Restoration Fire and Hurricanes in Longleaf Pine Sandhills

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Back-to-back hurricanes in 1995 provided an opportunity to explore how different forms of disturbance interact.

Historical accounts characterize intact old-growth longleaf pine (*Pinus palustris*) forests as having a canopy of scattered large pines, clumps of younger pines, scattered hardwoods, and a low groundcover of shrubs and mixed forbs and grasses (Means and Grow, 1985; Myers, 1990; Frost, 1993; Schwartz, 1994). The open forests of the southeastern United States were exposed to frequent, low-intensity fires caused by lightning strikes and set by Native Americans, which maintained this longleaf pine-dominated landscape. Hurricanes, which are a less frequent but consistent event in these systems, also modify the vegetation structure (Gordon and others, 1997).

Thus, the openness of these forests is the direct result of storm events and fire, which together maintain hardwood species at low densities. Typically, mesic sandhills and flatwoods can sustain annual and biannual fires, whereas drier sandhills would burn every three to five years due to insufficient build-up of fine fuels (Robbins and Myers, 1992; Frost, 1993). Open-canopied longleaf pine forests support the highest plant species richness in North America (Walker and Peet, 1983; Hardin and White, 1989; Walker, 1993). This high diversity is a direct effect of fire, which reduces competition from trees and shrubs and exposes mineral soil for the establishment of seedlings of new species (Streng and others, 1993). Before the land was fragmented by roads and land clearing, lightning and human-induced fires were able to spread over vast areas because only waterways, wetland communities, recent burns, and weather conditions blocked their spread through the extensive grasslands below the longleaf pine canopy (Robbins and Myers, 1992; Frost, 1993). Fire coverage would have varied widely, from small areas, when fires were extinguished by the same storm that started the fire, to fires of thousands of acres (Stout and Marion, 1993).

Many of the areas that remain in or have been planted in longleaf pine now suffer from an overabundance of hardwoods that have formed a high midstory. Hardwoods often resprout after logging or other operations and continue to dominate the midstory and canopy. Current management often does not include fire. As a result, most of the remaining 2 percent of the original 92.5 million acres once covered by longleaf pine communities is degraded. Establishment and growth of the pines, as well as habitat quality for many other species, have decreased.

Fire as a Restoration Tool

To examine the role of fire in restoring longleaf pine forests to a more open structure and to determine whether re-introducing fire to these systems that had long been protected from fire could help in reducing hardwood abundance, we developed a joint project between The Nature Conservancy, the University of Florida, Tall Timbers Research Station, and Eglin Air Force Base (Eglin). For the experiment, we compared the responses of vegetation, arthropods, birds, and herpetofauna in areas that were fire suppressed and areas with the same starting condition that were burned in the spring (April to June) of 1995. We compared these areas with more natural, frequently burned longleaf pine reference stands at Eglin. Each of the management techniques was applied to six 200-acre stands.

Eglin Air Force Base, on the western panhandle of Florida, has roughly 330,000 acres of degraded longleaf pine-dominated sandhills, and 12,000-15,000 acres of sandhills that burn frequently due to their close proximity to bombing ranges. The frequently burned areas have higher numbers of longleaf pine trees, fewer hardwoods, more herbaceous cover, greater species richness, and more exposed mineral soil (Provencher and others, 2001). Eglin land managers are working to return the degraded sandhills to as near their natural condition as possible. Their restoration efforts will result in improved habitat for the endangered red-cockaded woodpecker (*Picoides borealis*) and for other game and non-game species, such as northern bobwhite (*Colinus virginianus*) and gopher tortoise (*Gopherus polyphemus*).

