Fire Effects and Fire Management in the Upper St. Johns River Basin Marsh, Florida

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ABSTRACT

The upper St. Johns River basin marsh is over 400,000 hectares of herbaceous marsh, dominated by sawgrass (*Cladium jamaicense*) and maidencane (*Panicum hemitomon*) communities. Three major factors create and maintain the marsh plant communities: hydrology, nutrient levels, and fire. All three factors have been altered by human activities. To restore and preserve the floodplain marshes in the upper basin, the St. Johns River Water Management District is investigating the best use of fire to manage vegetation patterns and succession.

Year-long monitoring of sites burned in a dry season arson fire showed no lasting changes in plant species composition. Short-term changes which occurred in both burned and unburned sites appeared to be related to water elevations.

Results of an experimental dry season fire demonstrated that the fuel load in sawgrass communities recovered rapidly from the fire, and 20-months post-burn was higher than in the unburned sites. In the maidencane community there was no difference in biomass in burned or unburned sites. Species diversity decreased in the maidencane community 20-months post-fire but did not change in the sawgrass community.

These results and other work done on similar floodplain marshes indicate that effects of fire are variable and related to hydrologic conditions and nutrient status. Data on fire occurrence show that most lightning fires in marsh ecosystems are small (<10 ha); but the most area is burned in large infrequent fires. In order to manage fire in these systems we need to mimic the ecological role of fire but there remain many gaps in our understanding.

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INTRODUCTION

The upper St. Johns River basin marsh is over 400,000 hectares of herbaceous marsh, dominated by sawgrass (*Cladium jamaicense*) and maidencane (*Panicum hemitomon*) communities. Three major factors create and maintain the plant communities occurring here: hydrology, nutrient levels, and fire. All three factors have been altered by human activities. Levees and canals have affected the natural hydrologic regime, agricultural discharge into the marsh has increased nutrient loadings, and natural fire regimes have been altered by fire suppression and arson fires. The St. Johns River Water Management District is working to restore and preserve the floodplain marshes in the upper basin. One part of this program is the use of fire to manage vegetation patterns and succession. Although it is generally accepted that fire plays an important role in the ecology of herbaceous wetlands in Florida (Kushlan 1990; Wade et al. 1980), little is known of the effects of fire in these systems. None of the major plant species present have been shown to be fire-dependent in the strictest sense, that is having some aspect of their natural history which will not occur without fire. There are relatively few published studies that focus on the effects of fire in marsh ecosystems. Most of the research conducted reports on single fires and there is little information on the effects of fire frequency. The paucity of data leaves managers in a difficult position since management decisions often cannot wait for research results.

The St. Johns River Water Management District has an on-going effort to study fire in wetlands in order to provide information for making decisions concerning the use of fire in habitat management. Here we report on work that has been done on the upper St. Johns River basin. We discuss two separate studies of the effects of fire on vegetation. In the first study, we investigated changes in species composition and abundance over the period of a year following an arson fire. In the second we analyzed changes in biomass, species composition and abundances for a period of 20 months following a prescribed burn. We compare our results with those obtained from similar wetlands, present information on the fire regime in the basin, and discuss management implications.

METHODS

Study Site

The St. Johns River in east central Florida, flows northward over 485 km from near Vero Beach to Jacksonville. The upper basin or headwater region extends approximately 128 km from Fort Drum Creek north to Lake Poinsett. The river has a shallow gradient here of only 3.8 cm/km (Lowe et al. 1984). It is an area of extensive floodplain marshes where communities dominated by different species are interspersed in a broad mosaic pattern. Sawgrass (*Cladium jamaicense*) and maidencane (*Panicum hemitomon*) communities are common. Other communities include broad-leaved herbaceous species such as *Sagittaria lancifolia* and *Pontederia cordata,* and shrub swamp where willow (*Salix caroliniana*) dominates. Tree islands with willows (*S. caroliniana*) and red maple (*Acer rubrum*) occur in patches. Slough communities which include white water lily (*Nymphaea odorata*) and bladderwort (*Utricularia* spp.) occur in deeper water areas.

