STUDIES IN LANDSCAPE FIRE ECOLOGY AND PRESETTLEMENT VEGETATION OF THE SOUTHEASTERN UNITED STATES

by

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ABSTRACT

CECIL C. FROST: Studies in Landscape Fire Ecology and Presettlement Vegetation of the Southeastern United States (Under the direction of Dr. Robert K. Peet.)

In the South, it is expected that all the developable land will have been converted in a few more decades. This will mark, in our lifetime, an ending equivalent in magnitude to the close of a geological era. For the first time in evolution, survival of all native plant communities and species will depend on human management. To manage adequately we must understand natural communities at a deeper level that we do now. Since the soil-vegetation complex is the only thing in nature that integrates all environmental variables: slope, aspect, moisture, evapotranspiration, insolation, temperature extremes and the like, it is critical that we be able to define and map it. If we intend to restore altered habitats so that they once again support rare native plants and animals, we need to be able to map the natural vegetation that once existed on a site. The central idea presented here is that we can reconstruct both presettlement vegetation and natural fire regimes using principles of landscape fire ecology. I began with a project to map the original range of longeaf pine, a keystone species in the largest fire-maintained ecosystem of the South. Once occupying 92 million acres, longleaf pine was found to have been extirpated from 97% of its original range. For wetlands, in order to tease apart the complex relationships between southeastern wetland vegetation according to gradients of fire, moisture, and fertility, I divided the master gradients of fire frequency and soil moisture/organic matter depth into discrete classes, set up tables, and searched the coastal plain landscape for fire vegetation remnants that fit each cell in the tables. The tables in Chapter 3 give a way to look up the fire niche of species mentioned in historical records, a step in mapping natural fire frequency in the original landscape. A way then presented itself to map presettlement fire regimes using

topography and other components of landscape fire ecology. This, along with a survey of published fire history studies, was used to construct a map of presettlement fire frequency of the U.S. (Chapter 4). Then, on a local scale, historic records, vegetation remnants, and landscape fire ecology were used to reconstruct presettlement fire regimes of the Great Dismal Swamp region (Chapter 6). Defining the role of fire in a region is the first step in mapping presettlement vegetation. Since vegetation and soils covary, the soil series is the best unit available for mapping vegetation. Using soil series to put boundaries on vegetation, the problem then is to relate vegetation to soils, fire and topography. A series of principles in the new field of landscape fire ecology emerged in this process. Fire compartments, fire filters, fire frequency indicator species, fire frequency indicator communities, fire-exposed and fire-sheltered areas, fire-tension zones and landscape scale fire frequency gradients are some of the new concepts that go into reconstructing original fire regimes and fire vegetation. Using these principles, along with historical records and some 467 study plots in remnant vegetation, maps of presettlement vegetation were produced in four case studies: Pamlico County, Dare County, the Croatan National Forest, and the Savannah River Site.

KEY WORDS: Canebrake, Croatan National Forest, Fire Compartment, Dare County, Fire Ecology, Fire Exposed vs Fire Sheltered Areas, Fire Filter, Fire Frequency, Fire Frequency Indicator CommunitiesFire Frequency Indicator Species, Fire Shadow, Fire Tension Zone, Great Dismal Swamp, Historical Ecology, Landscape Ecology, Marsh, Mineral Springs Barrens, Pamlico County, Pocosin, Presettlement Fire Frequency, Presettlement Fire Regimes, Presettlement Vegetation, Soils, North Carolina, Savannah River Site, South Carolina, Swamp Vegetation Mapping, Virginia.

DEDICATION

To Vonda Frantz, my partner in "Dancing into the Universe"

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PREFACE

Three of the chapters of this dissertation were published during the course of this work. Chapter 2, was published as:

Frost, C.C. 1993. Four centuries of changing landscape patterns in the longleaf pine ecosystem. Pages 17-43 *in* S.M. Hermann, ed. The longleaf pine ecosystem: ecology, restoration and management. Tall Timbers Fire Ecology Conference Proceedings, No. 18. Tall Timbers Research Station, Tallahassee, FL.

Chapter 3:
Frost, C.C. 1995. Presettlement fire regimes in southeastern marshes, peatlands and swamps. Pages 39-60 *in* S.I. Cerulean and R. T. Engstrom, eds. Fire in wetlands: a management perspective. Tall Timbers Fire Ecology Conference Proceedings, No. 19. Tall Timbers Research Station, Tallahassee, FL.

Chapter4:
Frost, C.C. 1998. Presettlement fire frequency regimes of the United States: a first approximation. Pages 70-81 *in* T.L. Pruden and L.A. Brennan, eds. Fire in ecosystem management: shifting the paradigm from suppression to prescription. Tall Timbers Fire Ecology Conference Proceedings, No. 20. Tall Timbers Research Station, Tallahassee, FL.

What kind of forests preceded the second growth pine woods that occupied the sandy upland farmland that seem to make up the whole middle coastal plain landscape? I first began to ask that question from 1970 to 1976 when I lived in Pitt County, North Carolina. Later, from 1976 to 1981, while serving as the first park ranger at Merchant Millpond State Park in Gates County, near the Virginia line and the Great Dismal Swamp, I started several vegetation studies and began

to collect items from the four centuries of historical literature that might provide clues to the question of original vegetation.

I grew up spending summers with my grandparents in southeastern Virginia where I first heard the term pocosin (in connection with the village of Poquoson), and heard my father tell tales of the great peat fires in the Dismal Swamp that had burned all summer, darkening skies as far north as Hampton and Yorktown during his boyhood in the 1920s. While at Merchants Millpond I explored the southside Virginia Counties that had names my father, uncles and grandfather talked about in the summers. I read historical literature and spent time at the Colonial Williamsburg Research Foundation, where I was given access to microfilm of the British Colonial Records. I read the diaries of William Byrd, describing the land and frontier in the two-state boundary region in 1728. His description of longleaf pine along the Suffolk Scarp was seminal for my future explorations in search of presettlement vegetation. When I began, I didn't know of a single longleaf along the whole scarp between Albemarle Sound and the James River in Virginia, although I had seen a handful of trees in western Gates County. Byrd described the Dismal Swamp as dominated by white cedar, but all the *Chamaecyparis* I had seen there were a few patches in a sea of red maple, loblolly pine and shrubs. The colonial records of counties south of the James River in Virginia were full of references to naval stores, tar kilns and other suggestions related to longleaf pine. William Byrd and George Washington both described a vast canebrake called "The Green Sea," on the east side of the Dismal, but I found there only pocosin and red maple. Nothing seemed to fit existing vegetation. Reconciling the natural landscape described by early records with the very different vegetation found today became my major project.

Apologies to Proponents of the Scientific Method: In the process of getting to my goal—the ability to map presettlement fire frequency and presettlement vegetation, there were many steps, some of which were unavoidably subjective. The first step was collection of some 467 study plots on just over 100 soil series in the study region. 115 of these were intensive 1/10 hectare plots, and 352 were lists of species and cover values on specific soil pedons of a particular series, having a particular fire history. Time since last fire and other evidence of fire history were always collected. How the evidence from these plots was used to reconstruct presettlement fire frequency is the subject of Chapter 6. How landscape fire ecology, historical records and evidence from the field plots were used to make maps of presettlement vegetation is explained in Chapter 7 and

demonstrated in the four case studies that follow.