We were specifically challenged by the managers at Eglin to determine whether prescribed burns would increase the similarity of the plant and animal communities on currently fire-suppressed plots to those on nearby fire-maintained reference plots. For statistical reasons, we were unable to directly compare spring-burned or fire-suppressed plots to the reference plots because the latter areas could not be randomized with the other two treatments. (The locations of high-quality sites are fixed on the landscape, while we could randomly select paired fire-suppressed and burned plots.) However, restoration success should be measured against a high-quality reference site (National Research Council, 1992). We circumvented this statistical problem by testing treatment effects (by two-way analysis of covariance for a block design, using pre-treatment data as the covariate) on the similarity between each treatment and the reference condition for the plant, arthropod, reptile and amphibian, and breeding bird communities. Use of similarity indices then made possible a whole community comparison that included both common and rare species. We calculated proportional similarity (PS) between each treatment plot i (= 1,..., 12) and each reference plot j (= 1,..., 6) as, $PS_{ij} = 1-0.5\Sigma \; |p_{ik}-p_{jk}|$ (Brower and others, 1989),where p_{ik} is the proportion of variable k in treatment plot i, and p_{jk} is the proportion of variable k in reference plot j. We took the logarithm of the k values, or abundances of individual species, to prevent large values from dominating PS. This transformation increased the representation of rarer species. Plots that share all the same species in the same proportions will have a PS of 1, whereas plots

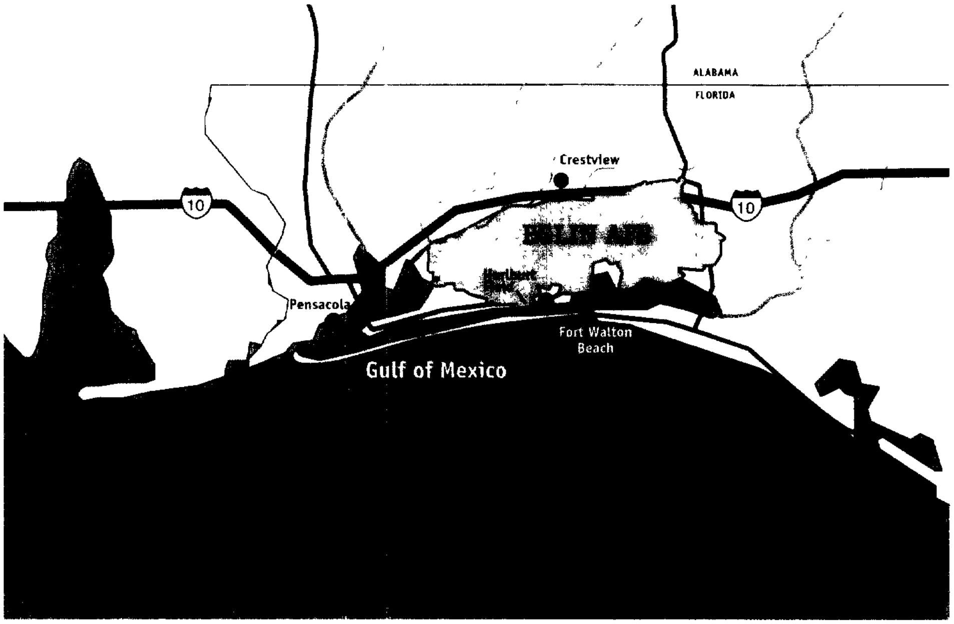

Figure 1. Map of Eglin Air Force Base and surrounding area on the upper Gulf Coast of Florida. Pensacola is to the west of Eglin across Escambia Bay.

Old-growth reference longleaf pine sandhills. Note the abundant growth of grasses, the reduced hardwood midstory, and the typical clumped regeneration of longleaf pine juveniles among the older trees, some as old as 500 years. *Photos by Louis Provencher*