In sawgrass communities, sawgrass typically accounts for 75–100% of the cover. Other species are found at low frequencies and cover. These may include *Salix caroliniana, Sagittaria lancifolia, Mikania scandens, Typha* spp., and *Polygonum* spp. Maidencane communities are often more diverse. Maidencane may have cover values up to 50–75%. Many of the same species present in sawgrass communities also occur in maidencane communities. Other species found frequently include *Pluchea* spp. and *Ludwigia* spp. (ESE 1994; Lowe and Hall unpublished data).

Field Sampling

In the first study we tracked changes in species cover and frequency after a winter arson fire for a period of one year. We sampled three sites in both sawgrass and broad-leaf emergent communities which had burned. Nearby sites of similar vegetation types, which had not been burned, were also sampled. Two unburned sites were sampled in the sawgrass community, and three in the broad-leaf emergent community. Cover of each species was estimated in a 50 m^2 circular plot in each site, and expressed using the Braun-Blanquet scale (Muller-Dombois and Ellerberg 1974). Inside each circular plot eight 1 m^2 quadrats were placed at 45° intervals 1 m from the perimeter. Species frequency was determined as the proportion of quadrats in which a species was present. Samples were taken at irregular intervals through the year beginning one month after the fire in the burned area and two months post-fire in the unburned sites. The burned sites were sampled six times and the unburned sites four times.

In the second study, we investigated changes in biomass and species abundances after prescribed burning. Five blocks were established with two 90 m^2 study plots within each block. One plot in each block was randomly assigned to be burned, the other assigned as an unburned control. Each plot contained both sawgrass and maidencane communities which were sampled separately. Pre-burn sampling was done in August 1990. High water levels delayed the prescribed burn until February 1991. Post-burn sampling was conducted at 12 months and 20 months post-burn. Immediately after the burn, each treatment block was mapped from aerial photographs to determine the extent to which it had burned. The percent of area that burned within each plot ranged from 75–90%. Between the pre-burn sampling and the prescribed burn, one block was burned in an arson fire, and dropped from further sampling. The last fire recorded in this area was in the winter of 1988/1989 (Florida Department of Forestry, Orlando District, unpublished fire records).

Biomass was sampled in randomly located quadrats. One quadrat was sampled in each of the two community types. For pre-burn sampling, the biomass quadrats were 1 m^2. Because of the large amount of material collected, quadrat size was reduced to 0.1 m^2 for post-burn sampling, and biomass adjusted to a per-square-meter basis. Above-ground biomass was determined by harvesting all vegetation within the quadrat at the soil surface. The vegetation was sorted by species (*C. jamaicense, P. hemitomon,* all others) and separated into live or dead categories, bagged and dried for 30 days. New quadrats were located for each sampling episode. For post-burn sampling, if the random location fell into an area that had not burned, it was relocated.

Percent cover and species composition was sampled in randomly located permanent 1×4 meter quadrats. One quadrat was sampled in each of the two community types in each plot. Cover was visually estimated and all species occurring in the quadrat were recorded. All quadrats in the treatment plots were burned.

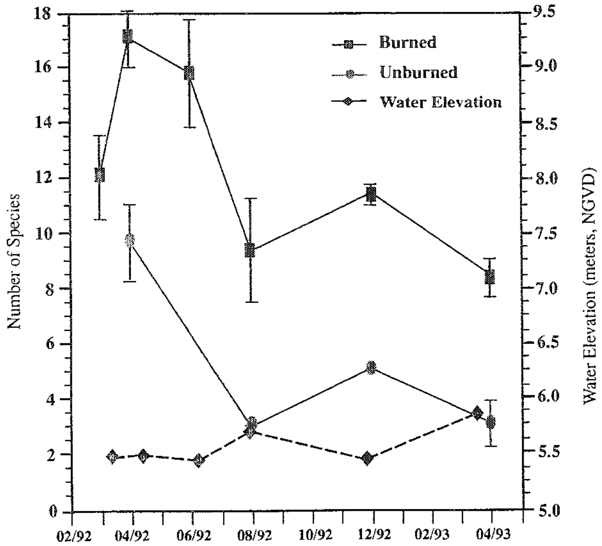

Fig. 1. Changes in number of species in sawgrass community for one year after arson fire. Changes in water elevation are shown by the dotted line. Bars indicate standard error.

