 1973), modifying the moisture-holding properties of the substrate. After the combination of logging and fire, former swamp forests frequently are dominated by willow ***(Salix caroliniana),*** sometimes accompanied by other wet-site trees and shrubs such as primrose willow *(Ludwigia* spp.), pop ash, and buttonbush ***(Cephalanthus occidentalis).*** This is the case at the southern end of Corkscrew Swamp sanctuary, where a former cypress strand was logged in the mid-1950's and parts of the logged area burned in 1962. Duever and others (1976) and Gunderson (1977), concluded that, in the absence of a cypress seed source and fire, such sites would become dominated by mixed-hardwood swamp forests. Frequent fires, however, probably perpetuate dense tangles of willows (Gunderson 1977; Loveless 1959a) or graminoids (fig. 57).

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[19]Duever, Michael. 1979. Personal conversation. Natl. Audubon Soc., Corkscrew Swamp Sanctuary, Naples, Fla.

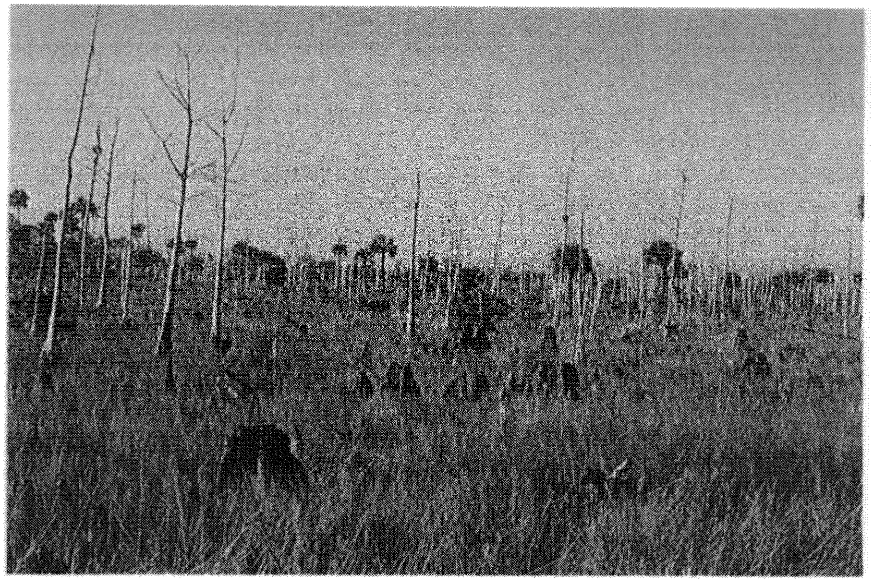

Figure 57. — Graminoids dominate in this logged and frequently burned cypress forest, Golden Gate Estates, Collier County.

The successional relationships among willows, mature mixed-hardwood swamps, and cypress forests are shown in figure 58 (taken from Gunderson's 1977 work). Ewel and Wade concur with the theory that mature mixed-hardwood swamps in south Florida are a fire-free version of the same environments which, with occasional fire, support cypress strands." As one of the most diverse and complex ecosystems in the State, they warrant protection. They contain numerous species not found elsewhere in the United States, including various epiphytes (Buswell 1937; Craighead 1963) and the royal palm (Little 1976).

Mixed-hardwood swamp forests are hydrologically important because, like cypress strands, they occupy the major zones of surface drainage and are the wettest nonsaline forests in south Florida during the dry season.

The cypress and hardwood swamps have probably long constituted one of the main natural barriers to the spread of wildfires. With increased drainage in south Florida, however, there is evidence that the swamp forests are drier than they were previously (Carter and others 1973), so fires now eat away at their edges. During the unusually dry years of 1971 and 1973-75, wildfires penetrated some of these drained swamp forests (fig. 59). Virtually all of the species found in the swamps (except cypress and cabbage palm) are extremely intolerant of tire, so such tires destroy a unique kind of south Florida community. Devastating fires can result in temporary

[17] Duever, M. (see footnote 16, p. 63) states he has not yet found a cypress forest in southwest Florida that did not contain evidence of past fires.

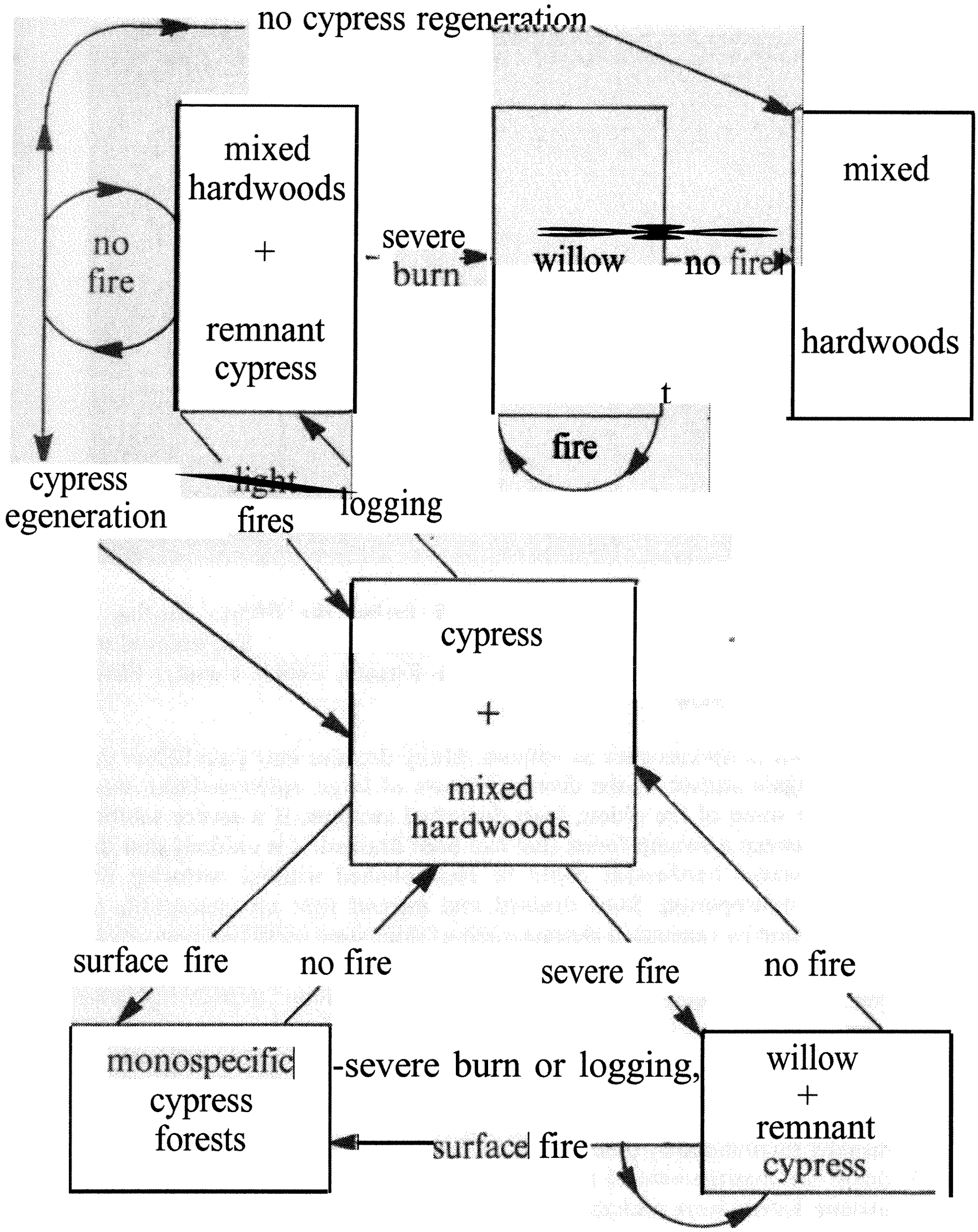

Figure 58. — Generalized successional scheme in south Florida swamps (after Gunderson 1977).

Figure 59. — The cypress was removed during the fifties, creating a hardwood swamp. One side of the road burned in 1974 killing many of the fire-sensitive hardwoods. Golden Gate Estates, Collier County. Photo taken May 1976.

dominance of species such as willows. Many decades may pass before the forests again consist of the diverse mixture of large, epiphyte-laden trees found in some of the oldest, least disturbed swamps. If a severe wildfire were to sweep a swamp forest that had been drained, it is unlikely that the mixed swamp hardwoods could be reestablished without restoring the original hydroperiod. Such drained and burned sites are susceptible to colonization by vegetation characteristic of drier sites, including pine ***(Pinus elliottii*** var. ***densa),*** wax myrtle ***(Myrica cerifera),*** and exotics such as melaleuca ***(Melaleuca quinquenervia)*** and Brazilian pepper ***(Schinus terebinthifolius).***

Because of their ecological uniqueness, hydrologic importance, esthetic appeal, and susceptibility to damage from fire, it is probably advisable to exclude fire from mixed-hardwood swamps in south Florida. They are usually surrounded by pine or cypress forests, so their future depends upon good fire management of these adjacent ecosystems. The edges of mixed swamp forests have probably always expanded and contracted in response to the fire regime in the surrounding lands. There is no reason why extra measures, such as permanent firelines along these ecotones, should be employed to prevent this normal ebb and flow of the borders of the swamp forests. Catastrophic fires, which might easily result in the long-term loss of one of our most complex forest types, should be prevented however. This may be best accomplished by judicious prescribed burning in the surrounding plant communities.

CYPRESS: STRANDS, DOMES, AND DWARF FORESTS

The cypress forests of south Florida cover more than 800 mi^2 (2000 km^2) and have their greatest concentration in the Big Cypress Swamp (McPherson and others 1976). Cypress occurs in many forms in south Florida, ranging from the bonsai-like dwarf cypress to the giant trees, which are the largest living things in the State. Whatever the form of their trees, however, all cypress forests in south Florida appear to have three features in common. All are dominated by a species of ***Taxodium***, and all occur on sites that are, or were, flooded for at least part of the year. Finally, counter to the intuition of most casual observers, all appear to be intimately tied to fire as a natural, recurring environmental factor.

Botanists disagree about the distinction between pondcypress ***(Taxodium ascendens*** Brongn.), which is smaller at maturity and has appressed leaves that are scalelike, and baldcypress ***(Taxodium distichum*** (L.) Rich.), which can be a huge tree at maturity and has leaves that are usually flattened and splayed outward from the twigs. Readers interested in this debate are referred to Craighead;[11] Gunderson (1977); and McJunkin (1977).

Cypress forests constitute a continuous gradient of form and structure, ranging across a variety of substrates, including rock (fig. 60), marl, sand, and peat. The stature of the cypress trees found on a particular site seems to

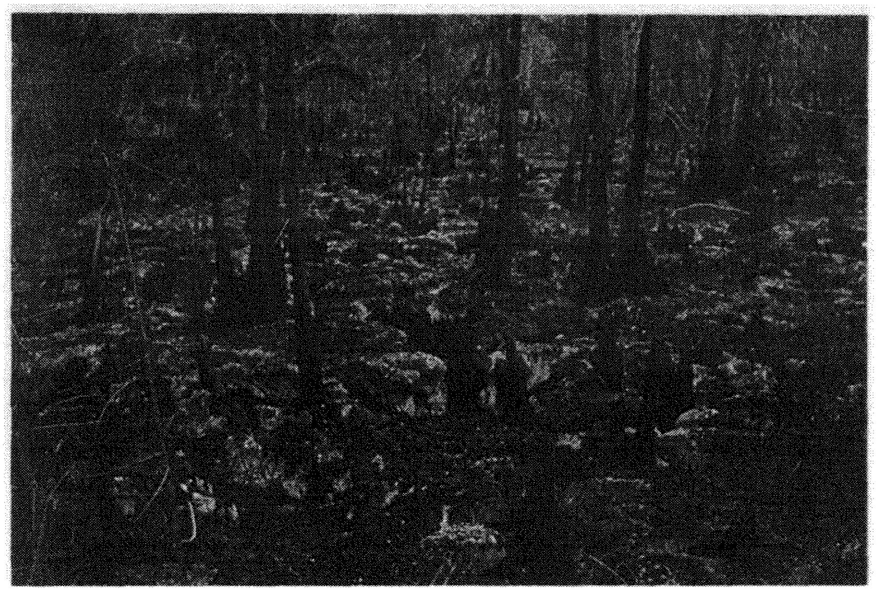

Figure 60. — Cypress growing on exposed cap rock, Gator Den Fire, May 1974. Northwest boundary, Everglades National Park.

[11]Craighead, Frank, Sr. [n.d.]. Unpublished notes on file, Naples, Fla.

be a function of both the substrate and the hydroperiod. Although the form and density of cypress forest represent a continuum (fig. 61), it is convenient to arbitrarily break that continuous gradation into three forest types: dwarf cypress, cypress domes, and cypress strands.

