FIRE REGIMES IN SUBTROPICAL SOUTH FLORIDA

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ABSTRACT

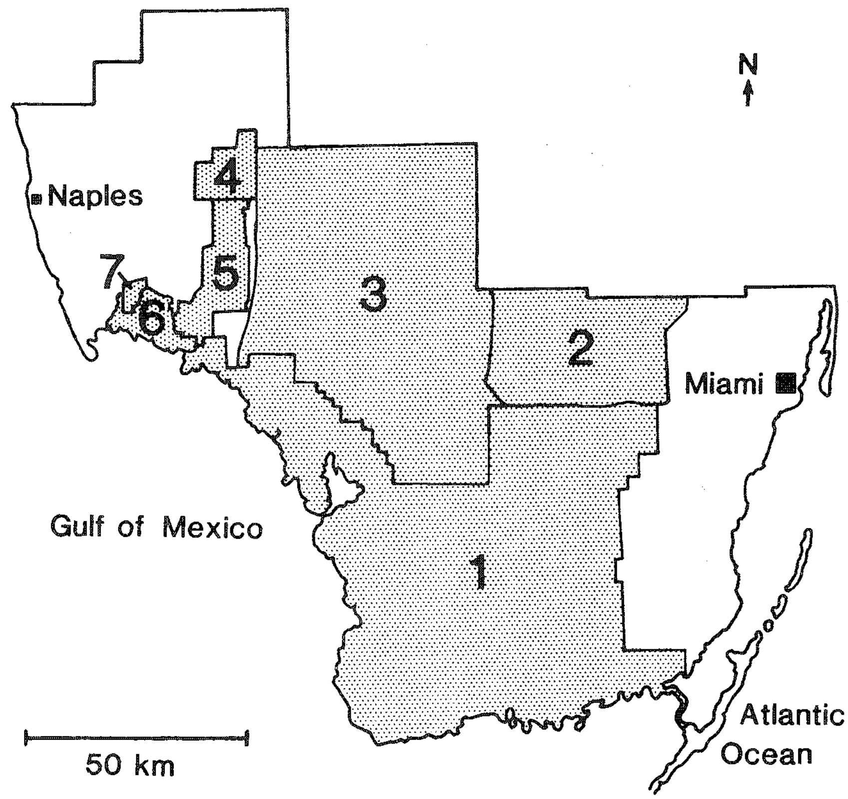
Much of southern Florida is occupied by natural areas supporting fire-dependent ecosystems. It is generally assumed that lightning-caused fire has always been an important force in driving south Florida fire regimes. However, during the last few thousand years human-caused fire may have substantially increased fire frequency and burned at times other than the lightning-fire season. The fire records of Everglades National Park document frequent lightning fires during the summer months, with particularly large areas burned in May to July. Even larger areas have burned in human-caused wildfires during April and May. In Big Cypress National Preserve, lightning-caused fire is minor relative to human-caused wildfire and prescribed fire.

It is unlikely we will ever know with much precision the pre-Columbian fire regime, but we do know that a wide range of fire regimes, as defined by season and frequency, is possible. I suggest that one approach to addressing the question of natural fire regime would be to develop computer models to simulate fire spread in the south Florida landscape. A complementary approach would be to evaluate the ecological effects of a wide range of potential fire regimes through field experiments. Ultimately, fire management programs will probably be designed to bring about desired effects rather than re-create a specific fire regime.

INTRODUCTION

The southern tip of the Florida peninsula (defined here as including Dade and Collier counties and the mainland portion of Monroe County) is home to two million people, yet still contains extensive public lands supporting natural vegetation. These lands include Everglades National Park, Big Cypress National Preserve, Fakahatchee Strand State Preserve, and the Florida Panther National Wildlife Refuge, among others (Figure 1). A large proportion of these natural areas is composed of vegetation types that burn relatively frequently, making fire management an important issue. Between Everglades National Park and Big Cypress National Preserve alone, a contiguous area of more than 4000 km^2 is subject to wildland fire. In this paper I provide a brief review of what is known about the fire regimes of south Florida and discuss the fire management options available to natural area managers.

Figure 1: Map of southern Florida showing major public natural areas subject to wildland fire (in Collier, Dade, and mainland Monroe counties). Boundaries of natural areas are shown as of 1989 and include some land not yet in public ownership. 1) Everglades National Park. 2) Water Conservation Area 3A and 3B. 3) Big Cypress National Preserve. 4) Florida Panther National Wildlife Refuge. 5) Fakahatchee Strand State Preserve. 6) Ten Thousand Islands National Wildlife Refuge. 7) Collier-Seminole State Park.