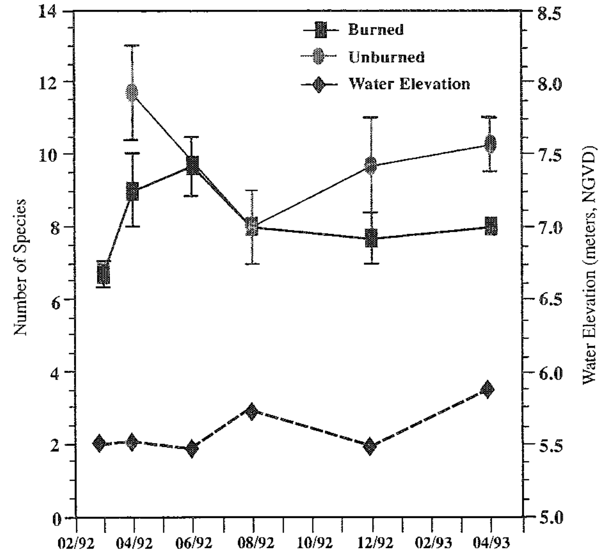

Fig. 2. Changes in number of species in broad-leaf community for one year after arson fire. Changes in water elevation are shown by the dotted line. Bars indicate standard error.

RESULTS

Species Composition Following an Arson Fire

Sawgrass and broad-leaf emergent marsh communities showed similar responses to the arson fire. In the sawgrass community, on both burned and unburned sites, the number of species fluctuated widely through time (Figure 1). The total number of species was higher in the burned site, but since no pre-fire sampling was done it cannot be determined if this was attributable to fire. A year after the fire, total number of species present was lower than immediately post-fire on both burned and unburned sites.

In the broad-leaf emergent community number of species fluctuated less widely over the sampling period (Figure 2). Here, the unburned sites had slightly more species, and total number of species did not change greatly in either burn or unburned sites after a year.

These shifts in number of species were caused by the presence and absence of rare and minor species. The dominant species, that is those that had high cover and frequency values, changed little over the course of the sampling (Figures 3 and 4). Dominant species included *C. jamaicense, Sagittaria lancifolia, Mikania scandens* and *Polygonum* spp. in the sawgrass community; and *P. hemitomon, Typha* sp., *S. lancifolia* and *M. scandens* in the broad-leaf marsh. These species are perennials, except for *Polygonum* sp. which is an annual, and were present as mature plants. All these species quickly regrew following the fire.

Most of the minor species occurred only as seedlings, although they were often quite numerous. A few individuals lived long enough to mature and flower but most did not. Species in this group included *Eupatorium capillifolium, Boehmaria cylindrica, Ptilimnium capillaceum,* and *Galium tinctorium* in the sawgrass community; and *E. capillifolium, Ludwigia repens, Hydrocotyle umbellata* and *Cyperaceae* spp. in the broad-leaf emergent community.

Biomass and Species Composition Following a Prescribed Fire

Sawgrass and maidencane communities demonstrated different responses to the prescribed burn (Table 1). Over the 20 month sampling period, live biomass decreased in the maidencane community, and there was no significant change in dead biomass. Burned and unburned sites were not significantly different. The cause of this decline is not known. It may have been due in part to seasonal differences in sampling periods. The pre-burn sample occurred in August, which is the latter half of the growing season, and the second sampling occurred in February, the middle of the dormant season. However, the 20 month post-burn sampling occurred in October, the end of the growing season, and levels of live biomass were also low.

In the sawgrass community, live sawgrass biomass was significantly greater in the burned than unburned site 20-months post-fire. There was no significant difference in dead sawgrass biomass.