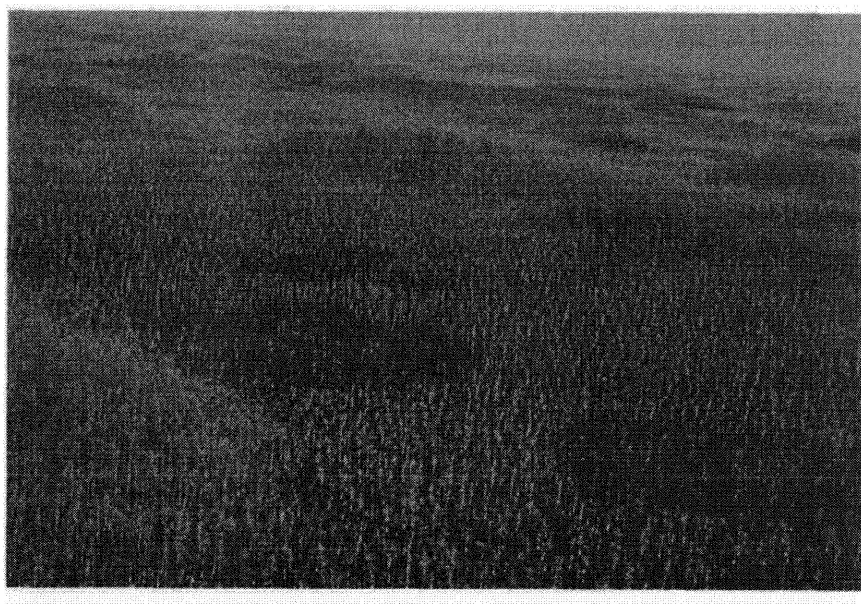

Figure 61. — Cypress forest in eastern Collier County during winter showing undulating waves of leafless cypress. Green patches in the background are tropical hardwood hammocks.

Dwarf cypress forests occupy shallow soils (sand or marl) overlying limestone. The trees are usually less than 12 feet (3.7 m) tall and their diameters at breast height (d.b.h.) are usually less than 4 inches (10 cm), yet ring counts indicate that they may be over 100 years old. Their characteristic silhouette gives rise to the local terms "hatrack" and "bottleneck" cypress (fig. 62). In one such dwarf cypress forest near the Collier-Dade County Jetport site, Ewel found 668 trees/acre (1650 trees/ha), the largest of which was 4.3 inches (11 cm) d.b.h. Egler (1952) reported a crown cover of only about 33 percent in such stands, an observation comparable to Ewel's. The ground cover ranges from scattered to quite complete and consists of a variety of grasses, sedges, and forbs. During the wet season, such sites are usually flooded to a depth of 8 inches (20 cm) or more. Algal mats often cover the soil surface and submerged parts of the herbaceous vegetation. These sites are not very productive, so fuel buildup is slow and fires probably occur only once every decade or two.

Where the soil is deeper, due to depressions in the surface of the underlying limestone, the size of the cypress trees increases. On these depressions, trees are often tallest in the center and gradually taper off toward the

Figure 62. — Dwarf cypress, Everglades National Park.

fringes. Sometimes, particularly in pinelands, the depression is well delineated and tree height changes dramatically, creating a domelike appearance.[19] At other times the change is very gradual, giving the vegetation the appearance of undulating waves when viewed from the air (see figure 61). Cypress trees in domes reach heights of 50 to 60 feet (15 to 20 m) and commonly attain diameters of 12 inches (30 cm) d.b.h. or more (fig. 63). Crown closure is nearly complete and the ground cover is sparse, perhaps partly because there is less light reaching the forest floor than in the dwarf cypress forest and partly because the hydroperiod is longer and the depth of flooding is greater. No long-term shallow-well records are available, but a hydroperiod at least 30 days longer than that of the dwarf cypress forests seems likely. Some understory shrubs, often including coco plum (*Chrysobalanus icaco*), are generally present however. An algal mat is usually absent in the denser cypress forests, probably because of insufficient light for its development. Craighead[20] believes the drought-year tires of the late 1930's, in what is now Everglades National Park, burned out the peat in many cypress domes that are now bayheads.

The third major type of south Florida cypress forest — the cypress strand — is found along major drainage paths (fig. 64), and is thus usually oriented more or less north-south. With the exception of one part of

[19] Many explanations of cypress doming have been suggested. McJunkin (1977) compared various theories in several cypress swamps along the lower southeast coast of Florida; he concluded the theory of differential marginal fire put forth by Kurz and Wagner (1953) best fit the domes he studied.

[20] Craighead, Frank, Sr. 1978. Personal conversation. Naples, Fla.

Figure 63. — Cypress dome interior, Corkscrew Swamp Sanctuary.

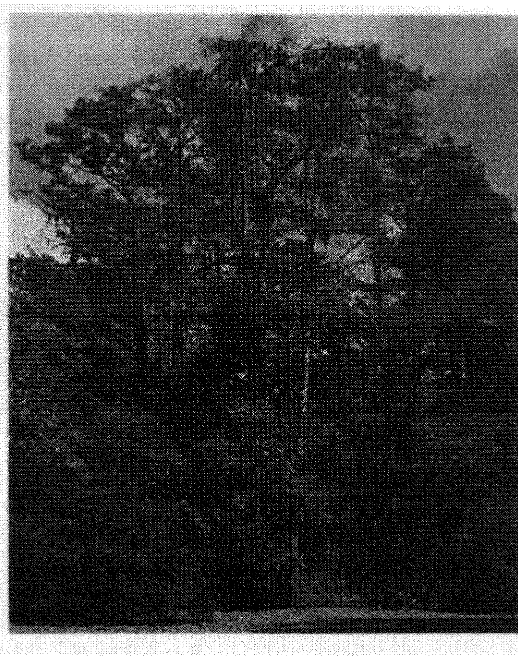

Figure 64. — Cypress strand interior, Corkscrew Swamp Sanctuary. Note the dense hardwood understory void of cypress and the growth of water lettuce *(Pistia strafiotes)* on the water.

Corkscrew Swamp Sanctuary and the Norris Tract (officially called Big Cypress Bend, U.S. Natural History Landmark) just west of Carnestown, all of the cypress strands of south Florida have been logged for the gigantic cypress found there.

Cypress strands are usually associated with relatively deep water during the wet season. Also, unlike the dwarf cypress and cypress domes, the water in cypress strands has a measurable (though very slow) flow rate. The hydroperiod in cypress strands may be 8 months or more (Duever and others 1976), and sometimes the soil is flooded all year. The dominating features of these strands are the huge cypress, many over 100 feet (30 m) tall and 6 feet (1.8 m) in diameter above the butt swell. The woody understory vegetation is quite diverse, much more so than in dwarf cypress forests or cypress domes, which have a shorter fire rotation. Herbaceous vegetation is limited to shade-tolerant ferns, epiphytes, and aquatic macrophytes which grow in the pools of water frequently found near the center of the strand. Common understory hardwoods include red maple ***(Acer rubrum)***, red bay. ***(Persea*** spp.), dahoon holly ***(Ilex cassine)***, pop ash ***(Fraxinus caroliniana)***, myrsine ***(Myrsine floridana)***, sweet bay ***(Magnolia virginiana)***, pond apple ***(Annona glabra)***, and willow ***(Salix caroliniana)***. These species took over many sites after logging, resulting in many of the mixed-hardwood swamp forests found today in south Florida.

Even though cypress occupies seasonally flooded sites and is usually thought of as a swamp tree, available evidence indicates that its continued existence depends on fire. Hare (1961), for example, found that cypress was one of the most fire resistant of the 14 species he tested by measuring the insulation properties per unit thickness of bark. Harper (1914); Garren (1943); and Komarek (1973) have noted that surface fires frequently leave cypress undamaged. Fires sometimes kill the aboveground parts of dwarf cypress trees, but they resprout readily (fig. 65). In a quantitative study, K. Ewel and Mitsch (1978) found that a wildfire which swept a cypress dome in north-central Florida killed most shrubs, hardwoods, and pines but less than half of the cypress trees which dominated the site. Three years after the burn, their study dome was composed almost completely of cypress, although recolonization by hardwoods and shrubs was occurring. The 1954-1955 drought fires in Okefenokee Swamp destroyed much of the adjacent pine, but, except where several feet of peat burned out, few of the larger cypress were killed (Cypert 1961).

Because cypress forests have been so dramatically affected by logging and drainage in south Florida, it is difficult to reconstruct the presettlement relationships between them and fire. It seems likely, however, that the cypress forests in south Florida were exposed to fire in inverse relation to the length of their hydroperiod and depth of wet-season flooding. Dwarf cypress forests, with a forest floor of herbaceous fuel and relatively short hydroperiods, were probably burned more often than were cypress domes. Cypress domes probably burned during some dry years when fire swept the surrounding dwarf cypress marsh or pineland. Monk and Brown (1965) mention that fire has been a continuing influence in the cypress domes of

Figure 65. — Dwarf cypress regrowth 2½ months after the Phantom fire, February 1972, Everglades National Park.

north-central Florida. Cypress strands probably burned very infrequently, yet without occasional fires, one wonders why they did not develop into more diverse forests containing both cypress and a variety of hardwoods. Some environmental factor — perhaps fire — must have helped cypress to capture and hold the site (see footnote 17, p. 64). It may have been a single catastrophic fire, followed by recolonization by cypress, or it may have come about through the action of numerous fires which killed the competing hardwoods and permitted the more fire-tolerant cypress to take over (fig. 66).

Without periodic fire, it is not clear what the fate of the dwarf cypress forests in south Florida would be. There are no unburned tracts of dwarf cypress forest that we are aware of, so the impact of total fire suppression in this vegetation type is unknown. Cypress domes, as opposed to dwarf cypress, have enough soil to support a variety of hardwoods. Without fire they probably become increasingly dominated by hardwoods, and thus change toward various types of bayheads and mixed swamps. Cypress are extremely long lived and still dominate the unlogged part of Corkscrew Swamp and the Norris Tract (see figure 64). These stands, however, show signs of decadence. Many of the cypress are hollow, often with broken tops because of lightning and/or hurricanes. The few cypress seedlings and saplings in the understory are so outnumbered by hardwoods that these stands

Figure 66. — Buttressed cypress at low water, Collier County, April 1974. Note the fire scars on background trees and the stump in photo center.

seem to be slowly headed toward eventual dominance by hardwoods. Some large cypress show signs of fire, but it is not known how extensive or frequent the fires were.

Human activities during the last century in south Florida — including drainage, logging, and severe dry-season burns — have probably had as great an impact on the cypress forests as they have on any other kind of ecosystem in the area. Fires on drained lands have been hot enough or deep enough to kill cypress in many areas, such as in the Golden Gate Estates. Often these burns are colonized by hardwood shrubs (fig. 67) or by pine (fig. 68). Many cypress-dominated lands are also invaded by melaleuca ***(Melaleuca quinquenervia)*** (fig. 69) or Brazilian pepper ***(Schinus terebinthifolius) (fig. 70)*** after disturbance.

Data upon which to base decisions regarding the use of fire in cypress-dominated ecosystems are extremely limited, but some guidelines can be deduced from indirect evidence. Dwarf cypress forests which have not been drastically affected by drainage should probably be regarded as fire types. Low-intensity fires do no apparent damage, but a buildup of surface fuels can result in crown scorch and, in some cases, mortality. It is unlikely that wet-season lightning fires, which sometimes occur in flooded sawgrass, ever occured with any regularity in dwarf cypress forests because most of the herbaceous fuel was either inundated by the floodwaters or too sparse to carry a fire. However, lightning fires were probably common in these forests whenever the water table dropped below ground level. Thus, proper management of lands containing dwarf cypress forests should include prescribed burns. Until more data are available, we suggest low-intensity headfires spaced about 10 years apart.

Figure 67. — Willow has taken over following a fire in a cypress forest, Golden Gate Estates, Collier County.

Figure 68. — South Florida slash pine invading cypress following drainage. Big Cypress National Preserve.

Figure 69. — Mature melaleuca forest occupying a former cypress strand, Lee County. Note the cypress snags.

Figure 70. — Brazilian pepper invading a cypress dome, Lee County.