To explore the data, I first used ordination of species data from the study plots using DECORANA, and classification using TWINSPAN. These quantitative methods, based on existing vegetation, produced little satisfactory information. This was not unexpected since, as mentioned above, the original dominant ecosystem of the uplands, longleaf pine with all its many variants and unique plant communities, had been replaced over some 97% of the landscape with anthropogenic, fire-suppressed vegetation (or no vegetation at all), so classification methods simply described the existing anthropogenically shifted vegetation. It also became apparent that the remaining three percent was mostly fire suppressed, was being burned at a rate lower than it would have experienced in nature, or had experienced a period of fire suppression—a bottleneck that eliminated many fire-dependent species. So far less than 1% of the remaining vegetation could be said to be equivalent to the presettlement condition. Likewise, most wetland vegetation had undergone a shift along the fire frequency gradient or, as documented in the writings of William Byrd and George Washington, been entirely displaced.

It seemed that ordination and classification of modern vegetation had little bearing on the problem of original vegetation. With no satisfactory quantitative way to sample vegetation and fire regimes that no longer existed for many of the soils of the region, I resorted to other methods. Using maps of soil series for placement of vegetation boundaries, I examined many burned and unburned stands to hypothesize about original vegetation on each soil series.

In order to be able to assign fire frequencies to historically described vegetation types, I constructed the tables of fire frequency and wetland vegetation in Chapter 3, using the 467 field plots and from field notes on many other sites visited but not sampled. Similarly for uplands, I listed the best approximations of fire communities on each of the upland soil series. I documented shifts in species dominants and changes in vegetation cover and structure with reduction in fire frequency by looking at multiple stands with different recent fire histories on the same soil series. I studied numerous historical documents and plotted known vegetation types as described for specific, locatable points in the landscape.

Having developed this background for each soil series, I used all the available information; field

data, historical records and principles of landscape fire ecology for mapping presettlement vegetation. In mapping it was necessary to extrapolate from a few known or historically documented points to many, but extrapolation was limited to cases that represented the same soil, slope, aspect, and position within the fire compartment. Additional field work was carried out when there were obvious variants of vegetation with different slope, aspect or degree of fire exposure or shelter from fire.

Most steps to this point were well documented, quantifiable in the field, or traceable to solid historical records. The actual mapping, however, required interpretation of the effects of fire in relation to where each soil pedon occurred in its fire compartment. Chapters 6, 7 and the four case studies are, therefore syntheses with considerable interpretation and increased opportunity for subjective error. An independent test of mapping results was needed. In Case Study four, the presettlement vegetation map was constructed entirely from remnant natural vegetation using principles of landscape fire ecology. A number of historical surveys had been located but the boundary line tree data on these historical plats were reserved to provide an independent test of mapping accuracy. When these surveys were plotted onto the final map of presettlement vegetation the error rate for 144 trees that could be reliably placed within particular soil pedons on the map was only 2.1 percent.

The method is less subjective than it may appear, but requires extensive field work on every soil series in the study area. The most subjective element occurs in the area of landscape fire ecology, and accuracy of the mapping will depend upon the skill of the investigator in this area. In any case, the results can be tested, at least for trees, and sometimes for vegetation types like marsh or canebrake that may be noted by the surveyor on maps.

The principles of landscape fire ecology proposed in Chapter 6 are hypotheses based on the observed distribution of fire communities seen in the field. Most of these remain to be validated using Geographic Information System methods in real landscapes. There are a number of untested hypotheses in Chapter 7 as well. One assumption not tested beyond simple field observations, was that vegetation found one soil pedon under a particular fire regime, could be extrapolated to other pedons of the same soil having the same slope, aspect and degree of landscape exposure to or shelter from fire.

Most of the principles suggested in the chapter on landscape fire ecology remain to be tested. All of them were suggested by field and historic evidence, but rigorous testing was passed over in the interests of reaching the goals stated above. With the rapid disappearance of habitats and the corresponding threats to rare plant and animal species associated with fire communities in the southeast, there is not much time left for protection, restoration and management of natural processes such as fire in the remaining natural areas. Those of us involved in managing habitats for rare species are faced with the need to burn and take other actions based on incomplete understanding, in order to prevent extinction of native species. We strongly hope for refinements and rigorous testing of the methods of landscape fire ecology. The stated goal of this dissertation, and the result presented here is a first method for approximating presettlement vegetation and fire regime. It is a synthesis of plot methods, historical vegetation records and interpretation of the role of fire in the landscape.

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ABBREVIATIONS

cc	Cubic centimeter
cm	Centimeter
dbh	Diameter of woody stems measured at breast height (4 1/2 feet above ground).
ft	Foot
USFWS	U.S. Fish and Wildlife Service
in	Inch
m	Meter
ha	Hectare
km	Kilometer
MFRI	Mean fire return interval
mi	Mile
NWR	National Wildlife Refuge
pH	Measure of soil or water acidity
PPT	Parts Per Thousand
Spp.	Species
SR	State road
US	U.S. highway
WRC	N.C. Wildlife Resources Commission
USFS	U.S. Forest Service

CHAPTER 1

INTRODUCTION

"In the end all we will protect is what we understand."
____Baba Dioum

In North Carolina, it has been calculated that, at the present rate of natural land conversion, all the land that can be developed will be developed in 74 years (David Jones, pers. comm.). That seems likely to be the case in most of the southeastern U.S. If that estimate is true, the next 6-8 decades will see all lands in the South dichotomized into either developed land or land with some sort of natural area status. When that occurs it will be necessary to manage the remnant natural lands, likely only around 3 percent of the original landscape (Noss et al. 1995)[1], for the survival of 100% of the original species and communities. As a first step, managing the earth for survival of species and the communities in which they occur will require knowing what natural communities originally were found on each site and understanding the processes that maintained the communities.

Restoring and managing natural communities will also necessitate mapping them at some level useful in the field. One part of understanding natural communities is being able to delineate where they occur and what environmental variables cause them to occur where they do. As distinguished in later chapters, the species composition and structure of natural communities are strongly influenced by fire, and their boundaries seem to correlate

[1] In a literature review of some 100 studies, Noss found that most major ecosystems of the eastern U.S. had only 1-5% remaining in a natural condition. Assuming all of the remnants can be protected and that the losses that do occur can be offset by restoration of degraded sites, 3% may be the best we can hope for, for long-term preservation.