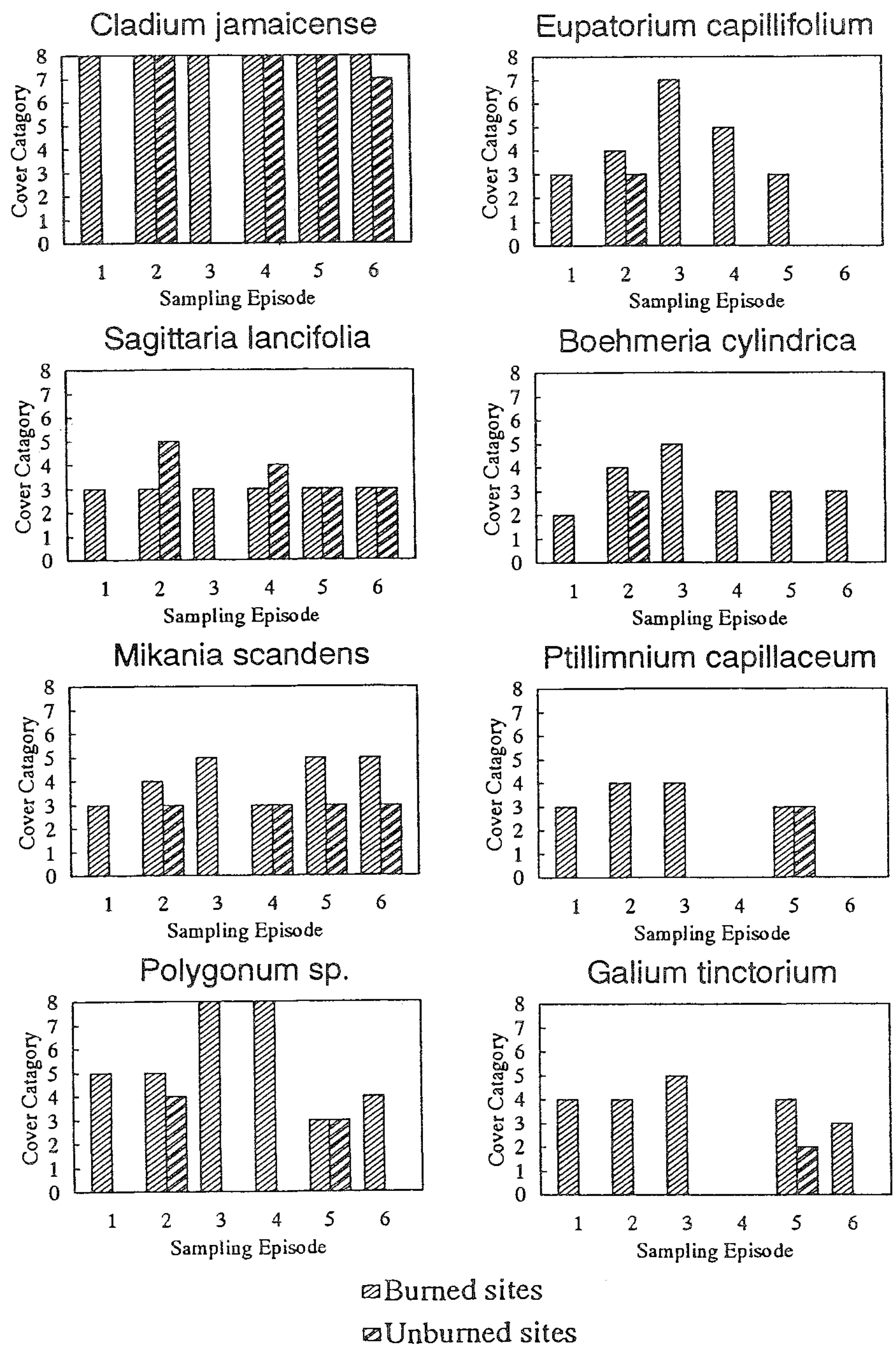

Fig. 3. Changes in cover in the sawgrass community following an arson fire. Mean cover category for each sampling episode. Major species are shown in the left column, minor species in the right column. Sampling episodes 1 = March 1992, 2 = April 1992, 3 = June 1992, 4 = August 1992, 5 = December 1992, 6 = April 1993. Sampling was not done in the unburned sites for episodes 1 and 3. Cover categories 8=75–100%, 7=50–74%, 6=25–49%, 5=5–25%, 4=<5% numerous, 3=<5% few, 2=solitary, 1=observed but not in sampling site, 0=not observed.

In the sawgrass community the fire had little effect on species diversity (Table 2). There were no significant differences (t-test, $p<.05$) between burned and unburned sites in mean species density (number of species per sampling quadrat), or species diversity as measured by the Shannon-Wiener Index. There were no significant differences in cover values for any species between burned and unburned sites 20 months post-burn. However, *Polygonum amphibium, Sagittaria lancifolia,* and *Salix caroliniana* all increased in cover and *Typha domingensis* decreased in cover in the burned sites after the fire.

