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Lawrence S. Earley

Looking *for* Longleaf

The Fall *and* Rise *of an* American Forest

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TWO

Fire in the Cathedral

Instantly the lightning, as it were, opening a fiery chasm in the black cloud, darted with inconceivable rapidity on the trunk of a large pine tree, that stood thirty or forty yards from me, and set it in a blaze. The flame instantly ascended upwards of ten or twelve feet, and continued flaming about fifteen minutes, when it was gradually extinguished, by the deluges of rain that fell upon it.
—William Bartram, *Travels* (1791)

You could easily characterize the land of the longleaf pine in terms of the rivers that cross it, or the swamps that give it its unique and mysterious character. From southeastern Virginia to eastern Texas, forty-two major streams cut across the Gulf and Atlantic pinelands on their way to the sea. Wetlands of all types puddle the land. When Hernando de Soto and his conquistadors marched north from Tampa Bay in search of treasure in 1539, they spent a lot of time during the next four years crossing rivers and swamps. In de Soto's day, 35 percent of the southeastern land mass was characterized as a wetland of one type or another. Pure and mixed stands of longleaf pine covered 60 percent of the Gulf and Atlantic Coastal Plains in 1539, but most of the rest was a wetland of one type or another.[1]

Indeed, at one time all of the Southeast had been under water. The Coastal Plain was born of the sea, and the sea still occupies a substantial part of it. Geologists say that the Coastal Plain is in a dynamic tension between its emerged and submerged portions. For the past five thousand years, the emerged portion of the Atlantic Coastal Plain has occupied a wide band ranging from the present shoreline to the Piedmont fall zone; the submerged portion, called the Continental Shelf, has extended from the shoreline to offshore waters about six hundred feet deep. The proportions of submerged and emerged land have changed in response to changing climate, and they are still changing today. At some points during the last 60 million years, Louisiana and Mississippi lay beneath a great inland sea that stretched all the way to Canada. The South Atlantic coastline lay as far inland as Columbia, South Carolina. You could have paddled a sea kayak from Augusta to Macon, Georgia.[2]

During ice ages, when glaciers moved southward across the North American continent and expanding polar ice captured more of the earth's oceans, falling sea level exposed the slope of the Coastal Plain far offshore. At the peak of the last glaciation 18,000 years ago, the South Atlantic coastline lay about 450 feet lower than it does today. As the climate warmed, the seas began their long climb back up the Coastal Plain. This process of sea level rise and fall, triggered by climate change, was primarily responsible for creating the flattened surface of the Coastal Plain. The landscape is so flat that Alexandria, Louisiana, about 125 miles from the Gulf of Mexico, is only 82 feet above sea level. Geologists have found a number of terraces across the Coastal Plain, each the result of a particular epoch of sea level rise, some marked by abrupt scarps that mark the farthest advances of the sea, all of them covered in various layers of sandy sediments deposited by the sea. The coastline today has been in its present position, more or less, for approximately the last five thousand years.[3]

But the rivers have also contributed mightily to the making of the southeastern Coastal Plain. When I drive from Raleigh to Cape Hatteras, North Carolina, or from Hattiesburg to Gulfport, Mississippi, I am traveling over ancient sea bottoms whose sandy sediments were delivered by the region's many rivers. Rivers draining the southern Appalachians far to the west carried the slowly eroding rock to the Atlantic Ocean and the Gulf of Mexico where rising seas could distribute it across the Coastal Plain. Rivers shaped the sandy sediments dropped by the sea, eroding them, over thousands of years, into a complex landscape of level plains, rolling hills, river valleys, and wetlands.

During glacial times, when the coastline lay lower than it does today, rivers could run energetically to the sea, cutting deep channels into the soft sediments. But when the climate warmed, ice caps melted, and the seas crept up the slope, rivers that once rushed over the Coastal Plain slowed down, sluggishly moving in wide looping meanders across one flat terrace after another toward the sea. Rivers that had run swiftly through deep channels across the Continental Shelf were drowned beneath the advancing sea, creating the shallow sounds that characterize eastern North Carolina today. The rivers meandering across the flattened landscape of the Coastal Plain were shallow, and they flooded often across wide alluvial valleys where vast wooded swamps of bald cypress trees and other swamp-loving plants grew, adapted to the wet soils. Water tables rose. The landscape virtually oozed much of the year.