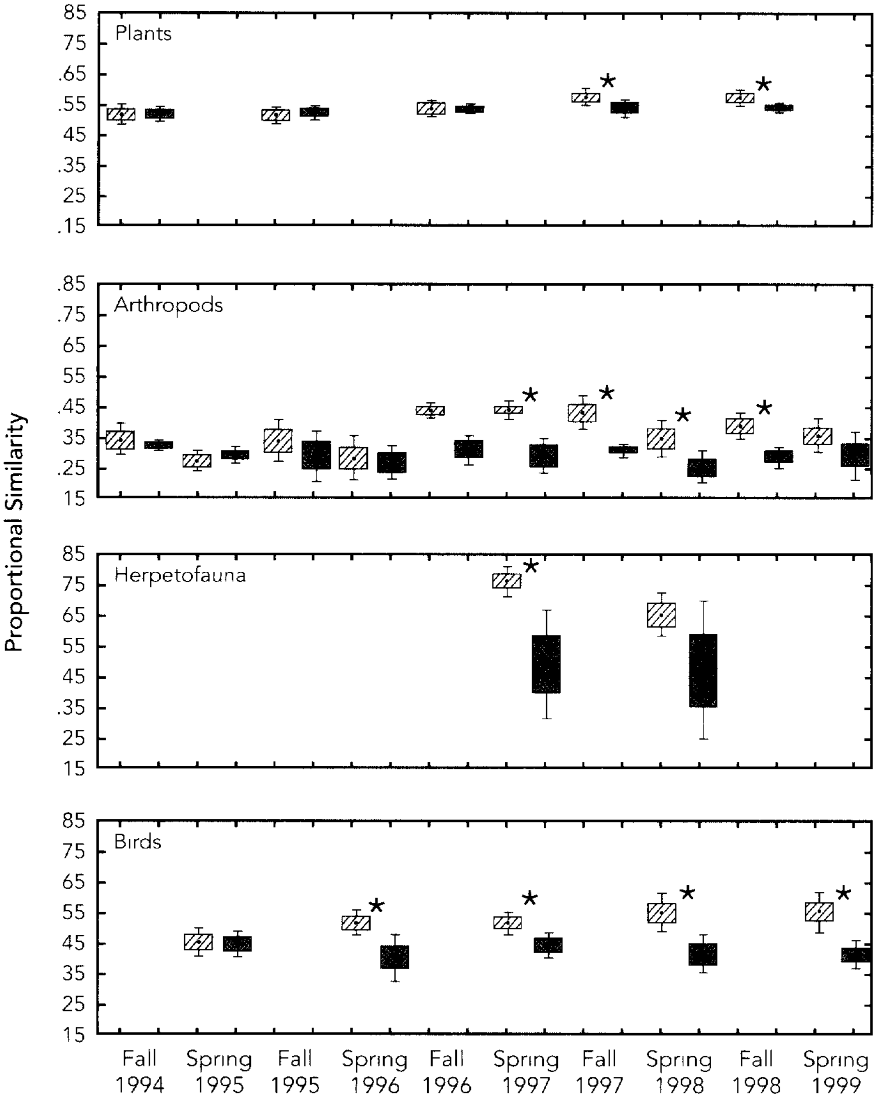

Figure 2. Proportional similarity for plants, arthropods, herpetofauna, and breeding birds between spring-burned (denoted by diagonally striped fill) and fire-suppressed (denoted by solid fill) plots. An asterisk indicates a significant difference (P<0.05) between treatments. Center of plot is the average, the edges of the box are ± one standard error, and the error bars are the 95 percent confidence intervals. N = 6 for all taxa, except herpetofauna for which N = 4.

that share no species will have a PS of zero.

We found that fire had a large effect on the communities we studied. The two treatments were equally dissimilar to the reference condition prior to treatment (herpetofauna were not sampled prior to 1997). Following treatment, the plant, arthropod, herpetofauna, and bird communities on the burned plots were generally more similar to those on the reference plots than were those on the fire-suppressed plots (Figure 2). For plant species, this difference was especially dramatic two years after the spring burning. Arthropods responded more quickly, with a significant difference between burned and unburned plots apparent within one year after treatment. These differences decreased with time, however, and showed substantial overlap in confidence intervals by the spring of 1999. In 1997, the herpetofauna on spring burned plots were significantly more similar to those in the reference condition than were those in fire-suppressed plots. While not significant, the same trend continued in 1998. One year after spring burning, the breeding bird species assemblage on spring-burned plots was significantly more similar to the reference condition than in fire-suppressed plots. This difference increased with time.

We have shown elsewhere that spring burns reduced oak (greater than breast height) densities by 18 percent compared to the fire-suppressed plots one year after burning, and by 41 percent three years after fire (Provencher and others, 2001). During the same period, steady increases in hardwood resprouts below breast height, forbs, and graminoids were significantly higher in spring-burned plots than those observed in fire-suppressed plots.