Fire management of cypress domes should probably be regarded as an incidental side effect of proper fire management in the surrounding dwarf cypress and pine. During a given year, some domes will probably be moist enough to prevent fire from entering, while other domes in the same area may be dry enough to carry fire (fig. 71). There is no reason to think that

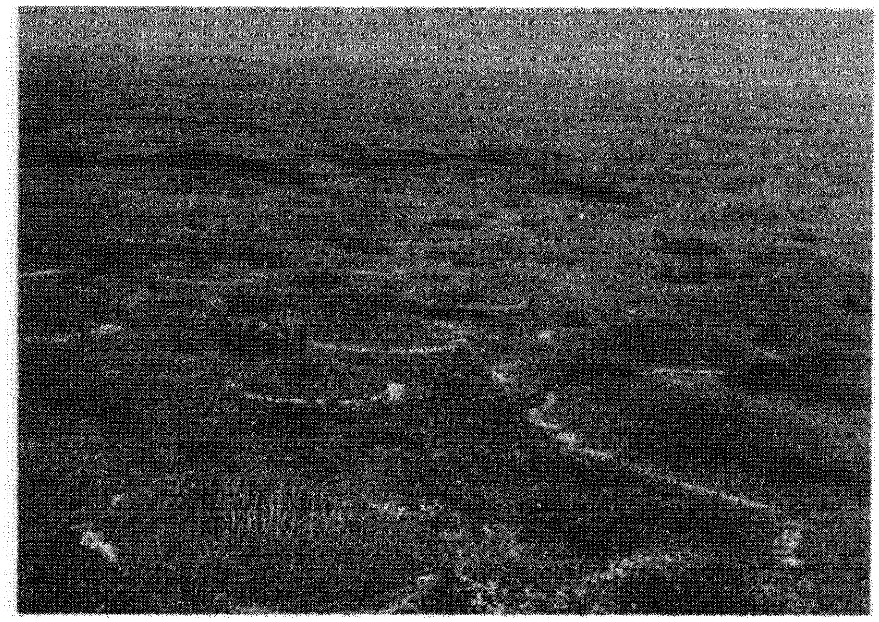

Figure 71. — Big Cypress fire, June 1973. The ring of bare sand encircling each dome is flooded during the wet season and supports a sparse plant growth that dies as the water table recedes during the dry season. These rings act as firebreaks, helping to protect the domes. Note the cypress snags in the dome in the foreground from a previous fire.

this situation is inherently undesirable. There would seem to be little reason to change this basic pattern, which results in a desirable diversity of habitats. A general rule might be to let nature make the decision regarding fire in cypress domes; man must, however, provide the proper range of options by correctly managing fire in the surrounding pinelands or dwarf cypress forests. From time to time the organic soil in a dome may burn (fig. 72). If this natural event is undesirable in the managed ecosystem, it can be prevented by gearing fire activities to organic soil-moisture content. Whenever moisture content is below 65 percent (ovendry weight), fire should be kept out.

Cypress strands require fire management both for their maintenance and for their reestablishment. Stands of huge cypress once formed some of south Florida's most important bird rookeries (Corkscrew Sanctuary is still a crucial nesting site for the wood stork), as well as habitat for numerous

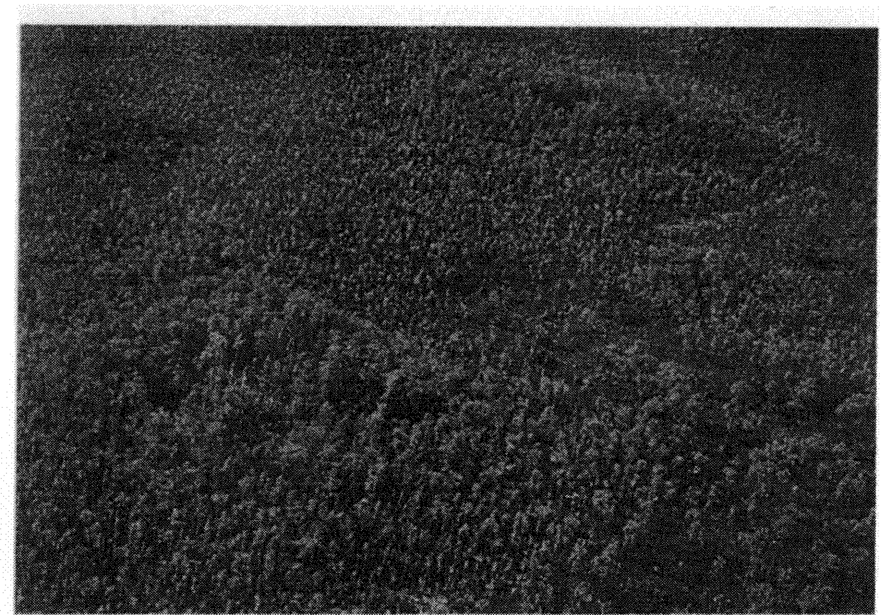

Figure 72. — **Cypress domes showing burned-out interiors, Everglades National Park.**

rare epiphytic plants (including many orchids) and species of wildlife such as the Florida panther and short-tailed hawk. Little and others (1970, p. 63) refer to the Leopold Report (Leopold and others 1969), which discusses the plight of 12 bird species and several mammals, amphibians, and reptiles inhabiting the Big Cypress Swamp and in danger of extinction. Responsible management of south Florida's natural resources should, therefore, probably include attempts to reestablish this kind of community. Drainage and logging have both taken their toll, as have the severe fires which often followed them. The difficulty of reestablishing such stands can be seen by examining figure 58 (taken from Gunderson 1977). This figure shows that the relationship between the strands and various mixtures of hardwoods is intimately related to fire. Too much tire can result in site capture by certain pioneer species, such as willows, whereas too little fire can result in excessive competition from other swamp hardwoods. Seed supply is particularly important because cypress seeds have low viability and are relatively immobile, and the survival of cypress seedlings is quite low (Gunderson 1977; Langdon 1958). Cypress seeds need a dewatering period to germinate, and the seedlings can drown if surface water submerges them (Demaree 1932; Langdon 1958). Without fire, the former cypress strands seem doomed to be replaced — perhaps permanently — by mixed hardwoods.

More so, perhaps, than any other ecosystem in south Florida, cypress requires a finely tuned fire management policy. Fire exclusion is not the best course of action, yet cypress is not as tolerant of and responsive to fire as are some of the other communities, such as the sawgrass glades and pinelands. Whenever a seed source is present, melaleuca tends to invade the ecotone between cypress and pine. With drainage, this ecotone is moving further into the cypress so that even without invasion by melaleuca, the area dominated by cypress can be expected to retreat as pine invades sites that were once too wet for successful colonization.

In north Florida, periodic fires in seasonally dry cypress forests will perpetuate cypress at the expense of any invading pine (Ewel and Mitsch 1978). An intense fire every 2 to 3 decades will kill most of the pine and hardwoods but few of the mature cypress. Removal of a thin layer of organic soil could probably be tolerated occasionally (fig. 73). However, implementation of such a plan would be risky; development of the fire prescription would involve estimates, and the consequences of a wrong decision would be severe. If the fire consumed more organic soil than called

Figure 73. — A shallow peat burn in cypress, June 1971.

for in the prescription, the job of extinguishing the fire would be difficult at best. Yet if the fire continued to burn, it might eliminate the cypress as well as the other vegetation, presenting a scene many people would consider both unattractive and a waste of wood (fig. 74).

An alternative fire management plan calling for frequent fire (perhaps every 3 to 4 years) would have a much better chance of success. Wharton and others (1976) described a somewhat analogous procedure whereby the Indians maintained extensive canebrakes along river floodplains in Florida by regularly firing them. This use of frequent low-intensity fires to maintain the cypress overstory on drained swamplands, however, remains to be

Figure 74. — Aftermath of a May 1974 organic soil fire in cypress, Monroe County.

demonstrated on an operational basis. The pine seedlings would be eliminated before they become large enough to withstand low-intensity tires. Cypress regeneration would also be killed, but the manager would have a century or more to wait for a sequence of several wet years (which occur at approximately IO-year intervals in the Big Cypress Swamp [Little and others 1970]) during which cypress seedlings might be favored over the pine. Duever[21] believes, instead, that drought years favor cypress regeneration over pine because the pine seedlings would have very shallow roots on these normally wet sites and would thus die whenever the water table dropped appreciably below ground level.

Although a definitive tire policy for south Florida's undrained cypress forests cannot be positively stated at this time, the need to develop fire prescriptions for cypress strands is not urgent, since the historic fire interval may have approached a century or two. They can be determined by simply observing vegetative changes after chance wildfires.

[21]Duever, M. 1979. Personal conversation. Natl. Audubon Soc., Corkscrew Sanctuary, Naples, Fla.

TREE ISLANDS: BAYHEADS AND HAMMOCKS

Within the graminoid wetlands are slightly elevated sites, dominated by hardwood shrubs and trees, that stand out in marked contrast to the surrounding herbaceous vegetation (fig. 75). Schneider (1966) estimated that these tree islands comprise 5 to 10 percent of the Everglades land area. They are common in Conservation Area 1, less numerous in the central Glades, and most abundant in the southern Everglades. Tree islands differ from one another in many respects, including topography, hydroperiod, shape, size, and vegetation, but they also share many similarities. They are all elevated above the surrounding terrain; the transition from them to the surrounding wetlands is typically abrupt; and they are all detrimentally affected by fire. Their surface soils are organic, except in the Big Cypress and farther to the west, where they are sandy.

Tree islands are generally divided into two groups — bayheads and hammocks — on the basis of elevation. Hammocks can be further classed as tropical or temperate, depending on species composition. The distinctions among tree island terms are often unclear (see Austin and others 1977 and Robertson 1953). Basically, hammocks, whether tropical or temperate, contain numerous species and occupy the higher elevations. Bayheads occupy the lower, but still slightly elevated, sites with longer hydroperiods; their species composition is limited to plants that can tolerate considerable flooding. Individual heads are usually dominated by a single species such as red bay ***(Persea borbonia)***, sweet bay ***(Magnolia virginiana)***, or baldcypress ***(Taxodium distichum)***.

Figure 75. — Numerous hardwood-dominated tree islands oriented in the direction of waterflow dot portions of the Everglades.

In the central part of the lower Everglades, there are large teardrop-shaped tree islands that contain both bayhead and hammock communities (see figures 14 and 33). These islands are aligned in the direction of surface waterflow; they have a rounded upstream end and a tapered tail extending downstream. The upstream end is elevated above high water and is dominated by a hammock community of tropical and temperate hardwoods. Floristically these tree island hammocks are quite similar to hammocks within the Miami Rock Ridge pinelands except that they are much poorer in species diversity. On many, hackberry (*Celtis laevigata*) is dominant, while on others, particularly in Conservation Area 3A, fig (*Ficus aurea*) dominates. The thin soil is organic and overlies an irregular limestone platform. Swamp hardwoods surround this community and extend down the central axis of the tree island. This vegetation is usually encircled by a band of robust sawgrass, which is narrowest around the hammock and broadest in the tail. The tails, although usually dominated by sawgrass, generally contain several species of shrubs and forbs, as described under the Sawgrass section. Most, if not all, of the island tails are flooded for at least part of the wet season.

Fire will readily carry into the tail, even in the wet season if it contains a high proportion of sawgrass. Wet-season fires in the tail prune back the woody plants but otherwise do little damage (see figure 33). Fire in the hammocks on these tree islands is, however, a different story. The plants there are highly susceptible to fire damage, especially during the dry season, because of their elevated, and therefore drier, organic soils (fig. 76). Dry-

Figure 76. — A 1971 drought-year wildfire burning out a tree island, Everglades National Park.

season ground fires may burn the organic soil down to bedrock, killing all vegetation. Late dry-season fires aggravated by drainage have damaged or destroyed a large number of these communities in recent times, particularly in 1962, 1971, 1973, and 1974 (fig. 77). Sawgrass fires generally go out with the nighttime rise in relative humidity, but the organic soil in the tree islands often continues to burn, reigniting the sawgrass the following morn-

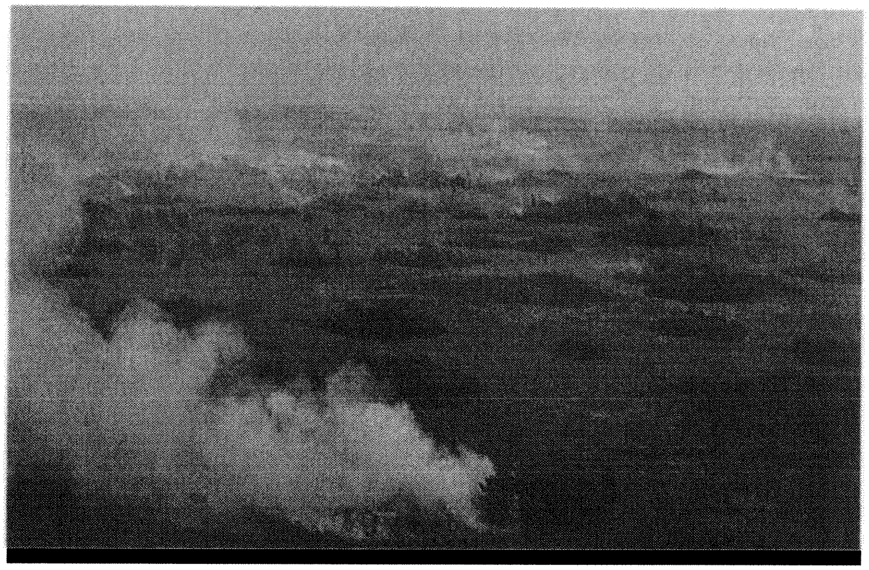

Figure 77. — **Bayheads burning during a June 1973 drought-year wildfire. Dade County. Compare with wet-season conditions in figure 75.**

ing. The sawgrass then carries the fire to other tree islands. One method of controlling this type of fire is to construct handlines around those tree islands already burning, thus confining the fire to them (fig. 78).