THE SOUTH FLORIDA ENVIRONMENT

General descriptions of the natural history of south Florida have been provided by Davis (1943) and Craighead (1971). South Florida lies north of the Tropic of Cancer (about 25-26° N) and experiences a subtropical climate with highly seasonal rainfall. The area receives an average annual rainfall of 1300 to 1500 mm, with about 75% occurring during the six months from May to October (MacVicar and Lin 1984). The relatively low rainfall during the rest of the year results in an annual drought that increases the fire danger in the spring. Summer rainfall results from frequent convectional thunderstorms and infrequent tropical storms and depressions. The lightning associated with convectional storms is an important source of wildfire ignitions. Temperatures are hot in the summer and mild in the winter, with only occasional freezes.

These freezes may influence fuel characteristics by killing back cold-sensitive vegetation (e.g. Caprio and Taylor 1984).

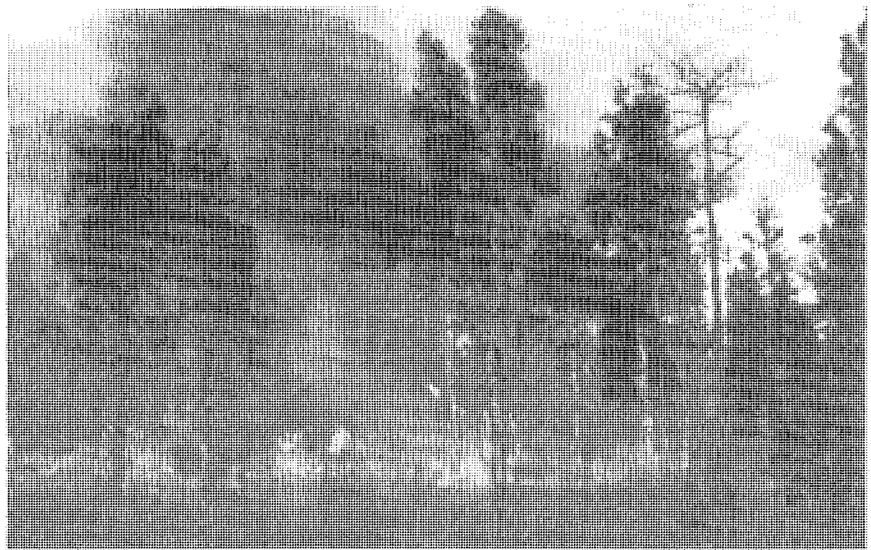
One of the most obvious characteristics of the area is the lack of relief. South Florida is extremely flat and low in elevation. The region is formed by a limestone plain overlain by shallow, unconsolidated sediments of sand, marl, or peat. The high rainfall, combined with low relief and elevation, results in substantial wetland areas being flooded during, and for a period after, the summer rainy season.

The area can be divided into four general physiographic units (Hoffmeister 1974). The mangrove and coastal prairie unit forms the terrestrial interface with the marine environment. Landward of this zone, on the east, is the southern terminus of the Atlantic coastal ridge, known locally as the Miami rock ridge. It is largely covered by the urban sprawl of Miami except for the portion in Everglades National Park. The Big Cypress Swamp lies on the west, and between the Miami rock ridge and the Big Cypress is the southern end of the true Everglades.

The vegetation, which forms the fuel for wildland fires, can be classified as a few general types. Forested wetlands are represented by mangroves and various manifestations of freshwater cypress swamps. Mangroves are not generally influenced by fire. Cypress (*Taxodium distichum*) and mixed hardwood strands are more or less linear swamps found in the deepest freshwater drainageways. Cypress domes are isolated swamps found in bowl-shaped depressions in the limestone. Cypress prairie, or dwarf cypress savanna, is a graminoid-dominated community with scattered, stunted cypress trees. The major nonforested wetlands include sawgrass (*Cladium jamaicense*) marshes and shorter hydroperiod wet prairies.

Upland areas are mostly covered with forests of south Florida slash pine (*Pinus elliottii* var. *densa*). The pinelands of the Miami rock ridge are particularly noteworthy because they contain several endemic herb taxa and a species-rich shrub layer that includes numerous tropical hardwoods and three palm species. Upland hardwood forests, known as hammocks, are much less extensive and are usually found where there is an accumulation of organic matter on elevated limestone platforms (Snyder et al. 1990).