Breeding birds associated with open pine forests appear to have responded directly to changes in habitat structure caused by the short- and long-term topkill of hardwoods. As others have observed (Engstrom and others, 1996; Burger and others, 1998), we detected increases in red-cockaded woodpecker, red-headed woodpecker (*Melanerpes erythrocephalus*), northern bobwhite, brown-headed nuthatch (*Sitta pusilla*), southeastern American kestrel (*Falco sparverius paulus*), and Bachman's sparrow (*Aimophila aestivalis*) in spring-burned plots (Provencher and others, 1999), making these areas more similar to the reference plots. Only the tufted titmouse (*Baeolophus bicolor*) declined significantly with increased hardwood reduction.

Reptiles and amphibians responded to the openings in the forest and the patchiness of the habitat caused by fire. Habitat heterogeneity increased because of the resprouting hardwoods, increase in growth of herbaceous plants, exposure of mineral soil, and increases in numbers of dead limbs that are used for perches. In other words, fire created habitat patches of different light and structure conditions, resulting in reptile and amphibian abundances similar to those found in the reference sandhills (Litt and others, *in press*).

Whereas birds and herpetofauna responded to these changes in habitat structure, the arthropods we sampled appeared to be more closely tied to the plants as resources. Fire causes plants to resprout, providing tender, nutritious new growth for plant-eating species, especially grasshoppers, leafhoppers, and planthoppers (Smith and Young, 1959; Owensby and others, 1970; Nagel, 1973; Dunwiddie, 1991; Stein and others, 1992). This being the case, we hypothesize that the decrease in similarity, from its peak in 1996-1997 to 1999, is due largely to the aging of plants that provide food for insects and to increasing shade from the hardwood resprouts.

Surprisingly, plants were slow to respond, and their response was moderate compared to other groups. Streng and her colleagues (1993) have proposed that changes in the densities of groundcover plants are limited by the rare occurrence of seedling establishment in a forest floor dominated by long-lived perennials. Therefore, they suggest that the responses of plants to fire regimes should be observed over an extended period of time. We believe this explanation is applicable in our study as well.


Collecting herb-layer arthropods in a fire-suppressed longleaf pine sandhill encroached by hardwoods.

How Fire Influences the Effects of a Hurricane

Hurricanes are another factor that influences stand structure across the southeastern United States (Gordon and others, 1997). We were able to examine the interaction between the effects of hurricanes and fire because several hurricanes occurred during the course of this study. In 1995, Hurricanes Erin and Opal hit Eglin directly and uniformly affected our experimental plots. This made it possible for us to compare the effects of the hurricanes on our fire-maintained reference and fire-suppressed plots. As it happened, we had burned our long-unburned plots just two to four months before the first hurricane hit in June and so did not collect data on these plots.

During the late summer and early fall of 1995, Hurricanes Erin (Category 1 Hurricane) and Opal (Category 3-4 Hurricane) made landfall near or on Eglin. Hurricane Erin made landfall near Pensacola on August 3, 1995 with Eglin reporting maximum wind gusts of 58 knots and maximum sustained winds of 43 knots (National Hurricane Center, 1995a). Hurricane Opal made landfall near Hurlburt Field on October 4, 1995 with maximum wind gusts of 125 knots and maximum sustained speeds of 75 knots (National Hurricane Center, 1995b). Between December and April we collected quantitative data on tree damage and mortality on the six no-treatment, fire-suppressed plots and the six fire maintained reference plots discussed above. We measured tree diameter at breast height (DBH), height before a tree fell, and height at breaking point of all wind-damaged trees. By necessity, we often had to take measurements on downed or leaning trees. Using the presence of dying foliage and young stems as indicators, we estimated the number of trees that were alive prior to hurricane events and counted those found leaning after both hurricanes as windblown.