Although the southeastern landscape was born from the sea and carved by rivers, it was fire and storm that effectively shaped the natural communities of the Southeast, especially the longleaf pine forests. William Bartram understood a lot of the varied longleaf ecosystem, yet even he did not suspect the key roles played by these natural processes.

The effects of hurricanes on the forest could be spectacular. In 1528 Spaniard Alvar Núñez Cabeza de Vaca complained that he and his fellow conquistadors, making their way up Florida's western peninsula, encountered "so many fallen trees on the ground that they barred our way." Many of the trees "were split from top to bottom from the lightning that strikes in that part of the world, where there are constantly great storms and tempests." A hurricane that blew out of the Gulf of Mexico in 1772 destroyed the woods north of Mobile for about thirty miles. Up the Pascagoula River "the pines were blown down or broke, and those which had not intirely yielded to this violence, were so twisted, that they might be compared to ropes," according to land surveyor Bernard Romans. J. F. H. Claiborne of Mississippi described a thunderstorm in a longleaf pine forest in a colorful, if perhaps overwrought, style:

> The day was dark and lowering. For weeks nor rain or gentle dews had refreshed the calcined earth. A heavy cloud hung overhead, and its pent-up fury burst upon the forest. The few birds that tenant these silent woods flew screaming to their eyries; some cattle dashed across the hills for shelter. The whole wilderness was in motion. The pines swayed their lofty heads, and the winds shrieked and moaned among the gnarled and aged limbs. A few old ones fell thundering down, casting their broken fragments around; and then the hurricane rushed madly on, tearing up the largest trees, and hurling them like javelins through the air. The sky was covered as with a pall; and lurid flashes, like sepulchral lights, streamed and blazed athwart it. The earthquake voice of nature trembled along the ground, and, ere its running echoes died away, came again, crash after crash thundering forth. But at length, as though weary of the agony, it paused, and the phantom clouds scudded away. The scene around was appalling! Hundreds of trees lay prostrate, while, here and there, others stood shiv-

ered by the bolt of heaven and smoking with its fires. God preserve me from another ride through these giant pines in such a tempest.[4]

The main legacy of lightning storms in the South was fire. Fire posed an evolutionary challenge for plants and animals of the longleaf pine forests: They had to adapt to it or retreat to places where fires burned less often. The fact that longleaf not only survived but also dominated the Atlantic and Gulf Coastal Plains for thousands of years means that it met this challenge successfully. Indeed, fire in longleaf pine forests is like rain in a rain forest. Within the evolutionary pressure cooker of an environment shaped by storm and fire, longleaf developed many extraordinary traits over the millennia, enabling it to dominate an immense area.

By one estimate, 100 lightning bolts are discharged per second over the globe, each one a current that zaps back and forth from cloud to earth dozens of times in less than a second. That adds up to about 8.4 million bolts each day. Within the square mile in which you live, you may expect between 40 and 80 such lightning strikes per year. Where they strike depends on the conductivity of the substance. Some trees are better conductors than others. Oaks and pines are more prone to injury from lightning than beech, even though beech is extremely thin-barked whereas oaks and pines are relatively heavily armored with bark. Bracken ferns near a lightning-struck tree die within a few days of the strike, while another ground-hugging plant such as runner oak seems unaffected.[5]

When Edward V. Komarek Sr. published these findings in the early sixties, he had been the director of Tall Timbers Research Station since 1958 and was on his way to nearly single-handedly promoting the science of fire ecology through the station's annual fire ecology conferences. His main contention, and the subject of many of the papers he wrote, was that fires in longleaf pine were inevitable and even necessary, and that they had left lasting effects on the plant and animal communities of the Southeast.