One alien vegetation type of interest is the melaleuca forest, dominated by an exotic tree, *Melaleuca quinquenervia,* introduced from Australia. This eucalypt tolerates a wide range of hydroperiods and thrives in upland situations as well as in wetlands such as prairies, cypress prairies, and drained sawgrass areas. It is remarkably preadapted to the environment of south Florida and its frequent fire (Wade et al. 1980, Myers 1983, 1984, Ewel 1986). Its thick, papery bark protects the cambium while the loose outer layers carry fire up into the crown. The trees have large numbers of serotinous capsules containing many wind-dispersed seeds; these capsules open and release the seeds soon after a fire. After a few episodes of fire and seedling establishment, dense stands of melaleuca can develop. Fires in these stands often become high-intensity crown fires, a fire type not naturally found in south



Fire in scattered melaleuca stand. Note flames carried up trunks by loose bark.

Florida. Remnant pine or cypress trees, which are relatively resistant to fire, are killed by these high-intensity fires. The melaleuca, however, is able to survive and resprout from the bole, thus completing stand conversion to monospecific melaleuca forest.

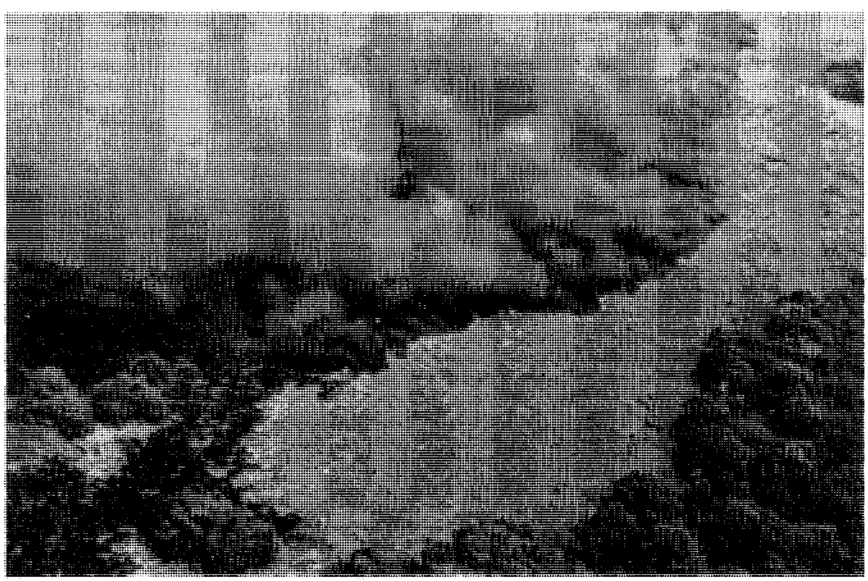
FIRE HISTORY

It is well accepted that fire plays an important role in controlling the distribution and composition of plant communities in south Florida (Egler 1952, Robertson 1953, Craighead 1971, Wade et al. 1980, Duever 1984, Snyder et al. 1990). The only direct evidence of fire from the pre-Columbian period is the presence of charcoal or ash in peat deposits well below the present ground surface (Cohen 1984, Parker 1984). The use of fire scars on trees has not proven useful for establishing fire history in south Florida as it has elsewhere (Taylor 1980). Likewise, there do not appear to be any eyewitness reports from the time of first European contact to shed light on the presettlement fire regime (Robbins and Myers 1989). The frequent occurrence of lightning-caused fires today is generally considered to reflect a pattern that has existed since before the arrival of Europeans.

Perhaps the strongest biological evidence for relatively frequent fire before European arrival relates to the habitat requirements of some of the endemic plants, as pointed out by Robertson (1953). More than 15 species of herbs are endemic to the Miami rock ridge pinelands (Avery and Loope 1980), and conditions favorable to these species rapidly decline as the fire-free interval increases. Within a few decades of fire exclusion, pinelands succeed to closed hardwood hammocks that contain none of the endemic herbs (Robertson 1953, Alexander 1967, Loope and Dunevitz 1981). It appears, however, that the only way to reconstruct the details of the natural fire regime for south Florida is to analyze recent fire history and fire effects and make inferences about the pre-Columbian situation.