Mean species density and species diversity in the maidencane community were significantly less in the burned than the unburned sites 20-months post burn (Table 2). Species which disappeared after the fire in-

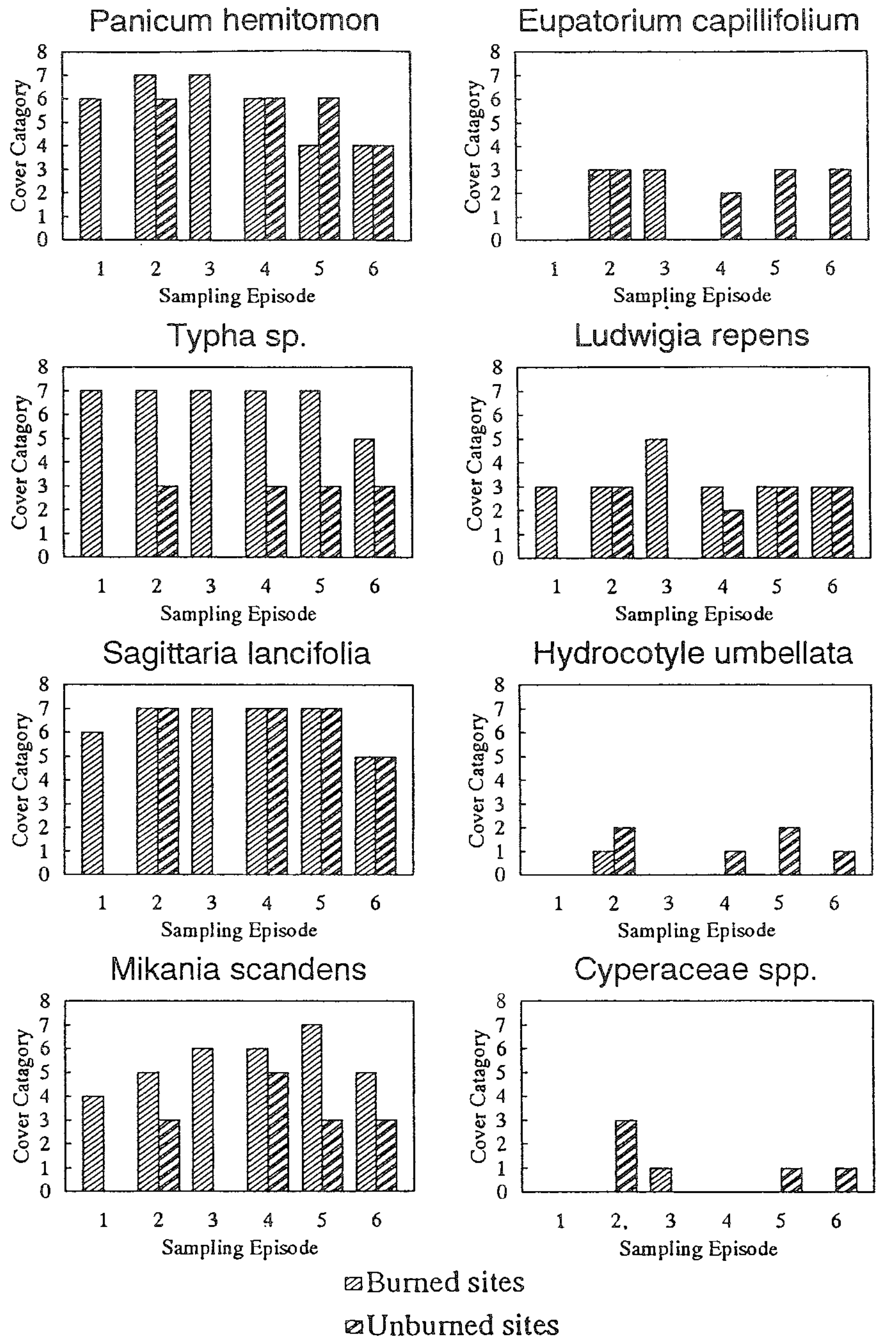

Fig. 4. Changes in cover in the broad-leaf community following an arson fire. Mean cover category for each sampling episode. Major species are shown in the left column, minor species in the right column. Sampling episodes 1 = March 1992, 2 = April 1992, 3 = June 1992, 4 = August 1992, 5 = December 1992, 6 = April 1993. Sampling was not done in the unburned sites for episodes 1 and 3. Cover categories 8 = 75–100%, 7 = 50–74%, 6 = 25–49%, 5 = 5–25%, 4 = <5% numerous, 3 = <5% few, 2 = solitary, 1 = observed but not in sampling site, 0 = not observed.