Lightning storms are common in the South because the semitropical climate is hot and humid and the moisture-laden air masses from the Atlantic and the Gulf of Mexico breed thunderstorms like oranges. Florida has more "thunderstorm days" (defined as a day when thunder is heard) than any other state in the country. Such storms create a lot of fires. Komarek found that one thunderstorm, coming after a drought, produced ninety-nine blazes in Florida alone. Thus a single thunderstorm traveling north out of the Gulf of Mexico could "spew" fires over a vast distance. The rain that accompanies lightning storms doesn't always extinguish fires. After one fire, a log at the Wade Tract Preserve smoldered for nearly ten weeks one summer, despite four or five downpours in the meantime. Such an ignition source could easily start one or several fires.[6]

Fuel for fires is everywhere in longleaf pine forests, particularly blankets of tawny needlefall, large cones, and thick clumps of flammable wiregrass. One of the most visible characteristics of a longleaf pine is its needles, which at eight to fifteen inches in length are longer than those of any other southern pine and often form a graceful corona at the twig ends when viewed from below. They grow in a fascicle or cluster of three from their basal sheath and are shed after the second year of growth. Unlike the leaves of a deciduous tree, longleaf needles clusters are not all the same age. A tree may hold needles that have just begun growing, as well as one-, two- or even three-year-old needles all at the same time. Though there is an almost constant sprinkle of needlefall year round, it is heaviest during the fall and winter.[7]

"Fire can mean a fire in grass, or in leaves, or in herbaceous plant growth, in forest debris, or even in the crowns of trees," Komarek pointed out. "It can travel slowly, quietly, and be as gentle as the whisper of a breeze; or it can travel with tremendous speed. . . . It can be so cool that one can put his hand under it without discomfort, or its heat can be so intense as to nearly consume one."[8]

One nineteenth-century traveler in Georgia, Englishman Basil Hall, left an especially vivid picture of a fire in a longleaf pine forest:

> On the 21st of March, we fairly plunged into the forest, from which we did not again emerge for many a weary day of rugged travelling. The interest of the forest scenery was a good deal heightened by an immense tract of it being on fire. How far this extended we had no means of knowing; but the volumes of smoke filled up the back ground completely, and deepened the general gloom in a very mysterious style. At many places, however, we actually came amongst the blazing trees, and were somewhat incommoded by the heat and smoke. I was amused at one particular spot by seeing a pitch-pine-tree burning in a curious way. The fire had somehow made a hole in the stem, near the ground, and burnt out a passage for itself, of several yards in length, in the heart of the tree; after which, the flame again made its appearance, thus producing a pipe or chimney. There was, consequently, a strong draught, and the poor pine was roaring away like a blast furnace, while its top was waving in the air, a hundred feet above, as green and fresh as if nothing remarkable were going on below.

> . . . [There was a portion] of the forest where not only the trees were on fire, but the grass also. It was an exceedingly pretty sight. A bright flaming ring, about a foot in height, and three or four hundred yards in diameter, kept spreading itself in all directions, meeting and enclosing trees, burning up shrubs with great avidity, and leaving within it a ground-work as black as pitch, while everything without was a bright green, interspersed with a few flowers.[9]

This kind of fire was typical of most blazes in longleaf forests, the flames rising perhaps a foot or two above the ground, driven here and there by the wind until finally doused by a heavy downpour or after running up against a creek or wetland. Fires like these could burn for days or weeks and cover an astonishing amount of ground. Fire historian Stephen Pyne reports that in 1898, a fire once burned over 3 million acres in southeastern North Carolina and "barely made it into the back pages of the Raleigh newspapers." The longleaf pine environments were so interconnected that a large fire that ignited in Albany, Georgia, might sweep through Tallahassee, Florida, four weeks later. Today, the longleaf landscapes are fragmented by roads and other artificial firebreaks, and many state forest services are prepared to battle the wildfires that do occur. In Hall's day fires were so common that most longleaf pine forests would have burned every three to eight years. Some burned every two to three years, and others sometimes even burned annually.[10]