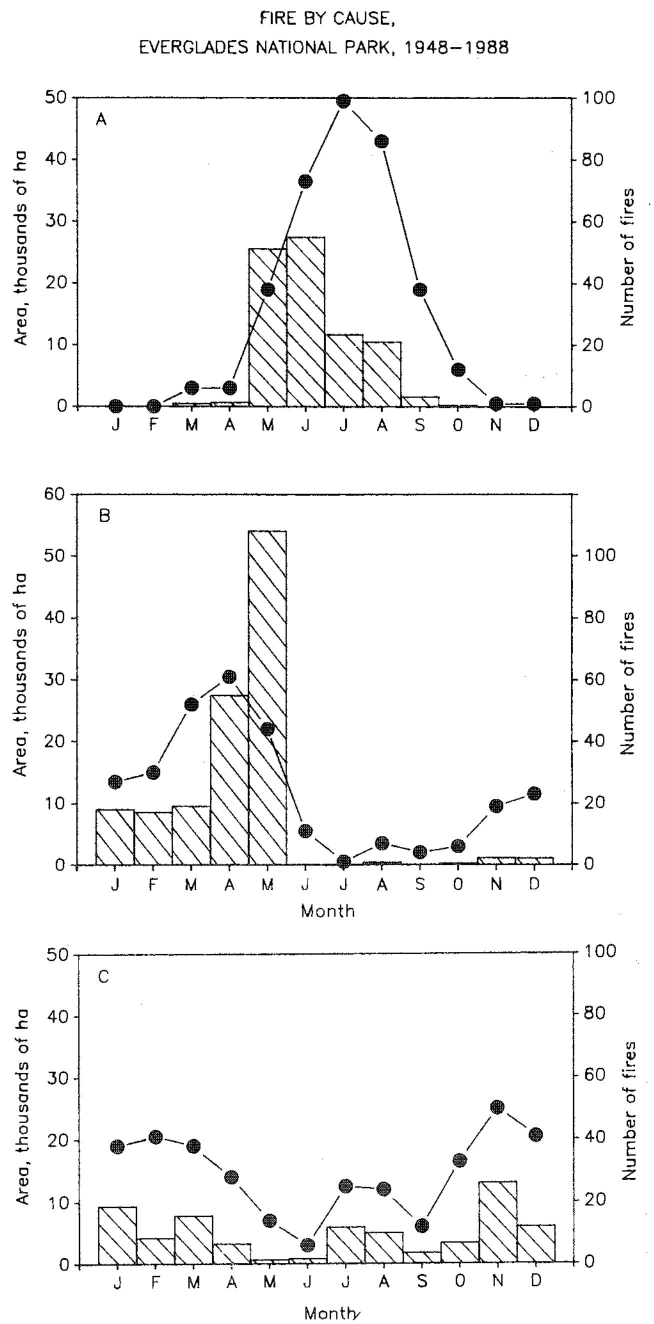
The longest-term data set on recent fire history in south Florida is derived from the fire records of Everglades National Park, which go back to 1948. These data are presented graphically in Figure 2. It must be emphasized that these records cover a period during which a range of water management and fire management activities occurred, and these undoubtedly influence the statistics. Nonetheless, the records provide a valuable foundation on which to base a discussion of fire regimes. The data summarize all fires inside the park irrespective of vegetation type. The statistics are dominated by fires in graminoid communities (prairies and sawgrass marshes) because these constitute the bulk of the burnable area.

The number of lightning-caused fires shows a somewhat symmetrical distribution that mirrors thunderstorm activity (Duever et al. 1986, Komarek 1964), with 93% of the fires occurring from May to September. Over 96% of the area burned by lightning-caused fires burned during the four months of May through August. Dry conditions (lower water levels) at the beginning of the rainy season result in larger mean fire sizes than those that occur later in the season. For example, the mean fire size for May is 674 ha, while that of June—which has the second largest mean fire size—is only 376 ha. Four



A September lightning-caused fire backing through a cordgrass (*Spartina bakeri*) prairie in the mangrove zone of Everglades National Park.

Figure 2. Fire statistics for Everglades National Park, 1948-1988. (A) Lightning-caused fires. (B) Human-caused wildfires. (C) Prescribed fires. The area burned is shown by bars and the number of fires by dots. Derived from Taylor (1981), Doren and Rochefort (1984), and Husari et al. (in prep.).