Too much water, on the other hand, is just as bad. Many trees in the Shark River Slough were killed by continued flooding in 1968 and 1969 (Craighead 1971), a result of excessive water release from the conservation areas (fig. 79). Tree islands in the southeast quarter of Conservation Area 3A have also been severely impacted by continued flooding (Alexander and Crook 1975).

The only practical large-scale means of protecting these tree islands is to maintain the historic hydroperiod as closely as possible and to burn the surrounding sawgrass, by prescription, when the hammock soils are too wet to ignite (see figure 33). Fire prescriptions are as outlined under the section on Sawgrass Communities. Ignition from a helicopter is often advisable (see figure 32). Aerial ignition provides an excellent overview of the terrain. Potential trouble spots can be easily seen, ignition patterns quickly determined, and spot tires rapidly set. Ignition placement, sequence, or timing can be easily altered if the spot fires do not behave exactly as anticipated.

Figure 78. — Bayheads already on fire were burned out from encircling handlines to confine the fire to them. A helicopter was used to ferry the crew between bayheads. Aerojet fire, Everglades National Park, April 1974.

Figure 79. — Hardwood trees killed by continued high water, Everglades National Park. Photo taken June 1970.

Further, a large number of tree islands can be surveyed and their borders burned on a given day with this procedure.

Large, elongated, north-south oriented tree island strands are also present in Conservation Area 1 (fig. 80). Common plants on these islands are: sweet bay, red bay, dahoon holly ***(Ilex cassine),*** wax myrtle ***(Myrica cerifera),*** willow ***(Salix caroliniana),*** elderberry ***(Sanbucus simpsonii),*** swamp fern ***(Blechnum serrulatum),*** royal fern ***(Osmunda regalis)*** briars ***(Smilax*** spp.), and aster ***(Aster caroliniensis).*** The surface of these islands is very irregular and barely elevated above the surrounding graminoid wetlands. Thus, standing water is present much of the year. The increased water level and lengthened hydroperiod in Conservation Area 1 for the past decade make damaging wildfires unlikely on these islands. Tree islands were, however, occasionally eliminated by fire under previous hydrologic conditions. Burned-out tree strands are occupied by submerged and floating aquatic plants, cattails, or sawgrass, depending on the degree of peat loss.

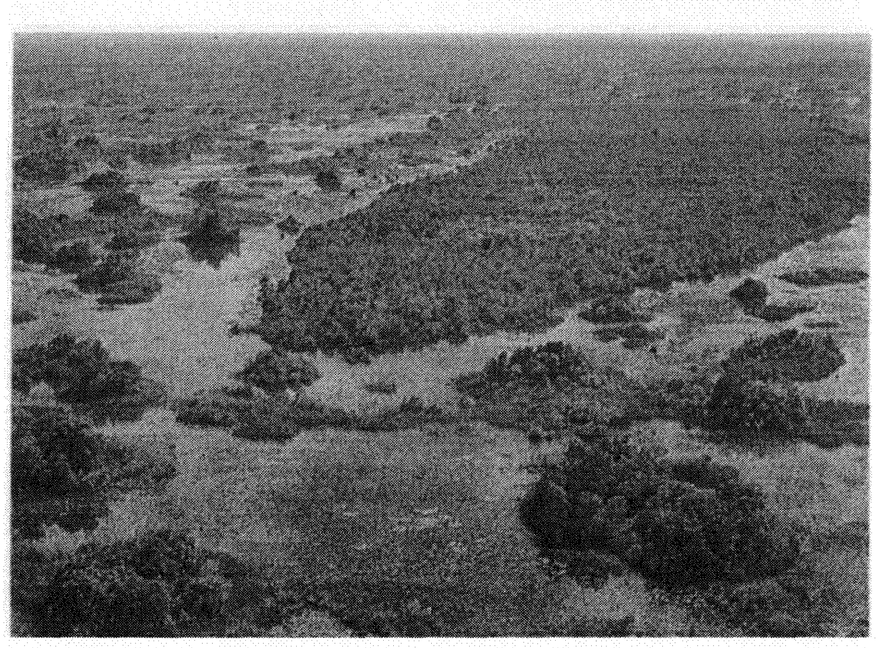

Figure 80. — Circular bayheads, tree strands, and graminoid wetland communities in Conservation Area 1.

BAYHEADS

In Conservation Area 1, small circular bayheads predominate (see figure **80).** They are elevated 2 to 3 feet (0.6 to 1 m) above the surrounding wetlands (Loveless 1959b), and their platforms do not have limestone bases, as is the case farther south. Bases are organic, often 9 to 12 feet (2.75 to 3.7 m) deep. It is quite possible they formed over natural basins in the limestone. Soil cores suggest that these tree islands are not attached to the underlying limestone and, thus, rise and fall with the water table.[22] Sweet bay, red bay, and dahoon holly are usually present, while royal fern and cinnamon fern ***(Osmunda cinnamonea)*** are common in wetter depressions, particularly around the edges of the platforms.

These islands may have sawgrass perimeters, but they are usually isolated by a slough which fire is not likely to cross except during the dry season. The presence of fire scars on older trees that predate the present high-water conditions suggests that fires do not necessarily burn out these islands completely, particularly if ignition is by lightning during the wet season. However, drought-season fires undoubtedly destroy the island. The ensuing ground tire consumes the organic soil to a depth that approaches the water table. A depression that fills with water and aquatic species during the wet season replaces the bayhead.

Gleason and Stone[23] have shown that large blocks of peat break loose during high water and pop to the surface, resulting in topographic highs. that are colonized by shrubs and small trees. These floating islands are called batteries (fig. 8 1).

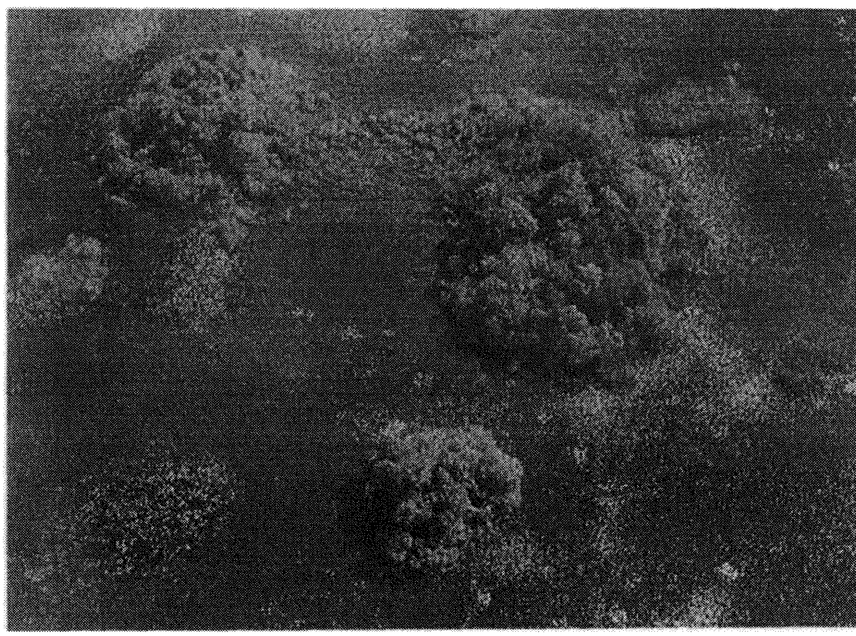

Figure 81. — Floating batteries of peat supporting mesic vegetation. Waterlilies colonize the depressions previously occupied by peat, Conservation Area 1.

[22]Craighead, Frank, Sr. 1979. Unpublished data on file, Naples, Fla.

*Gleason, P., and P. Stone. 1978. Unpublished data on file South Fla. Water Manage. Dist., West Palm Beach, Fla.

Small circular heads are also common on the marl prairies of the lower eastern Everglades (see figure 77). These islands are dominated by cypress, coco plum *(Chrysobalanus icaco)*, willow, sweet bay, red bay, or by exotics such as Australian pine *(Casuarina* spp.) and Brazilian pepper *(Schinus terebinthifolius)*. Many of these heads have a narrow margin of sawgrass, coco plum heads being the common exception. The floors of most are slightly elevated, but some of the smaller ones remain flooded into the dry season. During the wet season, these tree islands rarely carry fire. Vegetation in the surrounding wetlands is usually sparse, so the fuel load is low. However, these wetlands have a well-developed algal mat (see figure 38). When dry, this periphyton can smolder imperceptibly (see figure 39), slowly carrying fire considerable distances to denser graminoid stands and to tree islands (fig. 82).

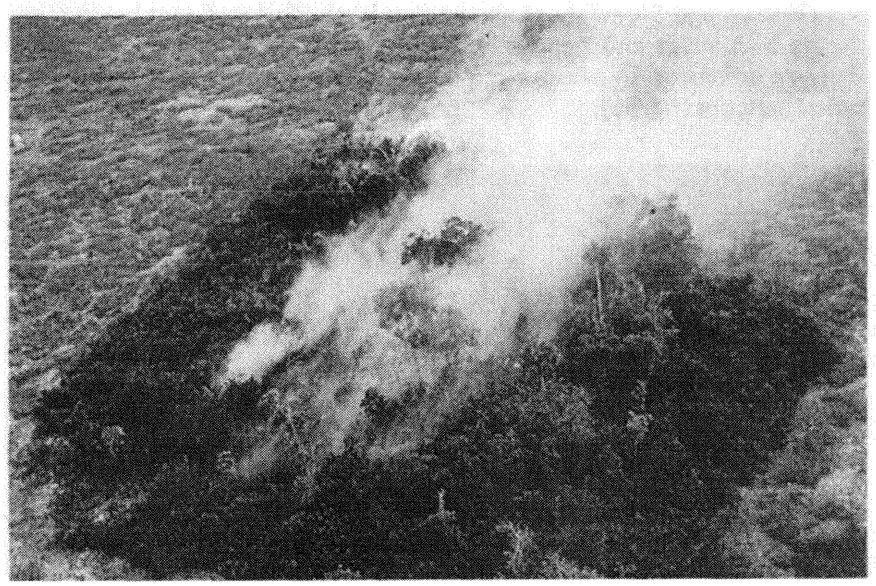

Figure 82. — A tree island burning out during a 1971 drought-year wildfire.

These islands have suffered extensively from tires, most recently in the early 1970's, because of the shorter hydroperiod and, thus, the more prolonged and severe dry season. If tire enters these heads, they are usually completely destroyed because the organic soil ignites and burns to bedrock (fig. 83). The 6- to lo-foot-deep (1.8 to 3 m) peat-filled cavities, created as the limestone is dissolved by organic acids, are also emptied of their plant material by these fires. The holes fill with precipitation and become permanent dry-season sources of water for wildlife (Robertson 1953). Circular areas of elevated limestone, occasionally with a few remaining typical tree island plants, mark the locations of former heads (fig. 84).

Another indicator of burned-out tree islands is very conspicuous from

Figure 83. — **A May 1974 drought-year wildfire consumed the vegetation and humus. Wind and rain will remove the ash, exposing underlying limestone. Everglades National Park.**

Figure 84. — **Limestone platforms mark the location of burned-out heads in the lower Everglades.**

the air — rings of saw-palmetto ***(Serenoa repens)*** that occur in the higher wetlands of the Everglades National Park (fig. 85). Here, palmetto often forms the outer perimeter of tree islands. During the dry season, fire will burn through the palmetto and ignite the interior peat. As the fire burns the soil from around roots, the trees and shrubs topple over and are consumed (see figure 83). According to Craighead (1970), these organic soil tires have little effect on the palmetto rootstocks; they soon resprout, forming the characteristic ring of palmetto.

Figure 85. — A ring of saw palmetto is all that remains after a tree island peat fire. Everglades National Park.

Particularly in Conservation Area 2B (fig. 86), drought and subsequent fire resulted in the establishment of dense melaleuca heads. High water levels have been maintained since then, however, temporarily slowing expansion of this species.