The key to the longleaf pine's survival and dominance in such a fire-rich environment was a suite of adaptations—thick bark, large seed size, inconsistent seeding, fall seed sprouting, and slow growth during the tree's early years—that enabled it not only to tolerate fire, but also to thrive with it. All pines are armored by thick bark that helps to insulate the trees' vital cambium from the lethal effects of heat. As a fire licks the bark of a tree, the temperature on the surface can rise to 1,600 degrees Fahrenheit. At a temperature of 140 degrees Fahrenheit, the cambium of a tree is killed. Thus bark can be considered the Maginot Line of a tree's fire defense. It's a natural insulator, with many internal air cells inside a mainly corky material, although its structure and composition differ from species to species. The bark of some tree species is thicker than others, and the thicker the bark, the more fire resistance it provides. Given identical bark thickness, some species more efficiently insulate than others. For example, fire kills the cambium of sweet gum in less than half the time as longleaf pine. As befits a southern pine, loblolly is better insulated than most hardwood trees, but not as well as longleaf.[11]

Longleaf's cones and seeds are also keys to longleaf's success in the region. The tree begins to produce cones when it is about twenty or thirty years old. Longleaf's cone is large, from four to twelve inches in length. Though by no means the biggest pinecone in existence (the sugar pine of California and Oregon produces a cone that can be two feet long), longleaf's cone is the largest of the southern pines. The cones that fall to the ground are the female strobili that hold the seeds. The male strobili are inconspicuous, appearing at the end of the lowest branches and looking very much like catkins. They emit clouds of buoyant pollen that fertilize the receptive female conelets in the spring, with the seeds maturing over a two year-period.[12]

The longleaf's seeds are large, too. They are so heavy that they fall close to the tree, unlike the smaller and lighter seeds of the loblolly pine which fall over a wider territory. This conveys an advantage to an opportunistic species like the loblolly, but the longleaf's large seed has a tremendous survival value, for it is loaded with enough moisture and nutrients to sprout almost immediately on fire-cleared mineral soil and begin its taproot growth before winter.[13]

Within a week or two after falling the longleaf seed pushes out its embryonic leaves called cotyledons. In a good seed year, it is not unusual to find hundreds of seed wings standing straight as soldiers, held aloft by the germinating seed. The autumn timing is not accidental. Lightning-ignited fires occur in any month of the year, but they peak in May and June. For a few months after, the mineral soil will be exposed and the seed, falling from the ripened cones from the end of September to December, will find a hospitable bed for germinating. Thus the autumn seedfall occurs just when the ground is most receptive to the seed and also when a naturally occurring fire is least likely. The seeds need light and room to grow. Without an occasional summer fire that eliminates thick accumulations of grass and debris, most of the seeds would never reach the ground; they would be hung up in the thick tangle of grasses and needles. If they managed to reach the ground, they would be deprived of moisture and growing space.

Other southern pines adapt to fire in other ways. Pond pine and sand pine, for example, also grow in natural communities that burn, but it takes extended dry weather conditions to create a fire hot enough to burn them. The infrequent fires—occurring anywhere from a decade or two to a century — burn intensely and catastrophically and can kill entire stands. Adapting to these kinds of fires, both species evolved a serotinous cone — one that releases its seed only in the heat generated by a fire.

Loblolly, slash, and shortleaf pines have adapted to fire by growing quickly and adding layers of protective bark. By the end of the first growing season, loblolly seedlings may already be seven inches high and will add a foot or more each year thereafter. If they can escape fire for five or six years, only a very hot summer fire will kill them. The frequent fires in longleaf pine communities, however, confined loblolly pines and other tree species to wetter places on the landscape — drains, pond shores, and river floodplains — where fires burned cooler.