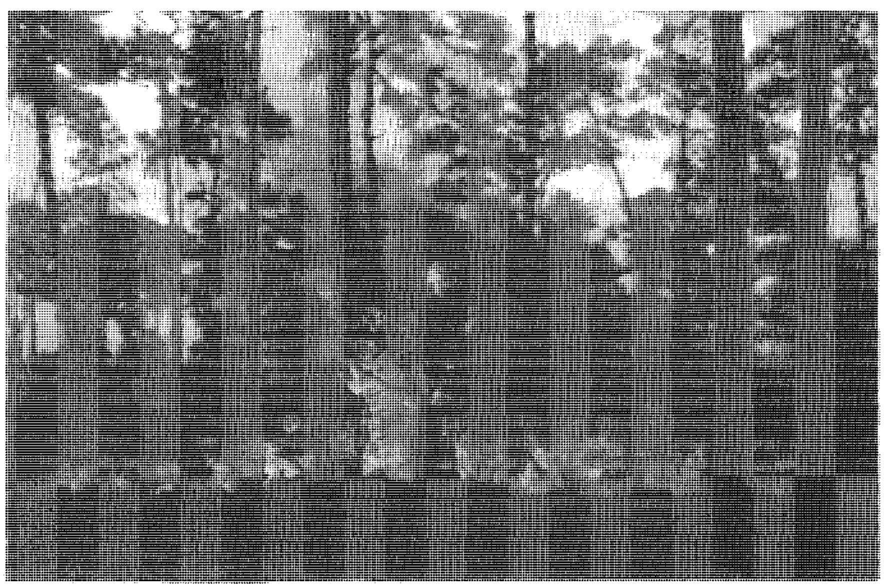


fires are responsible for nearly 60% of the area burned by lightning-caused fires during the period of record: the Pot Hammock fire in June 1951 burned 12,437 ha, the South Chekika fire in July 1981 burned 7,708 ha, the Panther fire in May 1985 burned 11,185 ha, and the Eleocharis fire of May 1986 burned 14,743 ha. The fires for 1989 are not included in Figure 2, but the Ingraham fire burned about 40,000 ha in May, making it the largest lightning-caused fire in the history of Everglades National Park. That fire alone would more than double the mean May fire size.

Human-caused wildfires occur mainly during the dry season months and are strongly correlated with moisture conditions. The area burned and mean fire size peak in April and May when fuels are likely to be driest and water levels lowest. In fact, about a third of the total area burned in Everglades over the period of record was burned by human-caused wildfire in these two months.

Prescribed burning began in 1958 in the pinelands of Everglades National Park and expanded to other fuel types in 1971 (Klukas 1973; Bancroft 1976, 1977; Taylor 1981). Most of this management burning was conducted during the cooler months until 1980, when the emphasis shifted to wet season burning in the pinelands (Figure 2). Prescribed burning continues at other times for the purpose of reducing hazardous fuels along park boundaries and for research (Doren and Rochefort 1984).

It is possible to calculate a crude fire-return interval for Everglades National Park, based on the 41-year record from 1948 to 1988. It must be realized that the area burned may have been reduced by suppression actions and artificial firebreaks but it may, on the other hand, have been increased by human igni-



A January prescribed burn in a Big Cypress National Preserve pine forest. Fire flaring up in crown of a cabbage palm (*Sabal palmetto*).

tions and artificially lowered water tables. Without a more sophisticated analysis of individual fire records, it is difficult to determine the net effect of modern human intervention. Klukas (1973) estimated that about 166,800 ha of burnable area exist in the park, a more conservative estimate than the 192,340 ha of "fire types" shown in the park's fire management plan (Everglades National Park 1979). During the 41-year period of record an annual average of 6,130 ha burned due to all causes. This results in a fire-return interval of about 27 years when averaged over all fuel types. Of course, certain fuel types burn much more frequently. When only lightning-caused fires are considered, the fire return interval is about 87 years.

Comparable fire statistics are available for Big Cypress National Preserve only since 1979, when the National Park Service assumed fire control responsibilities from the Florida Division of Forestry (Table 1). Most of the preserve, about 230,000 ha within its original boundary, is covered by burnable vegetation so that it constitutes a larger potential area for fire than Everglades National Park.

One of the most obvious features of the Big Cypress fire data is the preponderance of human-caused fire. About four-fifths of the 1,068 fires that occurred during the 10-year period (1979-1988) were incendiary or accidental human-caused fires (Table 1). In contrast, the total number of fires by all causes in Everglades National Park over the same 10-year period was only 350, and only 39 were human-caused wildfires (Table 2). The extremely high number of fires in Big Cypress is due largely to hunters and the presence of

Table 1. Fire statistics for Big Cypress National Preserve 1979-1988. Derived from unpublished Big Cypress National Preserve Draft Fire Management Plan.