Figure 1.1. Three hundred-year-old longleaf pine with 100-year-old turpentine boxing scar, almost healed. The tree was boxed in 1890 (determined by a core taken from new wood over the scar). Discovery of this tree, and the puzzles it presented, more than any other single event propelled me into the inquiry about presettlement vegetation and fire regimes that has occupied me for the past twenty years. A remnant of the virgin forest, this longleaf stands with five or six others in woods of loblolly and shortleaf pine, over an understory of turkey oak to 30 cm (1 ft) dbh. There was no evidence of fire for many years and no grass stage longleaf pine seedlings were found. The photo of the boxed tree was taken on November 26, 1980 in woods on the northeast corner of U.S. 13 and N.C. highway 37 on Alaga sand, a Typic Quartzipsamment. A felled tree 1.4 miles west along the road into the Gates County Sand Banks was 309 years old when cut in 1981, giving 1672 as the date of establishment. Fire had been absent for so long that there were beech in the understory! A dense ericad layer, particularly Gaylussacia frondosa and G. baccata, along with a dense layer pine needles and duff, had eliminated the herb layer except for a few Euphorbia ipecacuanhae and Pityopsis graminifolia. An exploratory ship sailing up the Chowan River in 1622 was surprised to discover a gang of men who had traveled overland from Jamestown in Virginia to make tar and pitch from dead longleaf pine lightwood at this site.

reasonably well with those of soil series, the best mapping unit we have available. To restore natural processes such as fire and post-fire succession, and to apply them in such a way as to simulate their natural occurrence, we need maps that show original fire regimes and where fire-influenced vegetation occurred. The likelihood of being able to do detailed mapping of communities that may no longer exist has been usually dismissed as an impossibility, something lost in the past that we can never know. The studies herein challenge this assumption, and suggest that we can reconstruct presettlement vegetation at the level of the soil series, a mapping level precise enough to be useful in restoring and managing remnant natural areas.

Thesis: The central idea presented herein is that we can reconstruct both presettlement vegetation and original fire regimes using principles of landscape fire ecology. This thesis is developed below in a series of papers that parallels the development of my interests in original vegetation and fire ecology.

The Importance of Understanding Presettlement Vegetation

In the past 20 years the quest for understanding presettlement vegetation has changed from an obscure pursuit to an essential conservation need. As will be explored later, most existing "natural" vegetation communities have been altered in species composition and stratal structure to some degree: many have been almost completely transformed. Chapter 2, for example, documents the elimination of longleaf pine from 97% of its original range, while one example in Chapter 7 demonstrates the replacement of 100% of the original plant species in a longleaf pine savanna community with non-pyrophytic species after 90 years of fire suppression. Chapter 5 demonstrates that some savanna species were dependent upon frequent fire for survival.

The need to manage land for preservation of species and community diversity has been recognized in mandates for their conservation on federal lands. Goodman (1994) instructed all branches of the U.S. Department of Defense to "...conduct installation programs and activities in a manner that recognizes, restores, and sustains the composition, structure, and function of natural communities...." Babbitt (1995) directed the heads of the Bureau of Land Management, the U.S. Forest Service, the U.S. Fish and Wildlife Service, the National Park Service, the Bureau of Indian Affairs and the National Biological Service that "wildland fire will be used to protect, maintain and enhance resources and, as nearly as possible, be allowed to function in its natural ecological role." This landmark directive included a report that called for use of the best scientific knowledge on the

role of fire (Philpot, C., and C. Schecter 1995). As a result of such directives, federal installations, from national forests to military bases, are evaluating remnant natural communities as well as the vegetation that once occurred, as models and targets for restoration. Although what managing agencies need are presettlement vegetation maps for the sites to be managed, the government, adhering to the presupposition that presettlement vegetation is unknowable, currently calls such documents "prior vegetation" (prior to what is there now). My work in the Croatan National Forest and the Savannah River Site below was done under contracts for mapping prior vegetation.

In the South, historical survey plats can be used to map vegetation cover types, based mostly on trees on the boundary lines. Historical photographs add further insight into community structure and vegetation strata. Mapping at a level useful for managing a specific site, however, requires detailed understanding of community species composition, especially at the level of the herb layer where most of the species diversity is usually found. Mapping communities where the herb layer is important requires being able to classify the community based on the whole species composition. In the past 20 years there has been expanding interest in community description and classification (Allard 1990, Radford 1981, Schafale and Weakley 1990), and in differentiating the communities present in complex ecosystems (Peet and Allard 1993). State Natural Heritage classifications and the current version of The Nature Conservancy's international classification recognize individual plant communities as elements of diversity that need to be preserved (Anderson et al. 1998, Grossman et al. 1998). Once we understand the vegetation well enough we need to be able to map it.

For mapping to be useful at the local level we need to get to a level of detail sufficient to work with restoring communities on specific sites in the field—a specific south slope or a particular ridgetop. Previous work on reconstructing presettlement vegetation (Delcourt and Delcourt 1977, Leitner and Jackson 1981, Linsey et al. 1965, Musselman et al. 1971) has resulted in vegetation maps at something like the Formation level. That scale may be useful for a broad description of original vegetation of a state or county, but land managers need something more specific. Mapping at the level of the Community Type is much more practical since that is the level at which biologists describe vegetation, and the plants in the plant community make up part of the habitat for the individual species. In Chapter 7 and beyond, communities are described for each soil series (the mapping base) and for each significant variant of slope and aspect within the soil series. In locating study sites it is necessary to distinguish truly natural vegetation from vegetation produced by human activities or by human interference with natural processes of succession and disturbance. Community remnants must be located in the field to represent each of the soil series, slope and

aspect situations where, by plan or by chance, the natural fire regime has persisted. Finally, since the majority of the plant communities in the U.S. were influenced by fire to one degree or another (Chapter 4), it is necessary to look at the role of fire. This involves identifying a series of sites having progressively longer periods of fire exclusion on each soil type in the study region. This is a requirement in order to be able to recognize the degree of fire suppression and species loss or species substitution that has occurred in each natural stand on the managed area.

The Importance of Understanding Landscape Fire Ecology

Fire history work by many authors is converging on the viewpoint that the presettlement United States was a fire landscape (see Chapter 4). If, in the original landscape, most vegetation was affected in some way by fire (including the idea that non-pyrophytic vegetation was confined by fire to certain fire-sheltered regions and microhabitats in the landscape), we must reconstruct presettlement fire frequency in order to understand the degree of its influence on presettlement vegetation.

Across the U.S., much of the native diversity of plants and animals depended upon original ecological processes such as fire. Many of the rarest species seem to be those which inhabited the most fire-frequent parts of the landscape. Of the 26 federally listed endangered or threatened native plant species in North Carolina, sixteen (62%) appear to be frequent-fire species that are declining with the long-term suppression of fire. To restore natural vegetation we must be able to identify and reproduce the regimes of fire, succession and other cyclic processes that sculpt vegetation and provide the array of niches and habitats required by native species of plants and animals. To manage any natural area for preservation of presettlement vegetation types, we must be able to duplicate the original fire regime, whether frequent, infrequent or nonpyrophytic. Deciphering the presettlement role of fire in the southeastern U.S. begins with a look at the region's most conspicuously fire-dependent vegetation, the longleaf pine ecosystem.

Chapter 2 reconstructs the historical range of longleaf pine, a keystone species in a major fire-dependent ecosystem of southeastern uplands. This study began as an exercise to see whether it would be possible to determine the full extent of the species even though it had been extirpated from much of its original range for over 100 years. It was encouraging that there was enough historical information to reconstruct the presettlement range of longleaf pine even where the ecosystem had been totally transformed, and where keystone species, such as longleaf and wiregrass, had been extirpated. It becomes obvious that presence of a fire-dependent species, either as a few remnant

specimens (Figure 1) or just as historical records, may tell us something about the original role of fire at the site where the plants were reported. If enough historical fire data points are obtained we should be able to map the parts of the landscape where fire was important.