Small elongated, somewhat teardrop-shaped tree islands dominated by either cypress ***(Taxodium distichum)*** or bayhead species dot the landscape in lower Taylor Slough, Everglades National Park. Unlike the cypress domes and strands of the Big Cypress, these tree islands generally have higher ground in the center. The largest trees sit atop the deepest soil-filled depressions in the limestone. The surrounding wetland has a well-developed algal mat, and the vegetation is generally ***Muhlenbergia*** prairie, or sparse sawgrass often interspersed with scrub cypress. These islands, too, have suffered the consequences of increased fire, particularly during drought years, as a result of altered hydrologic conditions (fig. 87).

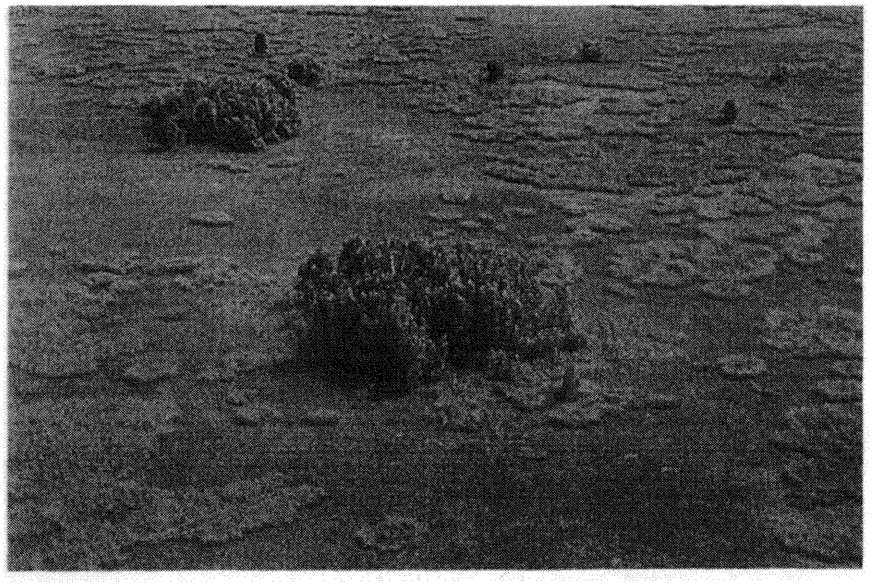

Figure 86. — Melaleuca heads and scattered individuals, Conservation Area 2B. Photo taken April 1976.

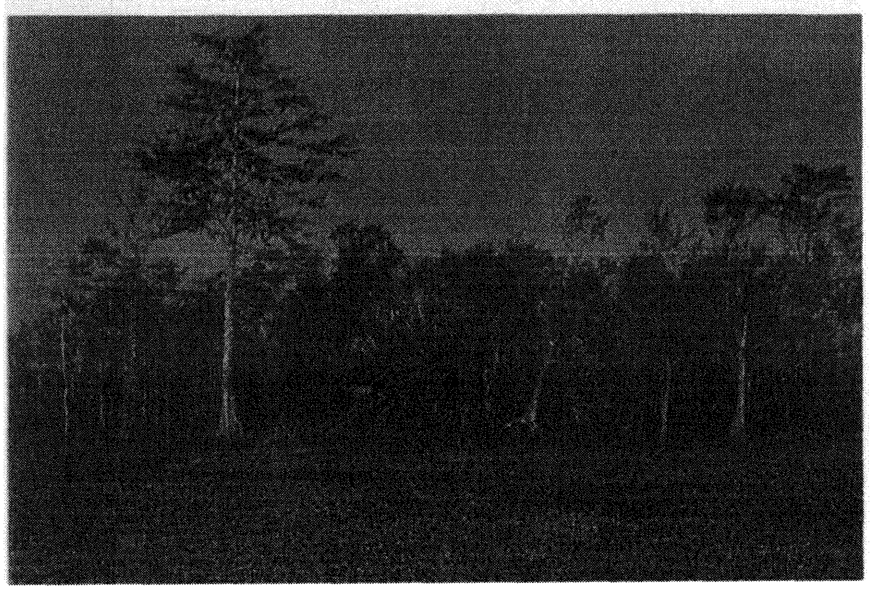

Figure 87. — Tree island damaged by a May 1966 wildfire, Everglades National Park.

The increased frequency of tree island fires has resulted in a concomitant increase in willow on those sites (Craighead 1971; Loveless 1959b). In fact, many burned-out bayheads are now willow heads. Here, willow forms dense thickets in the partially burned-out depressions which tend to remain wet long into the dry season. The outer edges of many other tree islands now have a large willow component. If enough willow is present, it tends to protect the island interior because, although fire will prune back willow, it does not readily penetrate dense stands. Many willow areas were originally sawgrass, then farmed, and finally abandoned because of salt intrusion.[34] The area of willow is expected to increase throughout much of the Everglades, particularly where peat and muck soils prevail, because the shortening hydroperiod results in fires preparing a good seedbed-in early spring when willow seeds are disseminated. The increased area of willow is beneficial to deer because it provides good escape cover as well as good browse.

According to Craighead (1971), willow heads commonly form after fire on elevated sites subject to periodic flooding and adjacent to a permanent source of water such as a solution hole, basin, or slough (fig. 88). "Willow heads are one of the most favored habitats of alligators and they, in turn, do much to maintain the depressions, which otherwise would quickly fill with organic matter . . ." (Craighead 1971, p. 137). These depressions are important for wildlife survival during the dry season.

Figure 88. — Willow head and gator hole during the severe drought of 1965.

Loveless and Ligas (1959, p. 205) state "tree islands are the key to an understanding of the ecology of Everglades deer. Without these elevated sites that provide refuge and forage during unusually high water levels, it is unlikely that deer could exist for any extended period of time in this environment."

[34] Craighead, Frank, Sr. 1978. Personal conversation. Naples, Fla.

A relatively short interval exists between the time when a particular tree island is too wet to burn and when the peat soils are too dry to safely burn. Moreover, burning will result in plant species changes that may not be compatible with other management objectives. Craighead (1974) states, that, in general, tree islands become susceptible to fire whenever the water table drops more than 2 feet (0.6 m) below ground level. Prescribed burning to promote willow and other preferred browse species is a viable wildlife management tool in many areas — but not on south Florida tree islands under present conditions! Preservation of the tree islands is crucial to the well-being of the Everglades deer; they can survive without willow but need high ground for escape, resting, foraging, and fawning.

HAMMOCKS

The high hammocks of the Miami Rock Ridge differ from other south Florida tree islands. Here, the adjoining vegetation is typically south Florida slash pine (*Pinus elliottii* var. *densa*). These hammocks are rarely flooded, if ever, and, were it not for fire, hardwoods would be the climax' vegetation. Miami Rock Ridge hammocks originated on older limestone that is 1 to 4 feet (0.3 to 1.2 m) higher, is harder, and contains more numerous solution holes than the surrounding rock (Craighead 1974). Solution holes are the most pronounced feature of Miami polite and are created as organic acids dissolve the limestone (fig. 89). John K. Small (1909), a pioneer south Florida botanist, made the classic statement that the

Figure 89. — Solution hole in the Miami Rock Ridge. Repeated fires have consumed the organic matter that once filled these holes.

surface consists mostly of holes. They come in all shapes and sizes up to 20 feet (7.5 m) deep and 30 feet (9 m) wide; many are interconnected by a maze of subterranean passageways. Organic matter once filled these potholes, but lowered water tables have allowed fire to consume most of the humus. As this humus is burned off by repeated fires, the areas become very difficult to walk on and the exposed, highly irregular limestone is referred to as pinnacle rock.

Craighead (1971) estimated there were once more than 500 of these hammocks ranging in size from ¼ acre to over 100 acres (0.1 to 40 ha). Davis (1943a) reported 140,000 acres (56,650 ha) of "hammock forests" in southern Florida. In some of the larger hammocks, nearly 100 species of trees and shrubs have been identified, not to mention the numerous forbs, graminoids, vines, ferns, and epiphytes (Schneider 1966). The species composition of these hammocks is variable, but among the more common trees are: wild tamarind ***(Lysiloma latisiliqua),*** live oak ***(Quercus virginiana),*** pigeon plum ***(Coccoloba diversifolia),*** gumbo-limbo ***(Bursera simaruba),*** poisonwood ***(Metopium toxiferum)*** bustid ***(Bumelia salicifolia),*** stoppers ***(Eugenia*** spp.), strangler fig ***(Ficus aurea),*** mastic ***(Mastichodendron foetidissimum),*** black ironwood ***(Krugiodendron ferreum),*** paradise tree ***(Simarouba glauca),*** and satinleaf ***(Chrysophyllum oliviforme).*** Because of the lack of light under the dense canopy, the floor is not densely vegetated, and the stand microclimate tends to be more humid and has less diurnal temperature fluctuation than the surrounding pineland. The hammock.soil has a higher percentage of organic matter and tends to be deeper than that of the surrounding pineland.

These hammocks are well known for the beautifully colored tree snails ***(Liguus)*** that inhabit them. Some varieties are now extinct, many are rare and endangered, and all are susceptible to fire (Craighead 1974).

Hardwood shrubs and trees are a normal component of pinelands. Without fire, they would rapidly increase in number and stature, resulting in a reduction in the amount of light reaching the forest floor. Conditions would become less favorable for pine regeneration, and species composition would soon be predominantly hardwood, with pine found only in the overstory (figs. 90A and 90B). Fire prevents this succession of pineland to hammock by killing the hardwood stems, or pruning them back to the ground. Many of the hardwoods that are well established will produce new shoots from roots and from the base of the trunk (fig. 91), utilizing food reserves present in the roots. This condition is more common if fire has not occurred for several years than if fire has been more frequent (Hofstetter 1973). Where surface fires are frequent in the pineland, the transition from pineland to hammock is abrupt. But, when fire is absent for more than 8 to 12 years, there is often a continuum from pineland to hammock (Alexander and Crook 1973, 1975).

Within 5 years, many of the understory species, including several endemics, are shaded out (Robertson 1954), and the succession to hammock with a remnant pine overstory is virtually complete after 15 to 25 years of tire exclusion (Alexander 1967; Robertson 1953). Once this point is

Figure 90. —Pineland succession to hardwood: A, 1953 photo; B, 1979 photo of the same cat-faced pine after 25 years without fire.

Figure 91. — Sprout development of pineland hardwoods following a prescribed fire. Note the exposed limestone. Everglades National Park.

reached, most fires will not penetrate the hammock. Under servere burning conditions, however, fire is capable of crossing the largest hammocks, killing many of the hardwoods and consuming the organic soil (Robertson 1953). This opens up the canopy and allows establishment of pine seedlings, but most of the hardwoods sprout prolifically from their root systems, outgrowing and shading out the pine seedlings. However, Craighead (1974) states that the composition of these second-growth stands is usually quite different from that of the original vegetation; in particular, bird droppings result in a large increase in berry-producing species. Further, much of the arborescent vegetation is at least. partially anchored in the peat-filled solution holes. If enough of the peat is consumed during a fire, the shrubs and trees loose their mechanical support and topple over (see figure 83).

The combination of hurricanes and fire can cause havoc in these high hammocks, just as they do in mangrove forests. Craighead and Gilbert (1962) mention that severe fires followed the 1935 hurricane, totally or partially destroying many inland hammocks. Altered water tables have had the same deleterious impact on these high hammocks as they have had on all other south Florida tree island types. Lowered soil moistures have increased the period during which peat-filled solution holes are susceptible to fire. Further, on the higher parts of the ridge, wilting of at least some shrubs and broad-leaved trees is now common during much of the dry season.

If the management objective of a particular area is to arrest succession and return it to pine, fire is an efficient means of doing so. The required intensity of the first fire and the time interval between the next several burns will depend upon how long fire has been excluded. Further discussion of these burning intervals can be found under the Miami Rock Ridge Pinelands Community.

In contrast to the high hammocks of the Miami Rock Ridge are the low hammocks found on the marl prairies of the extreme southern Everglades. These are characterized by one of two species: mahogany *(Swietenia mahagoni),* which cannot tolerate long hydroperiods as can bayhead species, or the rare paurotis palm *(Acoelorrhaphe wrightii).* These low hammocks are surrounded by moats which, in conjunction with the sparse surrounding vegetation and its long hydroperiod, protect them from fire except during prolonged droughts. No evidence of past fires has been found in these low hammocks. Craighead[25] sectioned two unscarred mahogany trees, after they were blown down in hurricane Donna, and estimated their age at 225 years.

In southwest Florida, tree islands are found on sandy peat overlying rock outcrops and surrounded by marsh, or on fairly deep sand ridges that occur near cypress strands. Common species include: bay, red maple *(Acer rubrum),* cabbage palm *(Sabal palmetto),* and water oak *(Quercus nigra)* (fig. *92).*

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[25]Craighead, Frank, Sr. 1978. Personal conversation. Naples, Fla.

Figure 92. — A tree island dominated by cabbage palm in southern Collier County.