Month	Fire Type							
	Lightning-caused Wildfire		Human-caused Wildfire		Prescribed Fire		Total	
	No.	Area (ha)	No.	Area (ha)	No.	Area (ha)	No.	Area (ha)
Jan	0	0	114	10,585	42	11,487	156	22,072
Feb	1	314	47	8,034	29	9,127	77	17,475
Mar	1	< 1	151	32,261	15	3,874	167	36,135
Apr	1	1	81	5,891	< 9	2,103	91	7,995
May	20	535	66	78,943	4	551	90	80,029
Jun	41	2,376	16	2,643	4	903	61	5,922
Jul	13	666	9	476	4	59	26	1,201
Aug	16	299	9	274	9	793	34	1,366
Sep	5	192	8	267	3	956	16	1,415
Oct	0	0	31	537	9	1,770	40	2,307
Nov	0	0	137	2,414	14	2,428	151	4,842
Dec	0	0	129	7,140	30	8,862	159	16,002
Total	98	4,383	798	149,465	172	42,913	1,068	196,761

a few hundred backcountry camps. Much of the human-caused wildfire is intentionally set for informal wildlife habitat management or camp protection, although a considerable amount is vandalism or accidental. The number of fires correlates well with periods of peak backcountry use, with the maximum occurring in March when turkey hunting season coincides with relatively dry conditions. In addition, it has been noted that Sunday is a particularly popular day for starting fires in Big Cypress (Taylor 1980, Doren and Rochefort 1984). In May 1981, the Turner 10 fire complex burned 67,200 ha of Big Cypress, making it at that time the largest fire in National Park Service history. This distinction disappeared rather dramatically with the Yellowstone fires of 1988.

Prescribed burning in Big Cypress National Preserve has been carried out mainly in the cooler months (Table 1) to reduce fuel loads and decrease the likelihood of large wildfires. In a few areas winter burns are conducted for range management in conjunction with cattle grazing leases.

Big Cypress experiences relatively little lightning-caused fire when compared to Everglades, despite the fact that the Big Cypress region experiences a greater amount of cloud-to-ground lightning (Taylor 1980). Big Cypress has recorded only half as many fires and about a tenth the area burned by lightning as Everglades for the same 10-year period (Tables 1 and 2). The number of lightning fires in Big Cypress may be underestimated because aerial reconnaissance flights for small, self-extinguished lightning fires were not routinely

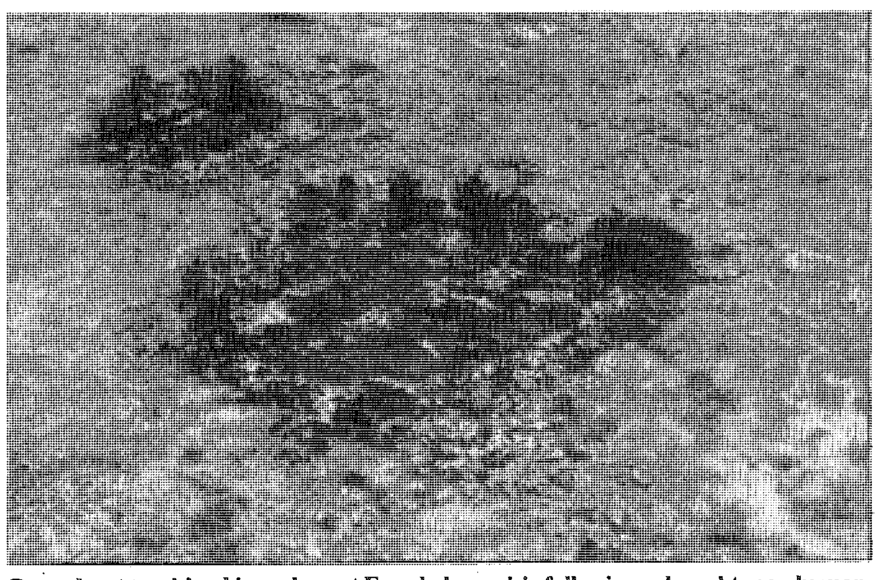
Table 2. Fire statistics for Everglades National Park 1979-1988. Derived from Doren and Rochefort (1984) and Husari et al. (In prep.).