If we compare the historical distribution of longleaf with its current range (only about 3 percent of the original), we see that it persists in only certain parts of the landscape, particularly in the most sandy areas. Historical records, however, show that originally it also was found on loamy and even some clayey soils. Field plots suggested that under a frequent fire regime, longleaf was dominant on all upland soils, whether sandy, silty or clayey, but when fire was excluded, longleaf and its associated savanna species were extirpated much more rapidly on the fine-textured and moister soils. It was also noted that fire influenced vegetation differently on different soils, both with regard to vegetation layers and to species composition. Comparison of species in plots on different soil series in the same landscape indicated that, under the same fire regime, it was possible to identify or predict the soil series based on its vegetation structure and species composition. This suggested the possibility that if we could reconstruct the original fire regime and then define the relationships of existing fire vegetation to soils, we can use the resulting information to map presettlement vegetation, at least within the region, using soil maps. Based on experience in the field, the size of area for which we could reasonably extrapolate should be about 4-8 counties. This can be done even if most of the original vegetation has been extirpated.

Beginning with longleaf pine communities, the idea of using soil series maps to map vegetation by correlating it with fire frequency, was followed up with study plots on many different soil series and with differing fire frequencies on each soil type. Other than on the most xeric sands, longleaf is not a species known to persist indefinitely without fire. So its former presence at a site, documented in the historical record, tells us that fire played some role, and the soil type and topographic position upon which it was found tells us something about the original fire frequency. This can be verified by looking at the same soils under known fire regimes. Further, difference responses to fire by different species raise the possibility that some might be used as fire frequency indicator species (this theme is developed in Chapters 5 and 7).

Chapter 3 reconstructs presettlement vegetation and the original role of fire in southeastern wetlands. Because of the large number of rare plants in and around the margins of these formerly fire-maintained wetlands (species such as Lysimachia asperulifolia, Parnassia caroliniana, Venus flytrap and a hundred others), it is critical to understand the pervasive role of fire in order to restore habitats

and processes required by these species. This paper attempts to tease apart the complex relationships between southeastern wetland vegetation and fire, moisture and fertility, by dividing the master gradients of fire frequency and soil moisture/organic matter depth into discrete classes, setting up tables, and searching the coastal plain landscape for fire vegetation remnants that fit each cell in the table. Eight fire frequency classes were used and plotted against four levels of soil moisture/peat depth ranging from wet mineral soils to deep peats. Three separate tables using this scheme were required to cover the variation in marshes, in very oligotrophic peatlands and in the more fertile peatlands. About half my field time was spent trying to sort out these relationships while doing 1/10 ha plots, species lists and fire history in these types. Most cells in the tables are represented by one or more of my some 467 plots, about 115 tenth hectare plots and 352 site surveys, each a species list with cover values for a particular stand of vegetation on a particular soil pedon.

While reviewing historical vegetation descriptions to see how well cells in the vegetation tables fit descriptions by early observers, it seemed that it might be possible to assign fire frequency classes to the southeastern landscape, at least to broad physiographic regions. This led to production of a map illustrating generalized presettlement fire frequency in four regions of the South (Figure 3.1).

Chapter 4 extends historical fire frequency mapping from that developed in Chapter 3 to the rest of the United States. Although thinly scattered over the landscape, there are enough fire history studies and fire scar chronologies to obtain a picture of the general role of fire in different physiographic regions and subregions. For a mapping base, I discovered a map of "land surface-forms" of the entire U.S. which classified the land in terms of three variables: the amount of local relief, the percent of land which is flat or only gently sloping, and whether the flat land is on uplands or in bottomlands (Hammond 1964). These criteria seemed to permit interpretation of the size of fire compartments and the density of impediments to fire flow in the landscape—the landscape factors that should have the most effect on fire frequency. In the paper, I proposed the idea of the fire compartment as a key element in landscape fire ecology. I don't think the term fire compartment had been used before. The idea is developed further in Chapter 7 as a probabilistic concept. A paper on fire compartments and topographic fire probability is in preparation (Langley and Frost).

When I plotted fire history studies onto Hammond's map, I dissolved the boundaries when two adjacent land surface-form polygons had the same fire-return interval, and I added polygons for sand pine scrub in Florida (Myers and Ewel 1990) and for three non-pyrophytic western vegetation types (Küchler 1964). I also made adjustments or added a few polygons based on the literature, as in the

Olympic Peninsula of Washington State, and for the Dismal Swamp region, about which I had much historical material and my own field work. I presented a preliminary version of the map in a poster session at the 1996 Tall Timbers fire ecology conference in Boise, Idaho, and adjusted the fire frequencies in a few places based on comments and references supplied by participants in the meetings.

I proposed the term 'site fire frequency' to represent the true historical fire-return interval for a particular fire compartment, as opposed to terms commonly used in the literature: point fire frequencies (as determined from dating fire scars on a single tree) and area frequencies (such as the number of fires per year on a particular national forest), both of which are likely to give an erroneous picture of the role of fire. In the case of point fire frequency, since it is unlikely that a single tree will record all fires on a site, a lower fire frequency will be reported than that which actually occurred. In the case of area fire frequency, many more fire compartments will be included as the size increases. Consequently, on an area as large as a national forest, which, overall, might experience 10 fires per year, the resulting fire frequency would be reported in months. This obviously distorts the picture since no individual site burns ten times in a year. The true mean fire-return interval in a particular fire compartment is the most important factor for the species present, and that is what is estimated by the map (Figure 4.1).

I also proposed a classification of fires in terms of ecological fire effects. The 10 categories range in intensity from light surface fires that remove litter, reduce grass and other herbs to the ground and kill small woody stems, up to catastrophic, stand-replacing fires. Intermediate categories, such as vegetation that typically experiences understory reduction fires, may have fire intense enough to consume all fuel and kill all vegetation in the understory, leaving only the fire-resistant trees. Examples of this fire-effects type range from pitch pine/ericad barrens in the east to Sequoiadendron giganteum-Pinus lambertiana/shrub communities in California. One step in reconstructing presettlement vegetation and fire regimes is to ask, "what were the ecological fire effects on the vegetation of the site being studied?" The question applies first to historical vegetation, where we could ask "what kind of fire regime results in pitch pine/heath?" It also applies to current vegetation where we might ask "what kind of fire would we have to use to produce the ecological fire effects that would restore pitch pine/heath, which the historical record says was present on this site but we find now occupied by hardwoods?" Being able to recognize in the field the type of structural changes brought about by fire, is one of the skills that contributes to reconstructing presettlement vegetation.

Another step in starting to construct maps of presettlement vegetation is compiling all useful historical information about the region, including herbarium records of any fire frequency indicator species that were there. Although we use the term fire-dependent species, there has been little factual evidence about such dependency in the literature and some fire ecologists have even questioned whether there are any species truly dependent upon fire (Agee 1993). Chapter 5 addresses the question of whether there are fire dependent species and classifies frequent fire vegetation of the southeastern U.S. into eight categories, seven of which appear to be fire dependent. Study plots in the Green Swamp, monitored from 1983 to 1999, demonstrated conclusively that Venus flytrap declines with fire frequency less than 2 years and is extirpated from natural sites when 10 year mean fire return interval falls as low as 3-4 years. This is a truly fire dependent species and, with its requirement for circumannual fire, it is the most frequent-fire obligate known. Being able to bracket the fire-return interval required by a species, especially species with very narrow niches, lets us put fire frequency points on the map every place such species appear in herbarium records and the historical literature. With enough points we can construct presettlement fire frequency maps.