PINE FLATWOODS

Pine flatwoods occupy more area in south Florida than any other kind of community except the Everglades marshes. Although they have been reduced to about half of their former extent (Birnhak and Crowder 1974) because of agricultural and urban development, they still dominate most of the Western Flatlands, including significant portions of Lee, Hendry, and Collier Counties. The pine flatwoods are one of the most economically important communties in south Florida, both because of the extensive area they occupy and because they are the mainstay of the timber and cattle industries.

South Florida slash pine (*Pinus elliottii* var. *densa*) is the dominant tree here, as it is in the east coast flatwoods and on the Miami Rock Ridge.[28] The east coast flatwoods are lumped with the west coast flatwoods in this discussion because they are very similar, even though separated by the Everglades. Perhaps the most conspicuous difference is that more tropical species are represented in the east coast understory.

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[28]Longleaf pine (*P. palustris*) and sand pine (*P. clausa*) are also found in south Florida but occupy very restricted areas. Longleaf pine is found on some dry flatwoods in Lee and Hendry Counties, and is very similar to south Florida slash pine with respect to fire. Sand pine is found associated with xeric oaks and other shrubs on eolian sand dunes. Fire generally does not enter sand pine stands except under a complex combination of fuel and severe weather conditions (Hough 1973). When conditions are right, however, fire will crown through the sand pine, killing the trees but opening the serotinous cones and thus paving the way for dense stands of reproduction. Most sand pine vegetation in south Florida has yielded to urban development. A few small patches remain within the city of Naples on the west coast and several remnant stands can be found in Palm Beach County on the east coast.

The dry prairies which no longer contain pine trees (and perhaps some of them never did), but which support shrubs and herbs typical of the surrounding flatwoods, are also included in the pine flatwoods category. The pine forests of the Miami Rock Ridge, on the other hand, are discussed separately from the flatwoods, for two reasons. First, the substrates in the two areas differ dramatically. The pine flatwoods have a higher water table and occupy acid sands, usually accompanied by a spodic horizon, or hardpan, whereas the pine forests of the Miami Ridge occupy elevated exposed limestone and are rarely subjected to more than short-term localized flooding. Second, there are marked floristic differences between the understories of these two forests. The flatwoods contain herbs and shrubs which, for the most part, are typical of other slash pine flatwoods communities, such as the *Pinus elliottii* var. *elliottii* forests of northern Florida. The pine forests on the Miami Rock Ridge, however, contain an understory dominated by tropical species and have a large number of endemic herbaceous species.

The taxonomy of *Pinus elliottii* var. *densa* is not yet settled,[27] and this variety appears closer in certain ecological characteristics to *Pinus caribaea*, (which it was earlier reported to be (Small 1913) and which occurs in the West Indies), than to *Pinus elliottii* var. *elliottii*, which is common farther north in Florida (Mirov 1967). Squillace (1966) reported that the two varieties of *P. elliottii* differed appreciably in several traits, but he concluded that they were not discrete genetic entities because the patterns of variation were characterized by continuity. McMinn and McNab (1971) and Squillace (1966) found that the south Florida variety was more variable in several respects than was the northern variety. Squillace (1966) suggested this plasticity may be the result of its evolution under severe environmental factors, such as the flood and drought conditions of south Florida's pine flatwoods which probably fluctuate widely over time.

The pine flatwoods of southern Florida occupy a variety of sites. In some places they are found on deep sands that are seldom inundated. At other places, the pine flatwoods exist as part of a mosaic where they share the landscape with cypress forests. Variation also results from past land use. One of the main activities that changed the pine flatwoods of south Florida was the logging which began in the 1920's and continued through World War II. After logging, the herbaceous and shrub components recuperated rather quickly, but the pines were slow to regenerate on some areas. The best regeneration is often observed around pond margins and in topographic depressions, while the drier upland flatwoods areas often remain pine free for very long periods. In some areas, logging and subsequent fires eliminated the seed source necessary for recolonization. Pine has still not reestablished itself on some of these sites. Saw-palmetto (*Serenoa repens*) now dominates many sites formerly occupied by pine, often to the extent that such areas are called palmetto prairies. Some of these prairies

[27] See Little and Dorman (1954) and Squillace (1966) for a thorough discussion of the subject.

may have once supported pine forest, though evidence is fragmentary because the pine stumps were either removed for turpentine distillation after the logging operations or consumed by fires. Other areas may have always been too dry for successful pine establishment and thus never supported any vegetation other than their present-day cover of saw-palmetto, grasses, and forbs. Pines can sometimes be established on such sites by planting seedlings, which bypasses the crucial seed-germination and establishment phases of tree growth. Wherever a dense palmetto cover exists, however, fire frequency and intensity are such that few young pines survive.

The depressions created by stump removal for naval stores, or by fires that burned out the resin-soaked virgin pine root systems, are wetter than the surrounding flatwoods. These moist depressions are favored sites for melaleuca establishment in pine flatwoods.

Another historical force that has shaped the pine flatwoods over the past 400 years is grazing (fig. 93). The pine flatwoods are the major range community of south Florida, and range management practices, including stocking rates and burning, have undoubtedly had an important impact on the landscapes we see there today. Very short burning rotations (1 to 3 years), which are commonplace in south Florida, virtually eliminate pine seedlings. They perpetuate the palmetto prairies and convert acreage to prairie as the mature pines die or are harvested.

Manipulation of historical water levels has also affected the pine flatwoods. Its effects have been less dramatic on the drier pine flatwoods, however, than on the wetter ecosystems such as cypress forests and marshes. Drainage has affected the area occupied by pines in south Florida

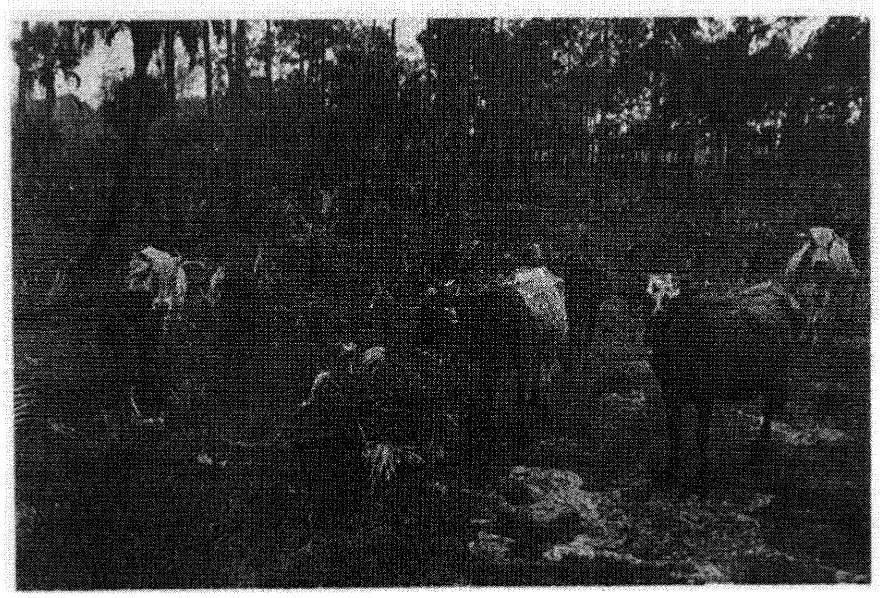

Figure 93. — Range cattle on a fresh burn, Collier County.

in two ways. Drainage of lowlands, especially those occupied by cypress and mixtures of pine and cypress, has resulted in an expansion of the pine into these areas. This is very evident in areas such as the Golden Gate Estates (see figure 68). This ecotone between pine and cypress is also very susceptible to invasion by melaleuca if a seed source is nearby. While drainage results in the expansion of pines into areas which would otherwise be too wet for its growth, it may also result in conditions too dry for pine establishment and survival on the driest sites formerly occupied by pine. These areas, now occupied by palmetto-dominated prairie vegetation, may thus be more extensive than they were prior to logging and drainage.

The site differences and stand histories together have produced flatwoods communities that are quite variable in both the status of the pine overstory, and the density and composition of the understory. Pine density ranges from completely absent to high enough to produce a closed canopy. Pine trees are usually abundant enough to dominate the landscape, yet not so close that their crowns touch (fig. 94). The ground cover, therefore, receives nearly full sunlight.

Figure 94. — Typical pine flatwoods with a south Florida slash pine overstory and palmetto-grass understory, Lee County.

This prevailing condition of open pinelands does not mean that management of south Florida slash pine for wood products cannot be economically attractive. For example, one plantation on an abandoned tomato field in southern Lee County contained over 27 cords/acre (242 m^3/ha) at age 16. This is excellent growth, considerably better than that on at least one of which was severe enough to destroy most other stand components (fig. 95).

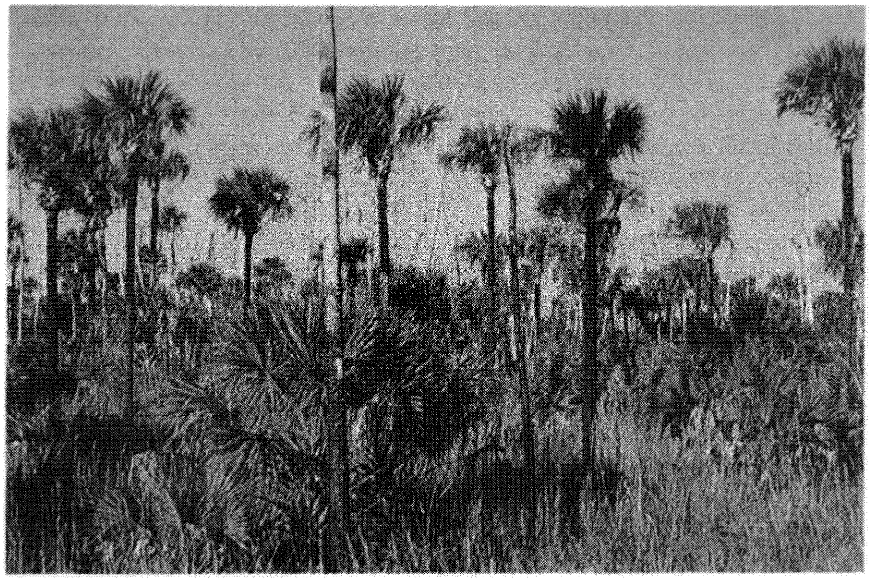

Figure 95. — A cabbage palm-graminoid dominated site indicative of frequent fires, Golden Gate Estates, Collier County. Note cypress snags in the background.

Melaleuca is more closely associated with fire than any native species in south Florida. Its foliage contains essential oils that are flammable (fig. 96), and it often forms extremely dense stands of several thousand stems/acre (5,000 stems per hectare) (fig. 97) which are conducive to crown fires. Fire is transported into the canopy by the loose outer-bark layers (fig. 98) which hang from the trunk and larger branches (see figure 69). This material makes excellent firebrands. Defoliation results in a profusion of both basal and epicormic sprouts (fig. 99). Because of these fire-related traits, and others mentioned in the Sawgrass section, native species do not stand much chance of being represented in the new stand if melaleuca was present and postfire hydrologic conditions are conducive to the germination and establishment of just a small portion of the millions of seed that are invariably disseminated (fig. 100).

The understory vegetation, like the overstory of pine trees, is also well adapted to fire. The aboveground parts of the herbaceous plants make up most of the fuel in the south Florida pine flatwoods, but following fire they rapidly recover, both from seed and by sprouting. Saw-palmetto can be held in check by the continued use of fire, but it inevitably recovers and cannot be eliminated by burning.

most land managed for timber in southwest Florida, but it does illustrate the potential of this species.**

Hilmon (1964) listed nearly 200 plant species he encountered on 400 plots in the pine flatwoods of southwest Florida. Of these, 10 were particularly common. Five of_ the 10 were typical "wiregrasses", pineland threeawn (*Aristida stricta*), bottlebrush threeawn (*A. spiciformis*), broomsedge (*Andropogon virginicus*), little panicum (*Panicum polycaulon*) and goobergrass (*Amphicarpum muhlenbergianum*); three were sedges, common beak rush (*Rhynchospora fascicularis*), thread beak rush (*R. filifolia* Gray), and little razorsedge (*Scleria georgiana*); the other two were sundew (*Drosera capillaris*) and saw-palmetto. Saw-palmetto was the most common shrub, while pineland threeawn occurred on virtually all sample plots except those in freshwater marsh.

Fire presumably has always been a natural component of the pine flatwoods. This community is a fire climax, and the species found here are fire adapted. Fuel adequate to carry a fire builds up every few years, and historically was ignited by lightning. A recent analysis by Maier (1977) shows that southwest Florida is the thunderstorm capital of the United States, and that 75 percent of these storms occur from June through September. Summer thunderstorms must have produced a large number of small (<25-acre [10 hectare]) fires, as they do today, but those that occured during the dry season, even though fewer in number, undoubtedly burned most of the acreage. Modern civilization put an end to these extensive low-intensity fires through its fire-control efforts and construction of obstacles, such as roads and canals. However, the increase in population has resulted in an accompanying increase in the number of fires. The presence of large numbers of tourists early in the dry season together with extensive drainage may result in fires occuring earlier in the dry season than in the past. In other ways, however, the current fire pattern may differ little from the historic condition.