Longleaf's strategy was quite different, and it dominated the region precisely because of it. Longleaf begins to grow quickly after germinating, but it puts most of its growth below the ground, not above it. Indeed, before winter the young tree has begun growing a taproot at a sometimes phenomenal rate. In two weeks, it can grow twenty inches long. In ten or eleven months taproots can be eight feet long, and at maturity they may well be much longer. A long taproot is an essential characteristic of a tree species that grows in dry, or xeric, soils, and the capacity to reach the deeper water and reach it quickly gives the longleaf an advantage not shared by many other trees. The long taproot also serves to anchor the tree in the open habitats and sandy soils in which it grows. Perhaps most important for the young tree, the taproot stores food that it will someday need.[14]

For the first few years of its life, a longleaf pine seedling huddles low on the ground and is almost indistinguishable from a grass clump, which is why this early growth is called the "grass" stage. Through its second and third springs it continues to grow slowly. If other southern pines are sprinters, achieving height growth quickly, the longleaf is more like a long-distance runner. It can remain within a foot or two of the surface for two to five or more years, then spurt quickly. In seven years, a longleaf pine may be growing four or five feet in height each year.

Longleaf dominates because of its grass stage. Like other pines, it is quite vulnerable to fire during its first year and even a light, surface burn may kill it. Late in its first year or early in its second it becomes fire-resistant, and now it fully distinguishes itself from the other southern pines. The terminal bud of the grass-stage seedling is surrounded by a bushy sheath of green needles. A fire may burn off almost all of its needles, but incredibly the growing bud is normally safe and the needles quickly grow back. In one experiment, tissue paper placed around seedling buds one to three feet high was not even scorched in a fire, though the needles were burned to within three inches of the bud.[15]

Although a seedling has been known to languish in its grass stage for a dozen or more years, dominant seedlings in most stands start height growth within a few years and grow past breast height in seven years. Drawing on the food stored in their taproots, the pine rockets upward as much as three feet in a single year and perhaps four feet each year thereafter, quickly lifting its growing tip above the level of most fires and gradually armoring its stem with thick plates of bark. After a few years of swift growth, the pine is usually invulnerable to all but the hottest blazes, and it continues to grow at a rate similar to and sometimes even exceeding loblolly and other swifter-starting pines.

Of course, not every seedling follows the same script. Seedlings from the same seed year may well undergo their growth spurt in different years. This unpredictability has frustrated many tree growers, yet a staggered emergence time is another fire adaptation, providing a further guarantee that at least some of its seedlings will survive a hot fire. The longleaf's notorious pokiness is actually critical to its success on the Coastal Plain.

Longleaf produces a few cones and some seed just about every year, but a good seed year occurs just once every five to seven years. This ability to "mast," or vary its seed production over an irregular period, is an adaptation that it shares with other tree species, including other pines and many oaks. In a good mast year, from 85 to 95 percent of the trees will bear cones and half of them will produce more than 50 cones per tree. Each cone releases about 50 or 60 seeds in a good year, although the number of cones and seeds tends to increase with the size of the tree. One ancient longleaf pine twenty-four inches in diameter at breast height and one hundred feet tall produced 150 cones and more than 100,000 seeds. Good mast years are rare and have entered the literature like the great vintage years of a Bordeaux. A big mast year is usually a regional phenomenon, not just a local one.[16]

Tree growers yearn for more regularity in longleaf's seed production, yet these lean years have a practical survival value to the longleaf. Irregular seeding may well be a coevolutionary trait that arose in response to seed predators. Few seeds ever survive to germinate. Even before they are out of the cone, seeds can be destroyed by insects, frost, and squirrels. Once they fall, they are attacked by birds, rodents, large and small mammals, insects, and other predators that can practically wipe out an entire year's production in less than six weeks. Once a longleaf pine's seed germinates, ants may beset the tiny seedling. The seedling's succulent cotyledons—the early needles—

are also palatable to ants and other insects. Young saplings are occasionally beset by bark beetles and southern pine beetles. As much as 99 percent of a seed crop may be destroyed by predators.[17]

Thus if the pine produced a similar number of seeds every year, rising wildlife populations might consume all of the seeds. Not bad for the animals, not so good for the pine, for the survival of the forest depends on at least some of the seeds escaping and germinating. That may be why the longleaf, like many oaks, overwhelms seed predators with a bumper crop one year and starves them for several years following.[18]