Chapter 6 is a short review of the accumulating evidence for paleowildfire (a term recently coined by paleoecologists, I didn't make it up). This is an update on the work of Komarek on the importance of lightning ignited fire as an ecological force. His work, especially his paper "Ancient fires" (Komarek 1972) inspired a number of paleobotanists and paleoecologists to revisit the evidence of fire displayed in the fossil record. This chapter reviews their findings and additions to our knowledge of fire in ecosystems of the distant past. The picture beginning to emerge is that terrestrial vegetation has coevolved with fire since the first substantial presence of vegetation on uplands around the Devonian-Carboniferous transition 360 million years ago. Fire adaptations such as serotiny in pond pine and specialization for 1-2 year fire habitats in Venus flytrap may be older than the species themselves.

Chapter 7 draws on some general principles from the work in the preceding chapters, and demonstrates how to reconstruct in detail the original vegetation and fire regimes of a specific site, using principles of landscape fire ecology. The soil series is used as the mapping unit. Chapter 5 discussed fire frequency requirements of Venus flytrap, whorled loosestrife (Lysimachia asperulifolia) and wiregrass, all fire frequency indicator species. Chapter 7 discusses how to use such species, along with presettlement fire frequency indicator communities such as canebrake, and fire compartment size to develop presettlement fire frequency maps. The rest of the chapter uses the

fire frequency map as a background against which to develop a detailed map of presettlement vegetation as shaped by fire.

The remaining chapters present case studies based on the methods developed in earlier chapters. During the course of field work I prepared presettlement vegetation maps of Pamlico County and Dare County, North Carolina, the Croatan National Forest in eastern North Carolina, and the Savannah River Site on the South Carolina-Georgia border.

The Pamlico study suggested an interesting correlation between vegetation, fire and soil texture in these flat lands, having pyrophytic vegetation on the sandy soils (both wet and dry), and nonpyrophytic, nonriverine hardwood forest on clayey soils. The Dare County mapping demonstrated a remarkable landscape-scale fire frequency gradient across mainland Dare, apparently set up solely by the difference in salinity in the adjacent waters. Improbable as this might seem, the evidence for historical vegetation and fire frequency depicts frequent fire vegetation on the eastern (saline) side with fires averaging every 2-3 years in flammable salt marsh and former canebrake, grading into less fire frequent pocosin and bay vegetation in the center of the peninsula. The salt-related fire influence extends nearly to the western side, but with decreasing fire frequency. Along the freshwater Alligator River to the west, there was a band of nonpyrophytic swamp forest dominated by cypress, tupelo and swamp black gum. This graded to the east into a long fire-return interval patch mosaic of Atlantic white cedar and pyrophytic cypress stands where fires periodically burned out pockets of peat, ponding water and initiating new cypress stands. Fire intervals in this area ranged from 90 to more than 300 years, where fire, presumably originating in the frequent-fire vegetation to the east and south, only periodically made it into the western edge under severe burning conditions of hot, dry weather and strong winds from the south.

The Croatan mapping also involved local fire frequency gradients, but necessitated dealing with soil series that had very different vegetation depending upon whether they occurred in the fire-exposed interior, or on peninsulas or shorelines where fire was infrequent and maritime influence led to presence of species like live oak and yaupon. Both the Croatan and Savannah River maps were transferred to GIS. At the Savannah River Site, a local fire frequency map was produced and there was further investigation of fire compartments and the effect of slope and aspect. Finally, the accuracy of mapping was tested with the evidence from historical land surveys in the vicinity of the Savannah River Site.

The central idea is that we can reconstruct both presettlement vegetation and original fire regimes using principles of landscape fire ecology such as fire compartments, fire frequency indicator species and fire frequency indicator communities. It seems to work best to reconstruct fire frequency and vegetation at the same time, comparing evidence from each with the other in successive approximations. An independent test of the results can be made by reserving historical boundary tree data until after mapping is complete, as was done with the Savannah River Site. Landscape fire ecology is a new field that has not yet been defined. Several fundamental concepts of landscape fire ecology emerged in these studies that should contribute to development of this field of study. Examples of new concepts, such as fire compartments, fire filters and fire barriers, regional fire frequency gradients, and fire-tension zones, are illustrated.

Landscape fire ecology and presettlement vegetation have become extremely timely issues. The following chapters describe ways of looking at the landscape to uncover the original fire ecology, and ways to map presettlement vegetation and fire regimes at a practical level for managing natural areas for the survival of al the species and communities they contain.

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CHAPTER 2

FOUR CENTURIES OF CHANGING LANDSCAPE PATTERNS IN THE LONGLEAF PINE ECOSYSTEM

ABSTRACT

Longleaf pine was exploited from first settlement, but before 1700, dependence on navigable water for travel and trade limited impacts to coastal regions and belts along navigable streams. In these settled landscapes, effects of domestication included land clearing and establishment of saturation densities of open range cattle and hogs, which fed on longleaf pine seedlings in nearby woods. Effects of commercial logging were negligible until introduction of the water-powered sawmill in 1714, but by the 1760s hundreds of these were turning out milled lumber. Still, deforestation was limited to narrow patterns defined by streams and rivers. By this time much of the eastern Piedmont was fully settled and the frontier had passed on almost to the Appalachians. By the Civil War, all the best land on the Atlantic slope was in fields and pasture, but much virgin forest remained on the Gulf coast. The naval stores industry began in Virginia, where boxing longleaf for crude turpentine was practiced all through the Colonial Period, and most of the longleaf there was decimated by 1840, but there had been little impact to the south, with the exception of stands along rivers in North Carolina. Then, in 1834, adaptation of the copper whiskey still to turpentine distillation made the process vastly more efficient and profitable. This activity, which left most of the primeval pine forest weakened or destroyed, swept south and then west along the Gulf, decade by decade, as northern stands were exhausted, reaching full swing in the last stands in Texas around 1900. Steam technology mushroomed by 1870, with proliferation of logging railroads, steam log skidders and steam sawmills, and virtually all

remaining virgin timber in the South came down during the era of intensive logging from 1870 to 1920. The 1920s saw the beginning of conversion of unmanaged woodlands to pine plantation, now about 15% of southern uplands. The presettlement range of longleaf pine is estimated at 92 million acres, of which 74 million were longleaf dominant and 18 million had longleaf in mixtures with other pines and hardwoods. By 1946, longleaf pine had dwindled to 1/6 its original acreage. This decline has continued until only about 3% remains.

INTRODUCTION

From Virginia to Texas, much of the coastal plain landscape was once covered by a "vast forest of the most stately pine trees that can be imagined..." (Bartram 1791). The spectacular failure of the primeval longleaf pine forest (Figure 2.1) to reproduce itself after exploitation is a milestone event in the natural history of the eastern United States, at least equal in scale and impact to the elimination of chestnut from Appalachian forests by blight. This paper discusses presettlement vegetation and summarizes major events in decline of the longleaf pine ecosystem (Appendix I) and its displacement from 97% of the lands it once occupied.