South Florida slash pine growing on sand is extremely fire tolerant, much more so than the northern variety. Ketcham and Bethune (1963), for example, reported on slash pine survival after a fire swept an experimental area 2 years after planting. They found that almost a third of the south Florida slash pine survived on those plots that were site prepared by burning, whereas none of the typical variety survived. Seedlings of south Florida slash go through a grasslike stage, much like longleaf pine, that greatly increases their resistance to fire. Likewise, older trees of the south Florida variety are more fire tolerant than are mature individuals of the typical variety. They sometimes recover after being completely defoliated by wildfire. In fact, the only native species that rival the tire tolerance of south Florida slash pine are longleaf pine and cabbage palm (*Sabal palmetto*). Those sites dominated by a herbaceous understory and cabbage palm overstory are indicative of very frequent fires (perhaps 1 to 3 years apart),

**Forest management planning assistance is available from Florida Division of Forestry District Offices.

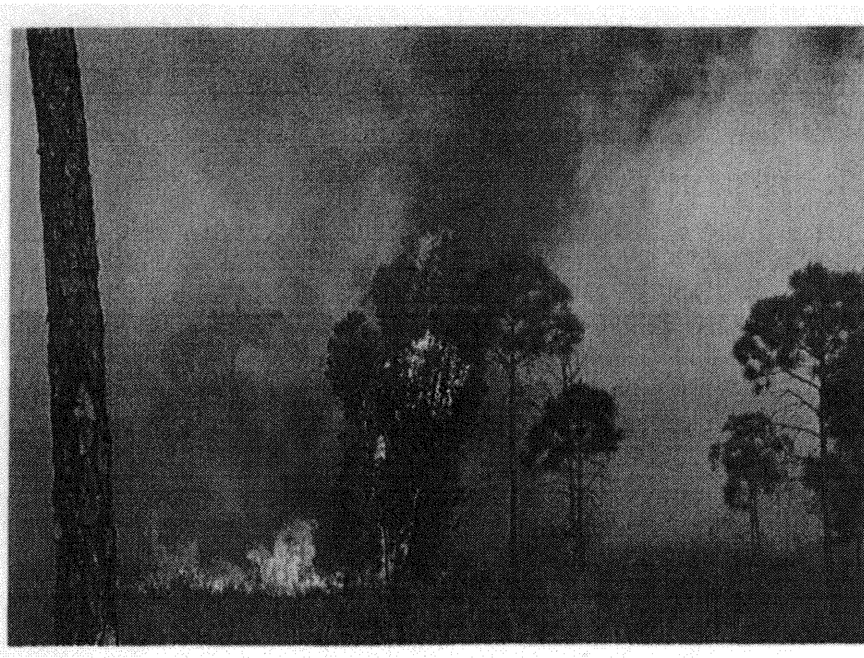

Figure 96. — Melaleuca torching out, Lee County, May 1977.

Figure 97. — Dense sapling stand of melaleuca beneath a south Florida slash pine overstory, Lee County.

Figure 98. — Burning melaleuca, Lee County, May 1977.

Figure 99. — Melaleuca basal and epicormic sprouts 2 months after a May 1977 wildfire, Lee County.

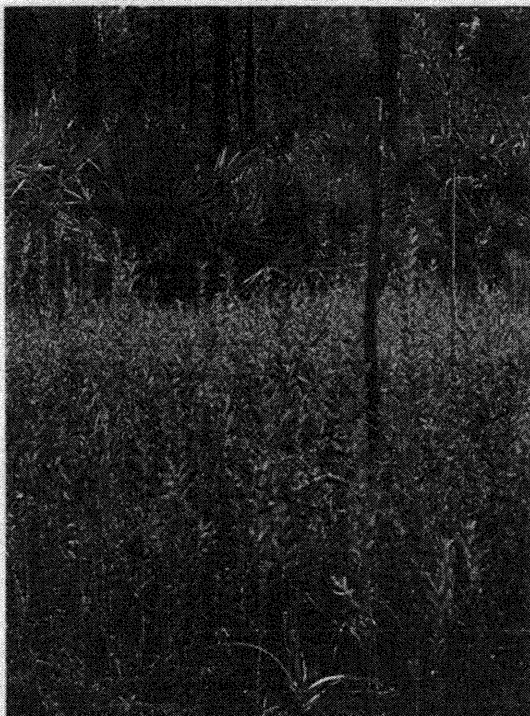

Figure 100. — Melaleuca reproduction taking over a former pine site after a 1976 wildfire, Lee County. Photo 20 months after the seedlings were killed back to ground level by the January 1977 freeze.

Fire suppression in fire-adapted communities, such as the pine flatwoods, can be as damaging as improper burning. In the south Florida slash pine forests of the Miami Rock Ridge, the rapid succession of pine forest into a dense, diverse hardwood forest as a result of total fire suppression has been well documented (e.g., see Alexander 1967). In the pine flatwoods, however, this rapid vegetative change has not been documented. Keeping fire from the pine flatwoods does result in vegetative changes, but they occur slowly. These changes are of two types. First, perennial plants, which might normally be set back by periodic fires, attain larger size. Hilmon (1968) found that saw-palmetto cover increased when fire was suppressed for 6 to IO years. This increase in cover was accomplished by fewer, but larger, individuals than were found in burned areas. However, these individuals will eventually be overtopped and shaded out by other species. Second, plant species that would normally be killed by fire in the pine flatwoods can invade and survive, but species diversity would not be nearly as great as it would be in the Miami Rock Ridge pinelands.

Another important change that occurs in the absence of regular burning is that fuel accumulates. The amount of fuel on the forest floor is a balance between the amount that falls and the amount that decomposes. In the pine flatwoods, one can think of fire as a giant decomposer; one which consumes the current fuel accumulation in a single stroke. Even in the absence of fire, however, the less conspicuous and slower working biological decomposers are at work. Litter and other dead fuels accumulate until the amount produced each year is equal to the amount consumed. In south Florida, these processes come into balance with one another within 10 years (Heyward and Barnette 1936).

The danger from fire exclusion may result not so much from the litter on the forest floor, but rather from the understory and dead pine needles which hang in the branches of the shrubs and trees. The live understory vegetation and the dead needles can act like a staircase, conducting a surface fire up into the canopy and greatly increasing fire intensity (fig. 101).

Figure 101. — Fire carried into the tree crowns by underbrush, Golden Gate Estates, Collier County.

Fire exclusion usually results in species changes, decreased forage quantity and quality, and increased danger from wildfires. It also results in conditions unfavorable for pine regeneration. The pine flatwoods evolved under circumstances in which fire was a normal, but not necessarily universal, part of the environment, and there is little reason to modify that natural condition.

Most burning in the pine flatwoods is done to "freshen" the range. The new plant growth that follows fire, and can be seen within days of the burn (Lewis 1964), provides nutritious forage during the dry winter and spring months. Burning for range management is usually staggered on a given property between November and May to provide fresh forage throughout the dry season (Hughes 1975). Range scientists advocate that flatwoods range be burned every 2 years and that cattle be kept off of the burned range for at least 4 weeks (and preferably 6) following fire to obtain maximum forage production (Hughes 1975). Range burning in the flatwoods of south Florida is, however, very often haphazard and such recommendations are often ignored; many cattlemen simply burn whenever they can and let their stock utilize the new growth at will.

The timing of a burn in pine flatwoods involves several trade-offs. Burning under a pine overstory to accomplish forest management objectives, such as hazard reduction or understory control, can be done anytime during the dry season when the fire intensity will be appropriate. Burns as late as May are more likely to damage the growing tips of the pine and to impair the rate of tree growth. Burning to optimize benefits to wildlife requires a particular schedule. According to Moore (1972), quail production is enhanced by burning one-third to one-half of a management block per. year on a 2-year rotation and completing the burns before nesting begins in March. In other areas of Florida, annual burning for quail management has been practiced for generations with excellent results (Komarek 1963). If some areas, burned every 3 or 4 years, are interspersed with those burned more often, mast and fruit production will be greater, resulting in increased turkey populations (Stoddard 1963).

In short, there is no "best" timing of prescribed burns that can satisfy all management goals. Multiple management goals require flexible burning schedules. A burning program that is properly scheduled and conducted can be used to good advantage in south Florida's pine flatwoods for range, timber, and wildlife management.

MIAMI ROCK RIDGE PINELANDS

The Miami Rock Ridge, which forms the southern end of the Atlantic Coastal Ridge, extends from near north Miami to Homestead, and then to Everglades National Park (Craighead 1971; Davis 1943a; White 1970). Elevation is maximum in Miami at about 20 feet (6m) and decreases until the outcropping limestone disappears underground near Mahogany Hammock in Everglades National Park. The ridge is composed of marine oolitic limestone that varies from nearly pure calcium carbonate to sandy limestone with inclusion layers of shells, and beds and pockets of quartz sand. The limestone is being dissolved by acids in the plant litter to produce a honeycombed structure of solution holes. When fire consumes the organic matter in these solution holes, the exposed uneven limestone surface is called pinnacle rock (see figures 89 and 91). Percolation of surface water is locally variable but is usually rapid.

The ridge was historically dominated by forests of south Florida slash pine (*Pinus elliotti* var. *densa*) interspersed with numerous hardwood hammocks of various sizes (Alexander and Crook 1973, 1975; Craighead 1971; Davis 1943a). Davis (1943a) reported that there were once 180,000 acres

(72,850 hectares) of "Miami region pine." Sand pine (*Pinus clausa*), once present at the north end of the rock ridge, has disappeared because of clearing for urban development.

Intensive lumbering of pines that extended from shortly after 1900 to the 1940's and subsequent intense fires severely altered the pinelands. Except for a sizable tract on Long Pine Key that was saved by creation of the Everglades National Park, most pinelands have simply been eliminated by urban development or agriculture. Virtually all the remaining pinelands outside the Park are threatened by: (1) too many fires (less than 4 or 5 years apart) that prevent pine reproduction; (2) too few fires that permit succession to proceed to hardwood hammock; and/or (3) intense fires that kill the overstory pines. Disturbances such as excessive fire often result in displacement of the pine by exotic species, mainly Brazilian pepper (*Schinus terebinthifolius*) ***(fig. 102)*** but also, to some extent, Australian pine ***(Casuarina*** spp.) and melaleuca (*Melaleuca* ***quinquenervia).***

Unfortunately, early descriptions of this pineland are lacking in detail, so the "natural" conditions are unknown. In general, the density of pines was probably not high enough to form a continuous closed canopy and pines were so sparse, at least in some areas, that the community could more appropriately be called pine savanna rather the pine forest. Virgin stands are reported to have contained many pine trees 90 feet (27m) high and 24 inches (61cm) in diameter at breast height (Craighead 1971). Robertson (1953, p. 22) reported that in the Redlands area west of Homestead, pine

Figure 102. — Miami Rock Ridge pineland being invaded by Brazilian pepper, Dade County.

logs "more than 30 inches (76cm) in basal diameter were not uncommon," and "many thirty foot 12 x 12 inch timbers" were removed during World War I.

As for current conditions, the second-growth pine on Long Pine Key has recovered from the logging of the pre-Park era (fig. 103). The density of pine trees taller than 7 feet (2m) is 200 per acre (500 per hectare). Some are now more than 60 feet (19 m) tall and 11 inches (28 cm) in diameter at breast height, but most are much smaller (Hofstetter 1973).

The pineland floor is sparsely covered with a combination of low palms and trees, shrubs, grasses, and forbs (broad-leaved herbaceous plants). Saw palmetto ***(Serenoa repens)*** and cabbage palm ***(Sabal palmetto)*** are the common palms. Velvet seed ***(Guettarda spp.)***, blolly ***(Guapira discolor)***, locust berry ***(Brysonima lucida)***, myrsine ***(Myrsine floridana)***, tetrazygia ***(Tetrazygia bicolor)***, varnish leaf ***(Dodonaea viscosa)***, marlberry ***(Ardisia escallonioides)***, indigo berry ***(Randia aculeata)***, and cheese-shrub ***(Morinda royoc)*** are among the more common shrubs. Tree species usually present in-. clude: poisonwood ***(Metopium toxiferum)***, bustic ***(Bumelia salicifolia)***, live oak ***(Quercus virginiana)***, stoppers ***(Eugenia*** spp.), sumac ***(Rhus copallina)***, fig ***(Ficus*** spp.), satin leaf ***(Chrysophyllum oliviforme)***, and wild tamarind ***(Lysiloma latisiliqua)***. Common vine and vinelike plants are rubber vines ***(Echites umbellata*** and ***Angadenia sagraei)***, snowberry ***(Chiococca parvifolia)***, and ground-holly ***(Crossopetalum ilicifolium)***. Typical graminoid and forb species include fire grass ***(Andropogon cubanisii)***, three-awn grasses

Figure 103. — South Florida slash pine with an understory of fire grass 6 months after an intense May fire, Everglades National Park.