Month	Fire Type							
	Lightning-caused Wildfire		Human-caused Wildfire		Prescribed Fire		Total	
	No.	Area (ha)	No.	Area (ha)	No.	Area (ha)	No.	Area (ha)
Jan	0	0	3	7	8	2,344	11	2,351
Feb	0	0	6	27	8	4,171	14	4,198
Mar	5	494	8	238	15	1,762	28	2,494
Apr	5	425	9	3,516	6	747	20	4,688
May	16	24,435	4	452	6	421	26	25,308
Jun	18	1,264	1	21	3	738	22	2,023
Jul	64	10,641	2	4	20	5,898	86	16,543
Aug	40	2,208	2	15	25	4,962	67	7,185
Sep	27	1,301	0	0	3	794	30	2,095
Oct	5	11	1	< 1	12	1,624	18	1,635
Nov	0	0	2	1	16	9,014	18	9,015
Dec	0	0	1	51	9	580	10	631
Total	180	40,779	39	4,332	131	33,055	350	78,166

flown at the end of the rainy season as they were in Everglades. The area burned by lightning-caused fire is also relatively small, possibly because human-caused wildfire and prescribed burning preempt lightning fire or because the preserve's fire suppression efforts have been successful. The seasonal distribution of lightning fires differs slightly in the two areas in that the number of fires is skewed toward the early part of the rainy season in Big Cypress. This may also be an artifact of less thorough reporting of small fires under wet conditions when vigilance for wildfires is reduced.

The fire-return interval for Big Cypress National Preserve is about 12 years for all fire types combined, while the return interval for Everglades National Park is about 21 years for the same 10-year period. This shorter fire-return interval for Everglades, relative to the interval based on its 41-year period of record, is due to increases in lightning-caused and prescribed fire that more than compensate for a drastic reduction in human-caused wildfire.

As might be expected, the fire frequency for different fuel types varies considerably. Fire statistics broken down by fuel type are available for Big Cypress in the preserve's unpublished draft fire management plan. The area of prairie and marsh is 66,000 ha; cypress prairie 64,000 ha; cypress and mixed hardwood strand and cypress dome 58,000 ha; pine forest 38,000 ha; and hardwood hammock 5,200 ha. Based on the preserve's 10-year record, the approximate fire-return intervals for major fuel types are 7 years for both prairie/marsh and pineland, 24 years for cypress prairie, 110 years for cypress strand, and 177 years for hammock. These numbers are not outside ranges that have been proposed for these vegetation types (Wade et al. 1980, Duever



Burned-out tree island in rocky east Everglades prairie following a drought-year, human-caused fire in April.

1984), although they tend to reflect the upper limits. For example, a fire-return interval of 3-7 years, or as frequently as every 2 years, has been suggested for south Florida pinelands (Wade et al. 1980). Because the intervals presented here are based on such a brief period of record, they must be considered tentative, especially for the longer return interval types.

NATIVE AMERICAN INFLUENCE

An important factor that should be considered in inferring pre-Columbian fire regimes from present-day fire patterns is the possible influence of native Americans in shaping the south Florida landscape through fire. The question of Indian burning and whether it should be treated as part of the "natural" fire regime has been widely debated (e.g. several papers in Lotan et al. 1985). Even though historical accounts of Indian-set fires in south Florida are lacking, I suggest here that the influence of aboriginal burning should not be discounted (see also Myers and Peroni 1983).

South Florida was inhabited by humans for thousands of years before the arrival of the first Europeans, and has probably been inhabited for as long as the landscape as we know it has existed (Carr and Beriault 1984, Griffin 1988, Widmer 1988). It is estimated that there were 10,000 Calusa Indians in southwest Florida when the Spaniards arrived (Griffin 1988). Archeological surveys have found 395 sites within Big Cypress National Preserve, with one site dated before 2000 B.C. and 283 sites containing materials dating from 2000 B.C. to 1800 A.D., a time before the arrival of the Seminoles (USDI 1989). Everglades National Park has 193 known archeological sites, and about half of them are located inland from the mangrove and coastal prairie zone (Griffin 1988). Some experts believe that the major Calusa settlements were coastal and that the interior sites might have served as temporary or seasonal hunting and fishing camps. Based on faunal remains, it appears that these native Americans subsisted mainly on aquatic animals such as fish and turtles, but also utilized terrestrial wildlife such as white-tailed deer (Widmer 1988).