Land uses ranging from 100 to 400 years of agriculture; open range grazing by hogs and other livestock; logging; production of turpentine, and elimination of naturally-occurring wildfires have left less than 3% of the upland landscape in entirely natural vegetation. While much has been made of the loss of some 10% to 30% of wetlands in the region (Hefner & Brown 1985), the elimination of natural vegetation on 97% of uplands (Table 2.1) has gone largely unremarked. The ability to reconstruct the long-term changes that have occurred in the southern landscape requires understanding what presettlement vegetation was like, how fire moves over the land, and the effects of 400 years of human intervention.

PRESETTLEMENT VEGETATION OF THE LONGLEAF PINE REGION

States bordering the Atlantic, and some of the Gulf Coast region lack the systematic data base of witness trees that were recorded when lands were surveyed under the township, range and section system in the rest of the country, so there can be no statistically verifiable reconstruction of virgin forests from such data. Even where General Land Office survey records are

available, interpretation is compromised because surveyors routinely failed to distinguish the various species of pine, just lumping them as "pine" on records and survey plats. There is, however, an exceptional narrative literature on the longleaf pine forests, dating from 1608 when Captain John Smith recorded the first export of pitch and tar made from pines near the new settlement at Jamestown, Virginia (Smith 1624).

Because of its primacy as the commercial tree of the South, longleaf became in the 1880's the first forest species to be studied in detail by botanists and early professional foresters. Major studies by Sargent (1884), Mohr (1896), Ashe (1894a) and Harper (1913, 1928) include literally hundreds of mentions and locations of longleaf pine as well as maps, lumbering records and calculations of acreage and board feet by state, allowing a reasonable approximation of its original range and abundance. Although widely scattered through the literature, numerous other historical references can be used to document original vegetation throughout the South. Figure 2.2 is a reconstruction of the original range of longleaf pine, using as a base a compilation of the state maps prepared by Sargent in 1881. Range maps and numerous locations provided by Ruffin (1861), Lockett (1870), Hale (1883), State Board of Agriculture (1883), Ashe (1894a), Mohr (1896, 1901), Harper 1905, 1906, 1911, 1913, 1914, 1923, 1928), Sudworth (1913), Mattoon (1922), Wakeley (1935), Wahlenberg (1946) and Little (1971) were especially useful.

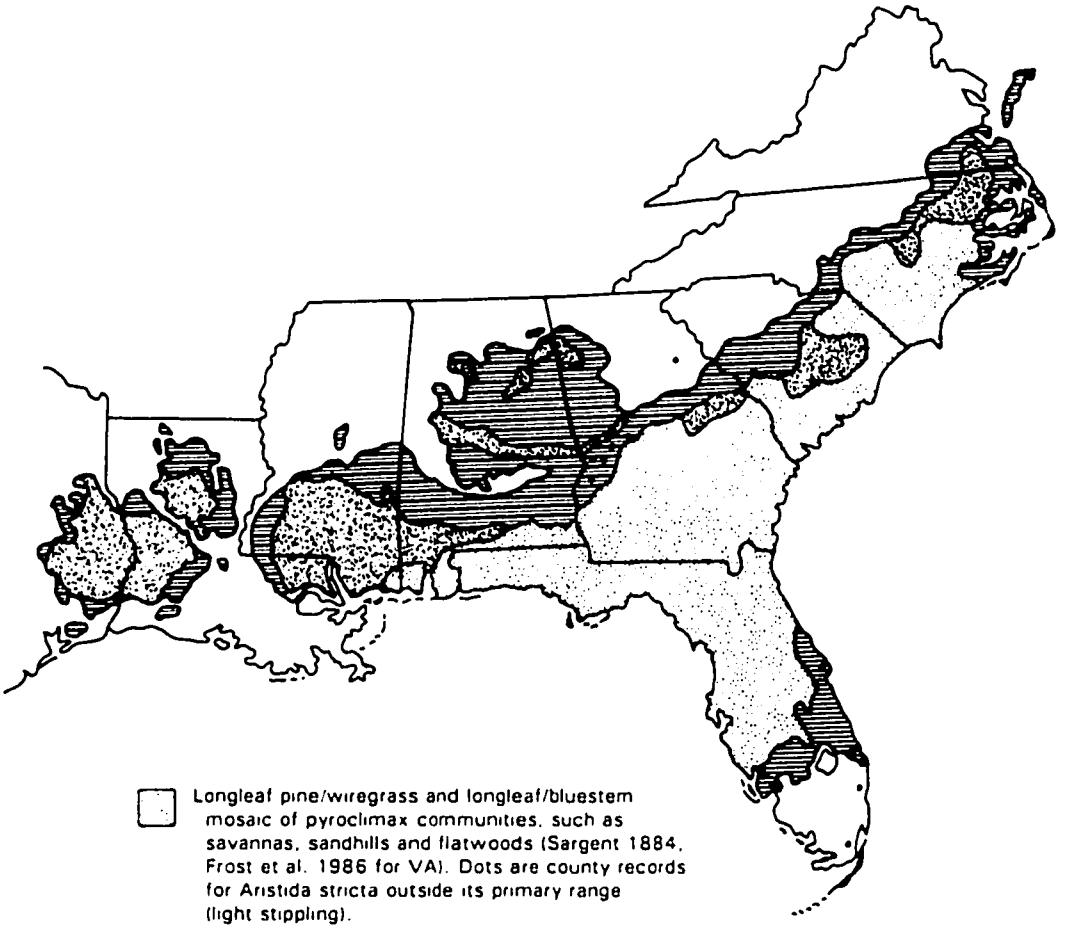
In calculating figures for the presettlement range of longleaf pine, individual state maps of pine forests of the South (Sargent 1884) were assembled into one large map, and compared it with other longleaf pine range maps by Sudworth (1913), Mattoon (1922), Wakeley (1935), the 1935 Southern Forest Survey (in Wahlenburg, 1946), Harper (1928), Mohr (1896) and Little (1971). In addition, historical references and field locations for longleaf were used to reconstruct its original northern range in North Carolina and Virginia, where it originally extended to within a mile of the Maryland border (based on an herbarium specimen, Moldenke pers. comm.). The resulting map (Figure 2) includes all areas indicated as having originally supported longleaf. In all, in the presettlement range of longleaf pine there were 412 counties in nine states.

Census statistics were compiled, county by county where available, for total area of each county, acreage in farms, acreage in forest land, improved farmland, crops, pasture and urban land (U.S. Censuses of Agriculture 1841, 1902, 1984). Areas of longleaf mapped as dominant or mixed

Figure 2.1. Virgin longleaf pine savanna ten miles east of Fairhope, Baldwin County, Alabama, August 13, 1902. Note the absence of woody understory and the classic bilayered structure (canopy/herb layer) of longleaf pine under a natural fire regime. Roland Harper (1913) commented that "...it may never be possible to take such a picture in Alabama again." (photo from Harper 1913).

Figure 2.2 Presettlement range and major divisions of the longleaf pine ecosystem, showing the transition between frequent fire communities of the Coastal Plain and less frequently burned lands of the Piedmont.