cluded *Cyperus* sp., *Mikania scandens,* and *Sagittaria lancifolia.* All had pre-burn cover values of <1%. *Typha domingensis* which was not present before the fire, appeared after the fire with low cover values <1%.

DISCUSSION

No lasting changes in species composition or abundances were seen in sawgrass communities in either study. Number of species and species diversity decreased in the maidencane community after the prescribed burn. The low frequencies and covers of many of these species makes it difficult to draw firm conclusions. Also results with single species were sometimes contradictory. For example, cattail (*Typha domingensis*) disappeared from the sawgrass sites 20 months after the prescribed burn, but appeared as a new species in the maidencane sites at the same time. *Sagittaria lancifolia* disappeared from

Table 1. Fire effects on biomass. Mean above-ground biomass, SD shown in parentheses. Pre-burn samples N = 10, post-burn N = 8 for each treatment in each community. * indicates significant differences between treatment groups by t-test, p < .10.

	Pre-burn biomass (g/m²)		20 Months post-burn biomass (g/m²)	
	Unburned	Burned	Unburned	Burned
Sawgrass community				
Live sawgrass	2092 (684)	2379 (857)	1289* (888)	2161* (800)
Dead sawgrass	981 (587)	1391 (137)	2133 (804)	2344 (250)
Total (all species)	3225 (915)	3850 (281)	3428* (1196)	4664* (1214)
Maidencane community				
Live maidencane	982 (371)	1103 (388)	267 (92)	254 (121)
Dead maidencane	112 (88)	242 (109)	222 (134)	173 (96)
Total (all species)	1211 (290)	1367 (415)	525 (117)	496 (206)

the maidencane sites after the fire, but increased in cover in the sawgrass sites.

Other investigators found no significant changes in species composition after fires in maidencane marshes (VanArman and Goodrick 1979). Forthman (1973) reported no changes in species in the sawgrass community after fire. However, in another Everglades study (Urban et al. 1993) density of sawgrass decreased and cattails increased one year post-fire, in both high and low nutrient sites. In *Juncus roemerianus* and *Spartina bakeri* marshes, minor species increased in cover in the <0.5m layer one year after burning. There were no changes in the dominant species (Schmalzer, et al. 1991).

The changes in species composition observed in monitoring the effects of the arson burn suggest that seed bank species take advantage of low water conditions to germinate. Fire may increase the rate of germination by exposing the substrate to more light, but our study did not demonstrate this. The changes that were observed occurred in both burned and unburned sites and were short-term. These changes appeared to be related less to fire than to changing water levels. Water levels were low immediately after the fire, and two of the sites were completely dry for several months. Water was higher during the June sampling; the sites had 15 to 30 cm of water. Water levels continued to rise, and in August the sampling sites had depths of about 45 cm. Water levels were low again in December but increased through the new year, and by April water levels exceeded those of the previous April.

Our results indicate a rapid recovery of sawgrass biomass after the prescribed burn. This may have been due to the nutrient status of the area. Phosphorus occurs at higher levels now than under pristine conditions, due to agricultural discharge into the marsh. Average total phosphorus in the water column for this area is .267 mg/l. In less impacted areas, total P levels average .045 mg/l.

Forthman (1974) found rapid regrowth of sawgrass culms and leaves following a fire in the Everglades. Live biomass 1 year post-burn ranged from 69% to 92% of pre-burn live biomass. In contrast, Steward (1984) found total sawgrass standing crop 18 months post-burn to be only 38% of pre-burn levels. Herndon et al. (1991) reported rapid regrowth of culms, and no significant changes in sawgrass densities where the culms were not submerged after the fire. When water level rose to cover the culms, sawgrass densities declined below pre-burn values and did not recover within the three years of the study. In a study of repeated burning in an Everglades Muhlenbergia prairie, Herndon and Taylor (1986) found under an annual burning regime sawgrass biomass decreased significantly between the second and third year.