Eight of the 34 species of trees encountered in a previous sampling (Rodgers and Provencher, 1999) experienced wind damage during Hurricanes Erin and Opal (Figure 3). Turkey oaks (*Quercus laevis*) suffered four times more wind damage on reference plots than on fire-suppressed plots (median: 40 percent compared to 10 percent), a significant difference ($P = 0.019$) (Figure 3). Sand post oak (*Q. margaretta*) was the only other tree species that followed the same pattern with no damage detected in fire-suppressed plots and 3 percent median damage found in reference plots. Although damage to longleaf pines never exceeded 8.2 percent, three times more trees suffered wind damage on fire-suppressed than reference plots (median: 3 percent compared to 1.1 percent). This difference, however, was not significant ($P = 0.26$). Sand live oak (*Q. geminata*), bluejack oak (*Q. incana*), and persimmon (*Diospyros virginiana*) all followed the same pattern as longleaf pine, with similarly low percentages of wind damage and non-significant differences between fire-suppressed and reference plots. Weeping haw (*Crataegus lacrimata*) and sand pine (*P. clausa*), which were present on reference plots, suffered negligible damage in fire-suppressed plots (Figure 3).

Although tree damage was evident all over the base, we were surprised by the relatively low frequency of damaged longleaf pines, especially older trees, compared to hardwood trees. However, our results are consistent with other hurricane damage studies conducted in the southeastern United States. Gresham and colleagues (1991) found that longleaf pine was the least damaged of all pines following Hurricane Hugo in South Carolina in 1989. They also found that upland oaks generally suffered more damage than