In a review of Indian burning in Florida, Robbins and Myers (1989) found some evidence that Indians practiced widespread burning. In northern Florida, burning by prehistoric Indians maintained grassy islands of longleaf pine in the sand pine scrub of Ocala National Forest (Kalisz and Stone 1984, Kalisz et al. 1986). Both Egler (1952) and Robertson (1953, 1962) suggested that Indians increased the amount of fire in south Florida over the background level caused by lightning, and that most Indian-caused fires were set as early in the dry season as the grassy fuels would easily carry fire. Egler (1952) believed that the area was dominated by broadleaved forest before the advent of Indian fires; Robertson (1953) thought that lightning fire alone was sufficient to create the fire-dependent vegetation types seen today. It seems reasonable to suggest that relatively large areas may have burned in the late dry season due to Indian-caused fires, much as large wildfires do today. Therefore, in pre-Columbian times, and perhaps as long as the south Florida environment has existed, it is likely that fires occurred at all times of the year, with the largest fires and greatest area burned during April, May, and June, just as they do now.

MANAGEMENT OPTIONS

I suggest that options for management of fire regimes in south Florida are broad with respect to both time of year and fire-return interval. Fire records show that at least some habitat types can burn at any time of the year. The lowest limit to fire-return interval is determined by the rate of fuel accumulation, because fires cannot burn without sufficient fuel. This is as low as once a year (or even more frequently under extreme conditions) for some pine and prairie types. The upper limit to fire-return interval is not as easily defined, but it might be considered to be the maximum period that assures continued existence of the characteristic biota. Today, societal constraints may impose practical upper limits to fire-return intervals which are lower than the natural or ecological limits. For example, pine forests may tolerate a 15- to 20-year return interval, but the difficulties in managing the smoke and spread of these relatively high-intensity fires may preclude the acceptance of such a fire regime.

I would like to propose two complementary research approaches that would aid decision-making in fire management: one from a fire behavior perspective and the other from a fire effects perspective. The fire behavior approach involves the modelling of fire regimes through the use of GIS (geographic information system) technology. Methods for applying fire behavior models on a landscape scale through GIS are currently under development (e.g. Ball 1990, Ball and Guertin in review). A map of fuel types for the area under consideration can easily be prepared and equations that relate fuel loads to time since burning can be developed. By eliminating artificial barriers such as roads and canals from the GIS fuel map, unimpeded spread of fires can be simulated over a sufficient time period to develop long-term fire statistics. Fire regimes can be simulated by using only lightning-caused ignitions or by introducing additional levels of human ignitions. This type of analysis would enable us to narrow the range of likely fire regimes. It might show, for example, that even in the absence of artificial fire breaks, a strictly lightning-driven fire regime would not have burned any one location more often than every 5 years on the average.

The fire effects approach utilizes field experiments and measures the ecological responses of the biota to a wide range of fire regimes. While scattered bits of anecdotal evidence are available (much of it summarized in Wade et al. 1980), information on fire effects can be most efficiently collected via a systematic, experimental approach. The long-term study of season and frequency of burning in pine forests of the South Carolina coastal plain by the U.S. Forest Service (Waldrop et al. 1987) is an example of the type of research suggested. The response variables should include, but not be limited to, population parameters of endemic, endangered, and dominant species. For example, the population response of herbs endemic to Miami rock ridge pinelands (e.g. *Poinsettia pinetorum, Chamaesyce deltoidea,* and *Galactia smallii*) to different seasons and frequencies of burning should give an indication of their natural fire regimes and provide direction for management policies (Snyder 1986). Wildlife habitat values must be taken into account as well. The federally listed Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*) nests only in seasonally flooded south Florida graminoid communities that must burn periodically. Another federally listed bird, the red-cockaded woodpecker (*Picoides borealis*), at the edge of its range in the Big Cypress Swamp, has specific habitat requirements for canopy pines and the stature of the forest understory, which are controlled by the fire regime.

While the results of experimental work would improve our ability to infer "natural" fire regimes, the primary goal of these experiments would be to document the effects of different management options so more informed decisions could be made. Because non-native species such as melaleuca are a problem in south Florida, it is important to consider the responses of exotic species to different fire regimes, along with those of native species.

It is unlikely that our knowledge of pre-Columbian fire regimes will ever be thorough enough to enable us to manage for a specific regime. Rather, we will be forced to manage for the desired results or effects. It is probable that the pre-Columbian fire regime in south Florida—whether it included significant aboriginal burning or not—was marked by relatively infrequent, early wet-season fires that today would be considered excessive in size and intensity. One important challenge, then, is to determine whether higher-intensity fires are necessary to maintain these ecosystems, or whether acceptable results can be achieved by carefully timed, more frequent, lower-intensity fires.

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