(Aristida spp.), muhly grass *(Muhlenbergia filipes)*, rattlebox *(Crotalaria pumila)*, partridge pea *(Cassia deeringiana)*, coontie *(Zamia pumila)*, and pinefern *(Anemia adianttfolia)*. Bushy bluestem *(Andropogon glomeratus)* is found on disturbed pine sites, and ladder brake *(Pteris longifolia)* is found on sites that are burned every year or so.

The following herbaceous and shrub endemics comprise an important and unique feature of this vegetative type: twinflower *(Dyschoriste oblongifolia* var. *angusta)*, phyllanthes *(Phyllanthus pentaphyllus* var. *floridanus)*, borrerias *(Borreria terminalis)*, tragias *(Tragia saxicola)*, spurge *(Chamaesyce porteriana* var. *porteriana* and *C. pinetorum)*, beardgrass *(Schizachyrium rhizomatum)*, partridge pea, Florida grama grass *(Tripsacum floridana)*, pineland morning glory *(Jacquemontia curtissii)*, poinsettia *(Poinsettia pinetorum)*, melanthera *(Melanthera parvifolia)*, lantana *(Lantana depressa)*, and pineland olive *(Forestiera segreata* var. *pinetorum)*.[29] While most of the preceding species are found throughout this pineland type, several species have restricted ranges. Terazygia, for example, is common only at the south end of the rock ridge.

In some pinelands, abundant light reaches the floor, there is free-air circulation, and eye-level visibility is good. In other pinelands the trees and shrubs are more abundant and taller and microclimatic conditions within these pinelands approach those of hammocks. Fire is the major factor that prevents succession from pineland to hardwood hammock. But below-freezing temperatures also play a role in that the hammocks are relatively frostproof, whereas the same species, when invading the surrounding pinelands, will often be killed.

Information concerning the fire history of the Miami Rock Ridge pinelands is lacking. Robertson (1953) cites a number of historical accounts showing that fire has been frequent over the past several hundred years and gives some compelling ecological reasons for assuming that a very short fire interval (less than 5 years) has existed over a much longer time period. Lightning strikes peak during the summer, but they occur throughout the year, and there is no reason to suspect fire was historically confined to the wet season. Dry-season fires are undoubtedly more extensive and are likely to be more severe than those in the wet season because water levels are typically lower.

If fire has been absent from Rock Ridge pineland for 15 to 20 years, hardwoods will be numerous and quite large. The humid microenvironment limits a fire's ability to carry through the developing hammock unless it is of sufficient intensity to also damage the surrounding pine (fig. 104). Careful planning and execution of an exacting backfire prescription is mandatory under these conditions. Klukas (1973) states that fire was successfully reintroduced into several such pine stands in the Everglades National Park. When fire is reintroduced, the first several burns may be patchy, leaving dense pockets of hardwoods untouched. Moreover, on

[29] Loope, L., and G. Avery. 1978. Data on file, Everglades Natl. Park.

areas that do burn, much of the hardwood vegetation will quickly resprout, creating an even greater density of hardwoods (Hofstetter 1973). This situation is overcome by burning every time adequate fuel builds up (2 to 3 years) for the next 6 to 9 years. Eventually, hardwood food reserves are depleted to the extent that sprouting, if it occurs, is not prolific. Whenever the hardwood understory was dense, Werner (1978) found that successive backfires when atmospheric temperature was high and humidity was low were effective in opening up the understory (fig. 105). Robertson (1955) suggests that frequent fires may decrease understory species diversity and result in domination by saw-palmetto. A cool fire will have little effect on hardwoods but will consume surface fuels and prevent another burn in the near future, thus favoring hardwood succession.

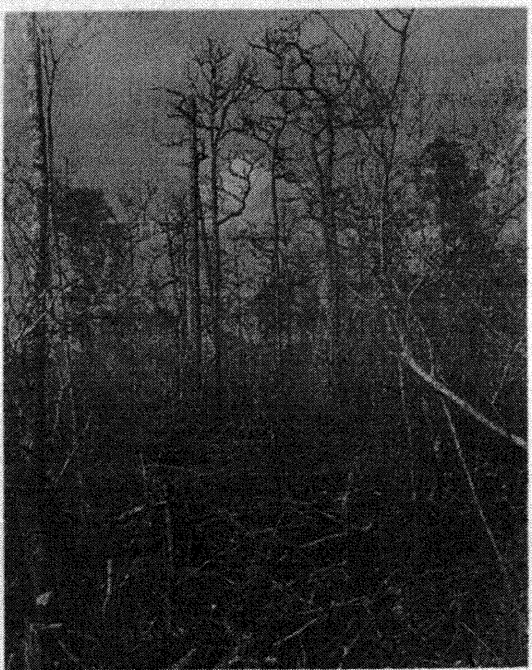

Figure 104. — Dead pine and hardwood after fire in a 12-year-old rough. Everglades National Park.

Once the hardwoods are brought under control, they can be kept in check by burning every 3 to 7 years on "good" sites and every 6 to 8 years on "poor" sites (Bancroft 1977a). This longer burning interval will give pine seedlings time to become fire resistant before the next burn (fig. 106). Hofstetter (1973) found that about 50 percent of the pines between 5 to 10 feet (1.5 to 3.0 m) tall survived a prescribed fire in a 7-year accumulation of fuel.

Season of the year to burn is an important consideration. South Florida slash pine releases its seed in early fall, so a fire later than this will

Figure 105. — Backfire in dense hardwood understory is an effective method of controlling the hardwood and preparing a seedbed for the pine. Everglades National Park.

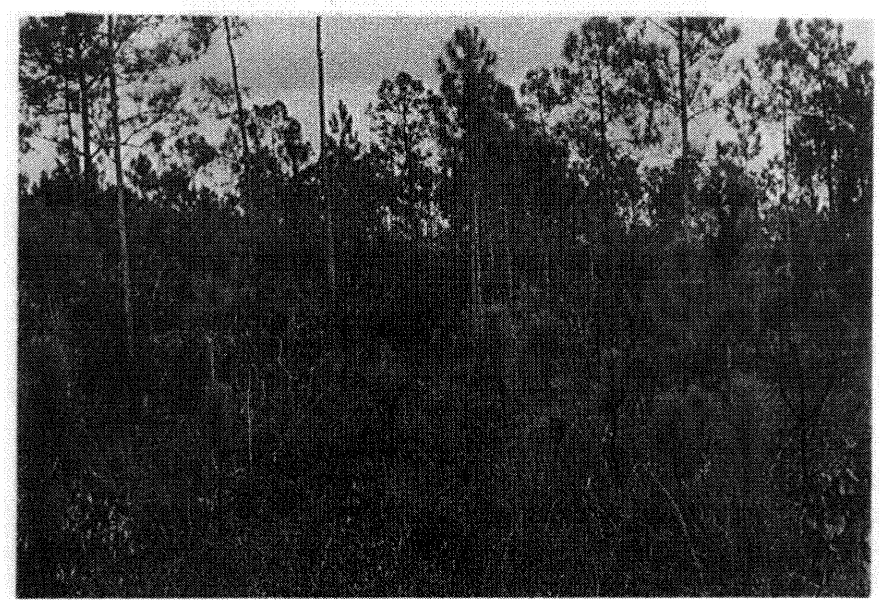

Figure 106. — Green needles indicate survival of south Florida slash pine seedlings after an October prescribed fire, Everglades National Park.

destroy the seed crop or young seedlings. Thus, if it has been decided that competition from the hardwood understory needs to be reduced on an area and there is a good crop of 4 to 5-year-old pine seedlings, a fall or winter burn should be scheduled. If pine reproduction is lacking, however, the burn should be scheduled before the next seed fall. Good seed crops cannot be expected every year. Only 2 years of heavy seed fall were recorded on Everglades National Park pinelands between 1966 and 1971 (Klukas 1973). However, since it takes 2 years for the cones to mature, the magnitude of the next seed crop can be predicted and burning plans modified as necessary.

Attention must also be directed to the effects of burning on wildlife populations. Healthy vertebrates are rarely killed by prescribed fire in Miami Rock Ridge pinelands. The chances of this happening can be further reduced by avoiding excessively intense or fast-moving fires that can overtake or trap an animal. Changes in animal populations following a burn are, however, to be expected. Fire reduces the cover and shade, resulting in. increased sunlight, more extreme minimum and maximum temperatures, and increased wind near and at the ground. Animals that require more sheltered conditions tend to move out after a burn, while those that require exposed stands move in. For example, following a burn in the pinelands of Long Pine Key, populations of cotton rats ***(Sigmodon hispidus)*** decreased, while those of cotton mice *(Peromyscus gossypinus)* increased (Hofstetter 1973). Robertson (1953, p. 84) states: "fire thus tends to maintain or enlarge the habitat area available to pine woods species, such as the pine warbler and bluebird, and to restrict the habitat area of forest-edge species, such as the Carolina wren and cardinal. These forest-edge species alternately advance into and retreat from the pinelands as the shrub understory becomes sufficiently dense to suit their requirements and then is once more reduced by fire." A fire that results in a uniform habitat will reduce wildlife diversity, while a fire that burns a stand irregularly, leaving some unburned areas, will promote increased wildlife diversity, compared to conditions prior to the burn.

Perhaps the best way to ensure the range of fire intensities that will produce a vegetative mosaic is to use spot fires prior to the height of the dry season when conditions become too dry to produce a mosaic. However, the exceedingly treacherous footing on the Miami Rock Ridge limits this technique to igniters that can be tossed or propelled into an area from the firelines or dropped from the air.

To more accurately predict the effects of different fire intensities upon pineland flora, Everglades National Park researchers are comparing the results of heading, flanking, and backing fires under different soil-moisture contents, relative humidities, and air temperatures. First-year data show that vegetation recovers its preburn density and species frequency within 4 months after all tire treatments (Taylor 1977). They found that the combination of fire and the hard freeze of January 1977 had a severe, long-lasting impact on the vegetation.

Current Everglades National Park pineland fire prescriptions require: winds from the N, NE, E, or SE at 5 to 20 mph (2 to 9 m/sec) to carry the smoke away from populated areas; air temperature, 70° to 80°F (21° to 27°C); relative humidity (RH) 35 to 55 percent; soil moisture, 100 percent ovendry weight (ODW) in hammocks and 50 to 80 percent in pineland; and a Drought Index[30] of 350 to 600.

The future of the remaining Miami Rock Ridge pinelands outside the Park looks bleak. Many pinelands are surrounded by, or adjacent to, urban developments. Here, concerns regarding air quality and fire damage to improvements restrict the use of prescribed fire. Several stands that may be large enough to ensure genetic variability occur in Dade County parks. These pinelands contain some pineland endemics and other rare species not protected in Everglades National Park,[31] but they will not survive without periodic low-intensity fires.

RELEVANT FLORIDA STATUTES [32]

590.2. — The Florida Division of Forestry (FDOF) has the authority and power to prevent and extinguish forest fires. Suppression forces may enter any lands for the purpose of preventing or suppressing forest fires.

590.25. — It is a felony to commit any act to obstruct the extinguishment of forest fires by the FDOF.

590.12. — It is against the law to set any forest, grass, marsh or land clearing debris fire without first obtaining authorization from the FDOF.

590.13 & 590.26. — Anyone setting an illegal fire is liable for all damages caused by the fire and all reasonable suppression costs.

51-2.06. — All authorized open burning must be conducted between 0900 and 1 hour before sunset unless the FDOF has determined conditions are such that a night burn will also result in good smoke diffusion and dispersement of pollutants. The FDOF can suspend any authorization if meteorological conditions change so that there is improper smoke diffusion and dispersion of pollutants.

590.025. — The FDOF can prescribe burn any hazardous wild land fuel accumulation on any lands under certain circumstances and subject to certain conditions.

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[30]See Keetch and Byram (1968).

[31]Loope, L., and G. Avery. 1978. Personal conversation. U.S. Dep. Inter., Natl. Park Serv., Everglades Natl. Park, Homestead, Fla.

[32]Excerpted from Fla. Dep. Agr. & Conserv. Serv. 1977.

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PHOTO CREDITS

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Everglades National Park, unidentified personnel, USDI National Park Service
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Figures 46, 69, 70, 97, and 98

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Available information about fire effects is presented for each of the major vegetative types in south Florida, and fire's relationship with certain exotic species is discussed.

Keywords: Fire management, tire effects, prescribed burning, wildfire, water levels.

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