PRESETTLEMENT RANGE OF LONGLEAF PINE



Longleaf pine/wiregrass and longleaf/bluestem mosaic of pyroclimax communities, such as savannas, sandhills and flatwoods (Sargent 1884, Frost et al. 1986 for VA). Dots are county records for Aristida stricta outside its primary range (light stippling).

Longleaf pine/bluestem savanna and woodland outside the range of wiregrass.

Longleaf pine-shortleaf pine-loblolly pine-hardwoods transition areas (Lockett 1870; Sargent 1884; Mohr 1897, 1901; Sudworth 1913; Harper 1923, 1928; Little 1971; Frost et al. 1986.

Scattered longleaf pine in slash pine areas transitional to south Florida communities (Sudworth 1913).

Table 2.1 Distribution of natural vegetation and land use categories in presettlement forests, in 1900, and in 1990.

	Percent of Uplands	Percent of Region	ha x 1000	a x 1000
PRESETTLEMENT				
1. Longleaf Pine	52.0	36.0	22,852	56,430
2. Mixed (wi.longleaf)	33.2	23.0	14,606	36,064
3. Mixed (w/o longleaf)	9.0	6.3	4,001	9,878
4. Upland slash pine	3.3	2.3	1,440	3,555
5. Beech-magnolia	2.5	1.7	1,108	2,735
11. Wetlands	0	30.7	19,496	48,137
	100.0	100.0	63,503	156,799
1900				
1. Longleaf pine	24.2	17.5	11,109	27,430
2+3 Mixed pyrophytic spp.	20.7	15.1	9,581	23,657
4. Upland slash pine	1.7	1.2	775	1,914
5. Beech-magnolia	0.4	0.3	166	410
6. Successional forests	25.0	18.1	11,501	28,399
7. Pine plantation	0	0	0	0
8+9 Pasture and Cropland	27.0	19.6	12,448	30,733
10. Developed	1.0	0.7	460	1,137
11. Wetlands	0	27.5	17,463	43,119
	100.0	100.0	63,503	156,799
1990				
1. Longleaf pine	2.1	1.7	1,050	2,592
2+3 Mixed pine-hardwood	0.5	<0.4	250	618
4. Upland slash pine	0.4	0.3	222	547
5. Beech-magnolia	0.4	0.3	222	547
6. Successional forests	44.0	34.6	21,963	54,232
7. Pine plantation	15.2	12.0	7,587	18,733
8. Pasture	6.4	5.0	3,165	7,814
9. Cropland	20.8	16.3	10,363	25,589
10. Developed	10.2	8.0	5,091	12,571
11. Wetlands	0	21.4	13,590	33,556
	100.0	100.0	63,503	156,799

Vegetation and Land Use Categories:

1. Natural, fire-maintained communities dominated by longleaf pine.

2. Natural, fire-maintained mixed species savanna and woodland (longleaf, shortleaf, loblolly, pond pine, and sometimes hardwoods in various combinations).
3. Pyrophytic woodlands without longleaf pine.
4. Natural, fire-maintained slash pine on uplands.
5. Southern mixed hardwood forest (nonpyrophytic beech-magnolia).
6. Successional mixed pine-hardwood forests resulting from logging, old field abandonment and fire exclusion.
7. Pine plantation (all species).
8. Pasture (included with cropland in 1900).
9. Cropland.
10. Cities, towns, roads, industry.
11. All wetlands.

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stands were digitized. Table 2.1 includes adjustments made for wetlands, other vegetation types within the primary longleaf pine areas (stippled), and regional adjustments for areas such as the northern range in Alabama and Georgia, where there were substantial inclusions with little or no longleaf. Cross-checks were made using other data such as Sargent's and Mohr's board feet estimates; old and new published forestry data, county statistics from the Censuses of Agriculture and various regional studies.

Figures for Southern Mixed Hardwood Forest and slash pine on uplands (such as the proportion of the pine rocklands of Florida within the original range of longleaf pine) are estimates based on material in Delcourt and Delcourt (1977) and other sources. Since no county figures were available for wetlands, starting estimates were made based on the average of 25.2% wetlands for the region (U.S. Congress 1984, Hefner and Brown 1985), with some local adjustments where data was available. Wetland estimates for 1900 and presettlement forests were based on figures for a 20 year decline from the mid-1950's to 1970's (Hefner and Brown 1985). Since the modern era of major wetland drainage was enabled by passage of drainage district laws around 1900 (Lilly 1981), it was assumed that at least an equal amount was drained in the 50 year period 1900-1950, and again in the much longer 300 year period 1600-1900. Drainage of upland wetlands was reported as early as 1682 in Virginia (Clayton 1682). Failure to account for historical drainage would result in an overestimate of longleaf pine.

The U.S. Census of Agriculture supplied figures for cropland and pasture in 1900. The extent and nature of forested land categories were derived from data on rates of cutting in 1881

(Sargent 1884) and in 1896 (Mohr 1896). Condition and extent of hardwood forests were estimated from descriptions by Lockett (1870), State Board of Agriculture (1883), Mohr (1884, 1896), Harper (1906, 1911, 1913, 1914), Hale (1883) and others.

Recent land areas for cropland and pasture were obtained from the U.S. Census of Agriculture for 1982. Forest statistics were compiled county by county from individual state publications (Bechtold 1985, Bechtold and Sheffield 1981, Cost 1976, Murphy 1976, Sheffield 1979, Southern Forest Experiment Station 1978, 1985, Tansey 1983, Thomas and Bylin 1982). Area of pine plantation (all species) was derived from data in Boyce (1979) and estimated further by regression from 1952 to 1986, with the assumption that all plantation older than 30 years had been harvested.

Amount of longleaf pine in presettlement forests. The final estimate of 92 million acres (37 million hectares) of lands with some longleaf pine in presettlement forests can be broken down into 74 million acres of longleaf dominant and 18 million with longleaf in mixed-species stands[1]. Table 2.1 shows an estimated 36 million acres in mixed communities with longleaf, based in part on Sargent's transition areas. From observations in the transition regions in Alabama, North Carolina and Virginia, it is apparent that these areas contained two kinds of mixtures: first, were pure stands of longleaf on south slopes and ridges, in a landscape with other pine and hardwood communities lacking longleaf; and second, natural stands in which longleaf occurred mixed with other pines and a few hardwoods (Sargent 1884, Ashe 1894a). If we allow for half these stands to be nearly pure longleaf, then the total would be around 74 million acres of longleaf dominant stands.

The earliest estimate of the entire range of longleaf pine was made by Mohr (1896) who suggested that the original acreage of "southern pines" was 100 million acres. By his definition this included all the range of longleaf pine plus "the shortleaf pine belt". To this must be added at least 1 million acres of longleaf that escaped his notice in Virginia because of their elimination from the

[1] The figures given in Table 1 should not be confused with the 82 million acres of longleaf pine mentioned in Ware, Frost and Doerr (1993): this paper did not include the complete range of longleaf pine because the authors were instructed to use as boundaries Kuchler's Southern Mixed Hardwood Forest Region (SMHF) as drawn on his map of "potential natural vegetation" (Kuchler 1975). Kuchler's designation was a hypothetical beech, magnolia, oak climax that would occur when these species moved out of their fire-refugial slopes and bottomlands onto the uplands in the absence of fire (Quarterman and Keever 1962, Kuchler 1975). In reality, however, longleaf pine and mixed-species fire communities dominated the southern uplands, and this assemblage extended beyond the SMHF region into northern Alabama and Georgia (Figures 2, 3, 13), where it could be found at elevations of up to 600 m (2000 ft) on dry, south-facing slopes of the southern Appalachians (Mohr 1901, Harper 1905).

landscape during colonial times. Subtracting the estimate of 92 million, which was arrived at independently, from 101 would leave 9 million for the shortleaf pine belt. No closer comparisons can be made because Mohr gave no sources for his estimates nor separate figures for the different regions he considered. Emerson (1919) estimated the size of "the long-leaf pine belt" at 250 million acres, but there is only 156 million acres possible in the range from Virginia to Texas even if all the wetlands were included (Table 2.1).