The longleaf's conservative seeding strategy is a fine trait for a long-lived conifer in a fire-prone environment. The longer a plant lives, the less important it is to seed often. Since fire is always random, even when frequent, it's bound to burn up a lot of seed and seedlings anyway, so the longleaf wouldn't accomplish much with more frequent seeding.[19]

Other plant species of the longleaf pine ecosystem also have had to adapt to frequent fires, and many of their strategies are similar. Some plants, for example, produce seeds that germinate only after the heat from a fire cracks their hard covers, allowing water to enter. Others seem to have abandoned sexual reproduction entirely. In a fire-prone system such as this, a perennial plant that sprouts vegetatively from a single root or rhizome year after year can quickly take advantage of the nutrients released by a fire. A seed-producing annual, on the other hand, would waste a lot of energy in germinating and developing a root system every year, especially if it were going to be killed off by the next fire. In habitats that are not disturbed by fire as frequently, seed-producing annuals make sense; here perennial plants with fire-proofed underground growing parts seem to have won the day. Fires that consume the top parts of the plants rarely harm their underground parts, and the plants are adapted to resprout quickly. The endangered rough-leaf loosestrife (*Lysimachia asperulifolia*) begins to bloom in early spring, vigorously flowering only where the plant has been burned regularly. It grows from an underground rhizome, producing buds in the fall that become shoots and enable the plant to resprout quickly after fire. The Venus fly-trap sprouts back in as little as two weeks after a fire from its rhizome. Woody shrubs—wax myrtle, gallberry, titi, and saw palmetto—will also sprout after fires. Turkey oaks and bluejack oaks sprout after a winter fire has apparently killed them. Sweet gums and dogwoods will do the same.[20]

The season in which a fire occurs often affects what grows in a longleaf pine forest. Forest managers on the quail-hunting plantations near the Wade Tract traditionally burned their land in February and March each year, after the hunting season ended and before the quail started nesting. For most managers, these annual winter fires are easier to control and they have predictable results: They keep the oaks shrub-sized and the forest open, and for the quail-hunting nimrods, an open forest means better shots during the quail-hunting season. But winter fires also tend to eliminate much of the new pine growth that sprang up after the autumn seedfall, and they don't eliminate the scrub oaks. In time, a regime of regular winter fires may produce a longleaf pine forest with fire-proofed thickets of turkey oaks and other oak species, as well as a sparse understory of grasses and herbs.[21]

Ecologists generally agree that longleaf and its associates evolved with lightning-ignited fires that burned predominantly during the growing season from April to September. Thunderstorms peak in August, but lightning in May and June starts fires that are more successful at killing the scrub oaks. Plant reproduction seems to be tied to fires at this time. Wiregrass will not flower unless it has been burned during the growing season, and growing-season fires trigger abundant flowering and seed and fruit production in a host of other plants. Thus ecologists encourage forest managers to work toward a regime of frequent though not annual growing-season fires.[22]

Some ecologists believe that longleaf and its plant associates may well be doing more than defending themselves against fire. They may actually be promoting fires.

This intriguing and controversial theory was proposed in 1970 by a U.S. Forest Service forester named Robert Mutch, and it has entered the botanical literature under his name. Mutch suggested that in certain ecosystems that depended on regular fires, many of the fire-adapted plants might have a vested interest, so to speak, in encouraging blazes to discourage competition. Thus natural selection might favor plants with flammable oils and resins in their leaves and stems. Plant communities with these characteristics would burn readily, discourage other plants with less or no resistance to fire, and improve their own chances for successful reproduction and long-term survival.[23]

As evidence, ecologists point to the highly flammable resin content in longleaf wood and needles. Longleaf is the most resinous of any southern pine, a factor that made it the leading source of turpentine and other naval stores for two hundred years. Longleaf pine needles are also the longest of all the southern pines, and they fall annually.