Table 2. Effect of Fire on Species Parameters. Cover, number of species and diversity pre- and post-burn. N = 10 for each group for the pre-burn sampling. N = 8 for post-burn sampling. * indicates significant differences by t-test, p < .01.

	Pre-burn		20 Months post-burn	
	Unburned	Burned	Unburned	Burned
Sawgrass community				
% Cover				
Mean	37.6	35.9	22.5	33.3
SD	5.3	9.7	9.2	13.7
N-Species				
Mean	4.5	4.4	3.6	3.6
SD	1.3	1.2	1.1	0.8
Shannon Wiener Index				
Mean	0.9	0.8	0.7	1.0
SD	0.6	0.5	0.5	0.2
Maidencane community				
% Cover				
Mean	38.6	44.5	26.2	17.3
SD	6.7	10.7	12.0	8.2
N-Species				
Mean	4.3	2.9	4.4	2.1*
SD	1.8	1.1	1.6	0.8
Shannon Wiener Index				
Mean	0.6	0.2	0.9	0.1*
SD	0.6	0.2	0.7	0.3

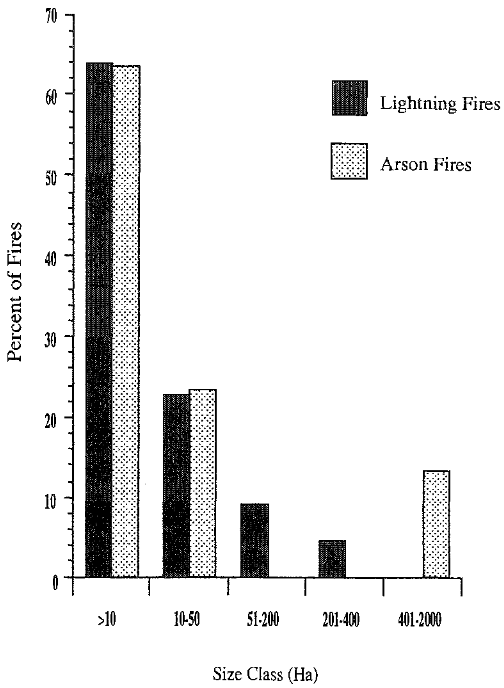

Fig. 5. Fire by size category, lightning and arson fires. Upper St. Johns River basin, January 1986–August, 1993.

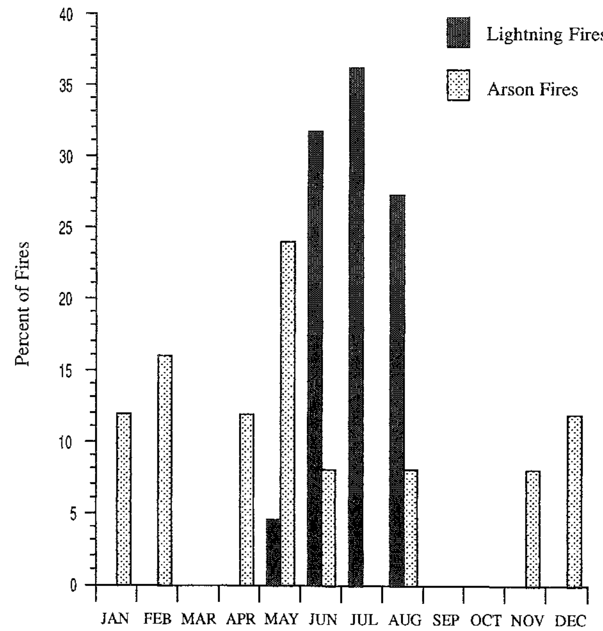

Fig. 6. Fire occurrence by month, lightning and arson fires. Upper St. Johns River basin, January 1986–August, 1993.