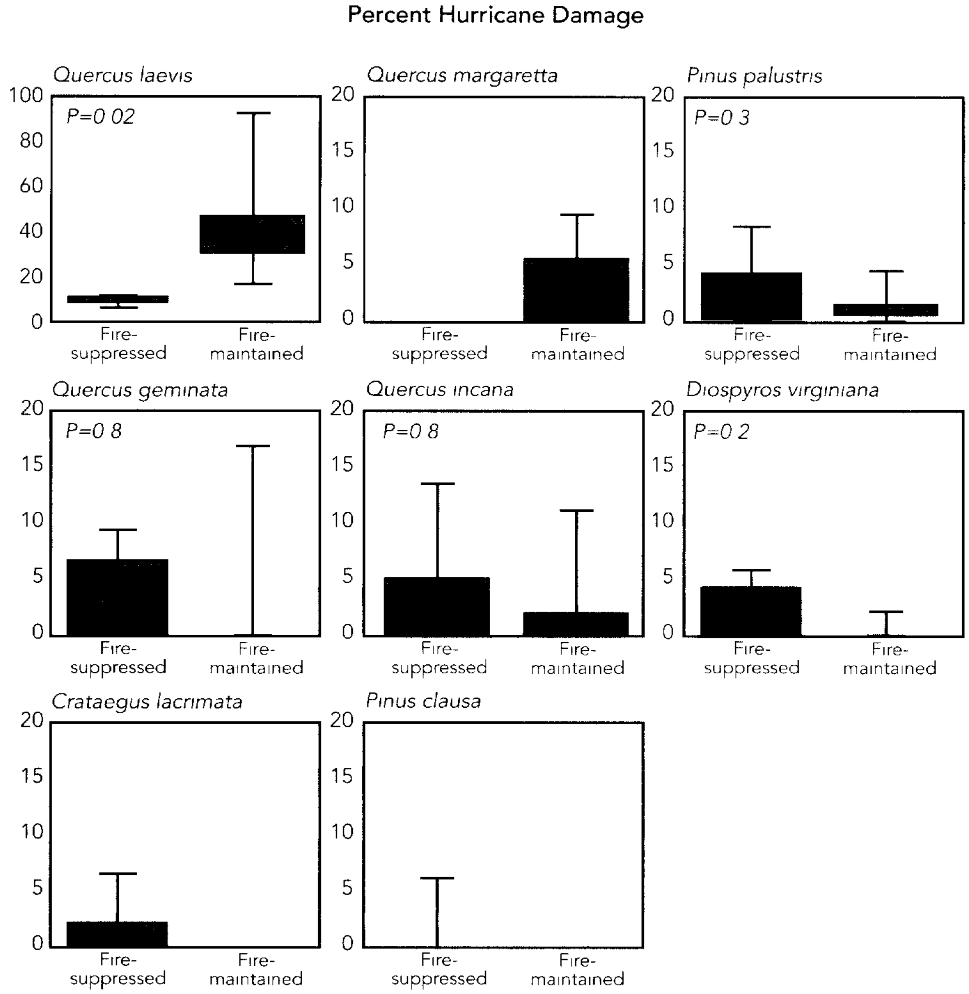

Figure 3. Percent wind damage from Hurricanes Erin and Opal to tree species sampled in six fire-suppressed plots and six fire-maintained reference plots in 1996. Percent damage was calculated by dividing the number of damaged trees (including resprouts) by the total number of trees per species. Values were averaged within plots. Replicates in the figure are plots. Differences were tested using a t-test for unequal sample sizes. Only five of six fire-suppressed plots sampled contained hurricane-damaged trees, whereas all six reference plots contained hurricane-damaged trees. Median, 25 percent and 75 percent quartiles, minimum, and maximum are plotted.

longleaf pines. Among oak species, sand live oak was more resistant to wind damage, a result also observed by Touliatos and Roth (1971) in southern Mississippi following Hurricane Camille in 1969.

The sensitivities of tree species to hurricane-inflicted damage depends on a) the strength of the wood, b) the shape and size of the crown, c) the extent and depth of the root system, d) the prevailing moisture conditions, and e) the shape of the bole (Touliatos and Roth, 1971; Putz and others, 1983). Gresham and colleagues (1991) proposed that longleaf pine resists wind damage better than other trees because it has deeper roots and also an extensive system of lateral roots. Under the more devastating conditions of Hurricane Camille, the height and extent of the crown of longleaf pine became a major cause of trunk snapping. Sand live oak, a well-rooted species with a low center of gravity and very strong wood, was especially resistant to wind damage from Camille (Touliatos and Roth, 1971). While the apparent resistance threshold of longleaf pine is within the range of historical storm intensities, it appears that longleaf pine is quite resilient to hurricane-force winds. The potentially high frequency of tropical storms and hurricanes over the lifespan of a longleaf pine suggests strong selection pressure for wind resistance. Indeed, Gresham and colleagues found less wind damage among species most common to the Atlantic Coast than among species commonly found further inland.

This then helps explain how old-growth longleaf pines, necessary for species such as red-cockaded woodpecker, have been able to survive the impacts of hurricanes over time. Perhaps the more important result from this study, however, was the greater vulnerability of turkey oak to hurricane-force winds in open, fire-maintained reference stands. Turkey oak stems probably shield one another from wind gusts. On the other hand, longleaf pine showed slightly greater vulnerability to hurricane force winds with increasing turkey oak densities. In effect, winds from hurricanes Erin and Opal imitated the role of fire by selectively damaging oaks relative to longleaf pines in already burned areas, but may have the opposite effect in areas dominated by turkey oaks. In other words, hurricanes may push tree composition to the extremes of a continuum ranging from pine savannas to turkey oak hammocks. Accelerated restoration of longleaf pine sandhills being invaded by hardwoods would, therefore, shift the community onto a trajectory toward an open forest structure, under the continuing influence of hurricanes.

Management Implications

Although this study encompasses a wide range of species of varying dispersal abilities and generation times, fire makes them interdependent. Many wildlife species such as red-cockaded woodpeckers, northern bobwhite, many songbirds, reptiles, and amphibians feed largely on arthropods. Others feed on plants and seeds that are produced profusely following fire, sometimes only after growing season fires (Robbins and Myers, 1992). Applying fire to open the midstory is of obvious relevance to those managing species of concern and game bird species. Fire is also the process that renews the palatable vegetation that is the first link in the trophic chain from plants to arthropods and the other wildlife that depend on them. Moreover, fire has an indirect benefit in hurricane-prone areas. It increases the probability that longleaf pines will survive and dominate these xeric pinelands, enhancing our ability to restore and maintain these areas and the species they support.


Hurricanes Erin (class 1) and Opal (class 3) damaged many sand pines (across road) and oaks (background) during 1995. Longleaf pine was resistant to wind damage.

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