Another plant that evolved similar pyrogenic qualities is wiregrass, a bunch grass that grows in longleaf pine communities from Virginia to western Alabama where little bluestem grass takes its place. By one reckoning, 90 percent of the understories of longleaf pine communities are made up of grasses, with wiregrass the dominant grass over almost all of the longleaf's eastern range. By looking at a clump of wiregrass, it's easy to see why it burns so easily. Each clump consists of hundreds of individual leaves, most of which are actually dead. Dig down into the tussock and you'll pull up what feels and looks like wood. Indeed, the live leaves have very few green cells; most are woody, fibrous cells, making the entire plant nothing more than a highly flammable piece of kindling.

Is it possible that natural selection favored wiregrass's tinderlike characteristics and the longleaf pine's heavy resin content and annual needlefall, ensuring that the forest burned and their competitors were disadvantaged?

A tidy debate has taken place in the ecological research community over the Mutch Hypothesis. Ecologists of Atlantic and Gulf Coastal Plain ecosystems have clearly been intrigued by the theory, although some of them reject its premise. Because a plant has flammable leaves or oily compounds doesn't mean that they evolved for the primary purpose of burning, these ecologists say. In a lively exchange in *Oikos* in 1984, James R. Snyder of the University of Florida complained that the hypothesis was "Mutch ado about nothing." Many of the characteristics that increase a species' flammability, he wrote, may only be secondary or incidental to other traits that evolved to enhance the plant's fitness in other ways. In the case of wiregrass, for example, the fibrousness of the leaves and its many dead cells may have fit the plant primarily to survive frequent droughts, not just to fuel frequent fires. So shallow-rooted is the plant, and so droughty are the upper layers of the soil most of the year, especially in sandhill communities, that one might wonder how the plant survived at all. This was the problem that intrigued B. W. Wells in the 1930s, and he explained its peculiar characteristics as adaptations to drought. "Thus in wire-grass we see a striking illustration of how plants meet low-water conditions: they reduce the relative amount of living cells, and besides check as best they may the evaporation of water."[24]

It's a chicken-and-egg debate. Though it is difficult to identify the evolutionary origins of the flammable plant materials in longleaf pine communities, it's unmistakably true that the ecosystem is self-reinforcing because of these flammable materials. With frequent growing-season fires, longleaf and its pyrogenic associates will survive and produce fuels for even more fires, thus maintaining an open environment favorable to themselves and unfavorable for fire-intolerant competitors.[25]

Not surprisingly, the distinctive wildlife species of the longleaf pine grassland system are as dependent as plants on an open landscape created and maintained by frequent fire, and they are as vulnerable as plants to its absence. Fires apparently do not cause any diminishment in the number of species in a grassland habitat. Grassland animals have evolved with fires, and they know how to deal with and benefit from fires.[26]

Large mammals and most birds seem to have the most effective means of escaping fire—they move away from it, or, since fires burn in patches most of the time, they flee to an unburned green oasis left by the patchy fire. Nestling birds are especially vulnerable to a fire, particularly since many bird species common to longleaf pine habitats nest on the ground or in low shrubs. Growing-season fires will kill some young birds, yet in the long run, ecologists say, it doesn't matter because fire improves the habitat. Fire eliminates the stalks of grasses and other plants that hamper birds' efforts to scratch for their food. A seed eater like bobwhite quail doesn't do well in heavy plant growth. Insects are more abundant after spring grassland fires and less abundant in dense thickets that have grown up in the absence of fires. Many ground-nesting bird species will renest if their nests are destroyed by fire. Bobwhite quail will sometimes renest three times a year.

Wild turkeys generally won't renest, producing a single clutch of eggs that hatch in mid-May. A growing-season fire may well destroy the nest and eggs, but turkeys respond positively to the open forest produced by growing-season fires. Some biologists contend that spring fires stimulate seed-producing plants that turkeys, quail, gopher tortoises, and many other species favor; increase insects that some animals eat; and increase the protein content in plants browsed by deer.