Data from the upper St. Johns River basin, and from Everglades National Park suggest that a relatively small proportion of the total area of a marsh experiences a fire in any one year. In the upper St. Johns River basin marshes, records on fires are very limited and must be interpreted with caution. Between January 1986 and August 1993, ninety-four fires occurred in the approximately 100,000 ha of marsh in Brevard County (Florida Dept. of Forestry, Orlando District, unpublished fire records). A total of 7,044 ha (7.0%) of marsh was burned. Thirty-two percent of these fires were caused by arson and 23% by lightning. The remainder were accidental or of unknown cause. On average, arson fires were larger than lightning fires (mean area burned = 136 ha and 20 ha, respectively) although part of this difference is due to a few very large arson fires (Figure 5). All the lightning fires occurred between May and August, but half of the arson fires occurred between November and February (Figure 6).

The Everglades marsh ecosystem supports vegetation similar to that found in the upper St. Johns River basin. Fire records for the Everglades National Park are more complete and show somewhat similar patterns. These fire records include pinelands, freshwater marsh and coastal vegetation types, but freshwater marshes account for the majority of area and fires (Taylor 1981).

Between 1948 and 1979 there were 436 wildfires which burned a total of 146,521 ha. This was approximately 51% of the terrestrial area of the National Park at the time. Lightning accounted for 43.6% of the fires and 22.5% of the area burned. Most of the lightning-caused fires were small. Almost half (46.3%) burned 10 ha or less. The small size of these fires is not due to fire suppression since most lightning fires in this area are self-extinguished (Everglades National Park 1992). Very large fires were infrequent. Fewer than 10% (6.9%) of the fires were over 400 ha, and only 2.5% were over 2000 ha (Taylor 1981).

Although small lightning fires were frequent, they comprised only a small fraction of the total area burned in lightning fires over the 31-year period. Fires under 10 ha accounted for only .5% of the total area burned, and all fires under 200 ha in size accounted for less than 15% of the burned area (Taylor 1981).

The seasonality of the lightning fires in the Everglades was quite distinct. Most (86.8%) occurred between May and August, and 30% occurred in June (Taylor 1981).

These data suggest that fire frequency in these communities is low. Earlier work conducted in the Everglades proposed a 3–4 year fire frequency for sawgrass marshes (Hofstetter 1974; Wade et al. 1980). This was based on observations in the Everglades that sawgrass communities with large amounts of litter were experiencing die-off (Hofstetter 1974). However, both sites that were burned and sites that were not burned recovered from this die-off (Taylor 1981).

More recently, longer fire intervals have been suggested for sawgrass communities. Snyder (1991), using the documented fire history of Big Cypress Preserve, found 12-year fire intervals for all fuel types combined and a 7-year fire frequency for marsh and prairie vegetation.

MANAGEMENT IMPLICATIONS

It is widely believed that fire is necessary in marshes to limit expansion of woody species cover (Craighead 1971; Hofstetter 1974; Kushlan 1990), although few quantitative data on this question have been collected. Fire rarely kills woody species in the marsh (Forthman 1973; Hofstetter 1974), but woody cover in small wetlands was reduced by fires in the growing season after extended dry periods (Huffman and Blanchard 1991).

The research done so far points out that the effects of fire are highly variable and are related to hydrologic conditions. Nutrient status is probably also an important factor. The marshes of the upper basin have experienced human-caused alterations in hydrology and nutrients which have had significant effects on vegetation patterns. Therefore it is not sufficient to merely reinstitute what we believe to be the natural fire regime. We need to investigate the ecological role of fire in this system and work towards reinstating this role in order to restore and maintain the communities.

Results from our experiments suggest that fire is not a useful management tool in reducing fuel loads in sawgrass communities, nor does fire appear to increase species diversity in this system.

The ecological function of fire in these ecosystems remains to be elucidated. Particularly lacking are studies of the effects of fire frequency and fire intensity. It is likely that fire plays an important role in limiting woody species cover but this needs further investigation. Additionally, it has been hypothesized that the maintenance of both maidencane and sawgrass communities, which apparently do not differ significantly in hydroperiod, is the result of fire (Lowe 1986). He suggests that severe fires may kill sawgrass and provide an opportunity for maidencane to establish. Without these fires, sawgrass would supplant the maidencane community and eventually dominate the entire area.

Since management decisions cannot await the outcome of long-term studies, it is vital that managers monitor and report the effects of the prescribed fires they carry out. Pre- and post-burn sampling of species composition and cover could provide important information on the role of fire in floodplain marshes. Such monitoring efforts could also make an important contribution to our understanding of the effects of fire frequency.

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