Some wildlife species are even attracted to fire rather than flee it. One afternoon, while witnessing a prescribed fire in North Carolina's Sandhills Game Land, I noticed a red-tailed hawk circling overhead. While two technicians ignited the wiregrass, another lightly disked a grassy road to provide a firebreak between burn compartments. Even as the first wisps of smoke curled up into the air, the hawk swooped into a pine tree overhead and peered at the work going on below him. "That's ol' Red," one of the technicians told me. "He always comes around when we burn." The hawk was instinctively drawn to the fire to find rodents moving out of harm's way. Instead of fleeing the flames in fear, the hawk saw an opportunity for an easy meal.

Even the hawk's prey are not helpless in the face of a typical fire. Mice, rats, and voles—part of a primary food chain in a grassland ecosystem like the longleaf pine—follow a variety of strategies to avoid fire, depending on the circumstances. Rodents are burrow excavators and when fires occur, they can duck into them and escape the flames and heat from the typical grass- and needle-fed fire. If they are caught in the open, however, they can hunker down in a low spot and let the fast-moving fire run right over them. If they are lucky and the burning conditions are right, they might suffer nothing more serious than singed fur.

Edward Komarek of Tall Timbers believed that cotton rats could sense when fire approached and the direction from which it came. Given the burning characteristics of most longleaf pine forest fires, these animals had enough time to place their young in little "popholes" where they would be safe. He also found pathways from the unburned islands to the burned areas where the cotton rats were feeding on the tender grasses that began to emerge from the blackened soil just days after the fire.

Another bird species not generally considered a resident of longleaf pine forests foraged in dead pines killed by fires and lightning. The extinct ivory-billed woodpecker is best known as a native of the bottomland hardwood swamps that grew about the myriad rivers of the Southeast. Yet in some places, these large woodpeckers nested in swamps and foraged in the surrounding pine forests for wood-boring insects, their favorite food. Some of the original, old-growth pine forests had high populations of wood-boring beetles that attacked trees that had been injured or killed by lightning or by lightning-ignited fires. Such an abundant source of food didn't go unnoticed by the ivorybills. Because of their great size, ivorybills required a huge territory of as much as six square miles per pair. That amount of forest could support 36 pairs of pileated woodpeckers and 126 pairs of red-bellied woodpeckers. What hurt the ivorybills was a trait they had developed during their evolution. They singled out large, old, and recently killed trees and scaled away plates of bark to reach the first layer of grubs and beetle larvae underneath. The ivorybill's feeding strategy worked fine with a huge forest that contained a lot of old fire-killed trees, but as these forests disappeared, the ivorybill lost an important food base.[27]

A longleaf pine forest may seem parklike, yet it is really a combat zone in which longleaf vies for survival with rival pine species and the resident oaks. As long as fires burn regularly and keep the ground open, there's no contest. Longleaf and its fire-dependent associates dominate the landscape without serious competition. In the absence of fire, however, competitive species creep up from the wet places where they have been confined. With its prolific, annual, and predictable seed, loblolly quickly seeds in the empty places; shrubs and hardwoods, formerly controlled by fires, grow taller and more numerous, with thicker stems. There's less fine fuel on the ground to burn, and oak leaves burn less readily and more coolly than pine needles. The oaks can fireproof themselves and create conditions for their own dominance.

As hardwoods muscle into the open spaces between the pines and up into the canopy, they outcompete the pines for root space, and the grasses, herbs, and legumes are eliminated along with their provender of seeds and berries. These deciduous forest conditions discourage the populations of gopher tortoises, Bachman's sparrows, red-cockaded woodpeckers, Florida scrub jays, and fox squirrels that could once make a living here. Now blue jays, red-eyed vireos, hooded warblers, flying squirrels, and a suite of species that favor shrubbier hardwood forests find a home.

The longleaf, with its unpredictable seed years and its need for bare soil in which to germinate, cannot regenerate. Veteran longleaf pine trees are still there, but the little seedlings can't grow and the old pines die without successors. The grasses, shrubs, and wildflowers, with their need for sunlight and root space, are shaded out and cannot reproduce. The longleaf pine community may deteriorate so much that it may not be capable of being restored. What was dominant for five thousand years because of fire essentially disappears without it.