Amount of longleaf remaining in 1994. Outcalt and Outcalt (1994) arrived at an estimate of 3.3 million acres of remaining longleaf, using U.S. Forest Service's forest inventory and analysis data. Of this, 11%, or 363,000 acres was estimated to be plantations. Because of the cycle of reporting by states, the data were 2-6 years old, and initial reports from the Florida survey suggested an additional 100,000 acre loss. Since Florida comprised 29% of the total longleaf this would be equivalent to an additional range-wide loss of 245,000 acres. Subtracting this figure and the acreage in plantation leaves 2,592,000 acres in naturally regenerated longleaf pine.

Of the remaining longleaf, there is extreme variation in stand structure and quality. Of 352 longleaf pine remnants examined in North Carolina, only 91 stands (26%) were being maintained by fire, while the rest (74%) were fire-suppressed and in transition to other forest types (Frost unpub.). The suppressed stands were heavily invaded by hardwoods and loblolly pine, and instead of the two-layered structure typical of natural longleaf communities there were heavy shrub and midstory layers of loblolly pine, scrub oaks and southern red oak. The resulting shade, along with a deep pine needle litter and duff accumulation had completely eliminated wiregrass and the rest of the herb layer on many sites (Frost in prep.). If this ratio of burned and fire-suppressed stands holds true for the rest of the range, only about 674,000 acres or less than 0.7% of the original extent, remain in good condition rangewide.

Fire relations of the original forests. Historically, agents of fire included lightning, Indians and European settlers. Agents of fire suppression were bodies of water, topography (steep slopes, islands, peninsulas [Harper 1911]), and government agencies (Sherrard 1903). Varying effects of fire in the landscape mosaic have been attributed to fire frequency, fire intensity, and season of burn (Garren 1943, Komarek 1974). Given that lightning fires would have been growing season fires, fire frequency must have been the most important fire variable in presettlement vegetation.

Mattoon (1922) commented that longleaf lands experienced fire at an average of every 2-3 years over millions of acres. On the Pamlico Terrace and other terraces of the lower Coastal Plain from Virginia to Texas, there were numerous tracts of land from several hundred to over a thousand square kilometers in size without a single natural firebreak. In Florida, Komarek (1965) reported one single summer day when 99 wildfires were started by lightning. On the Pamlico Terrace, where a single ignition might burn 1000 km^2, a few ignitions in each state might be sufficient to burn most of the landscape. On the other hand, fire frequency should decrease inland on the more dissected upper Coastal Plain and Piedmont, where numerous separate ignitions would be required to burn the decreasingly smaller fire compartments. The resulting decrease in fire frequency might explain the admixtures of other pine species and hardwoods with longleaf in the transition regions (Sargent 1884).

Before immigration of Indians into the Southeast during the last half of the Wisconsin glaciation 12,000 to 20,000 years ago, essentially all fires would have been caused by lightning. Komarek (1964, 1965, 1968, 1974) has martialled convincing evidence to support the idea that lightning alone is adequate to account for evolution of pyrophytic vegetation, the antiquity of which probably far exceeds the appearance of aboriginal peoples on the scene.

Accounts from the Colonial Period describing Indian burning practices (Smith 1624, Lawson 1709, Byrd 1728, Martin 1973) indicate that use of wildfire by the southeastern Indians was largely limited to fall and winter when fires were set to drive game. On the outer Coastal Plain where annual summer lightning fires preempted fuel, the effect of any Indian burning may have been only a slight increase in coverage of land area, by the inclusion of peninsulas and patches of uplands that otherwise were naturally protected from fire. On the other hand, Indian influence may have been much more significant on dissected inland terraces and the Piedmont, where their primary effect, in compartments missed by lightning, would have been a net increase in fire frequency.

Distribution of major communities in presettlement forests. Sargent (1884) divided the range of longleaf pine into two regions. In Figure 2, the stippled areas were compiled almost exactly as drawn on his individual state maps. In these lands he described longleaf as the "prevailing growth" on the uplands. This included a diverse mosaic of pine savannas, sandhills and flatwoods, with

variants in other habitats, such as riparian sand ridges, Carolina bay sand rims, coastal scarps and dunes, as well as more fertile rolling lands and hills of the interior (Peet and Allard 1993, Harcombe et al. 1993). In Figure 2, this first region is divided into two, depending upon presence or absence of wiregrass. Wiregrass in North Carolina and the northern third of South Carolina is Aristida stricta, that from southern South Carolina to Mississippi is A. beyrichiana (Peet 1993). The lighter stippling, along with outlying dots, indicates the known historical range of wiregrass, based on herbarium records (Parrott 1967, Peet 1993) and a few other historical records. For instance, both Harper (1913, 1928) and Mohr (1901) included Houston County, Alabama in, "...the counties of Alabama east of the Perdido River, along the Florida state line, known as the 'wire-grass counties,' where on the loose white Ozark sand it almost alone forms the grassy covering" (Mohr 1901, p.113). Ellicott (1803) said that wiregrass was found in Washington and Clarke Counties, Alabama as far upriver as St. Stephens: "the upland on these rivers is of an inferior quality from their mouths up to the latitude of Fort St. Stephens, and produces little besides pitch pine [longleaf] and wiregrass...." The original limits of wiregrass may never be known, much of the periphery of its range having been farmed or fire suppressed long ago.

Sargent's second major assemblage of communities was the transitional forest between coastal plain regions dominated by nearly pure stands of longleaf, and the oak-hickory-shortleaf pine woodlands of the Piedmont. Sargent described the transition regions as "long leaved pine (Pinus palustris) with hardwoods in about equal proportion" in the Gulf states and "short leaved (Pinus echinata) and loblolly pine (P. taeda) intermixed with hardwoods and scattered long leaved pine" in the Atlantic states. The transitional woodlands, on the east side of the primary longleaf range in Virginia and North Carolina, not described by Sargent, were a variant in which pond pine (Pinus serotina) was added to the mixture (Ashe 1894a, Frost in prep.).

Mixed patches versus mixed species. In Sargent's transition regions it is also necessary to distinguish the difference between mixed patches (of pure longleaf on south slopes and ridges) in a landscape with other forest types, and true mixed-species stands.

Mohr (1896) and Harper (1905, 1923, 1928) described pure stands as well as mixed stands. They pictured the mixed pyrophytic types as open woodland with a geographically varying mixture of the dominant trees, which were longleaf, shortleaf and loblolly pine, post oak, white oak, southern

red oak, hickories and various scrub oaks. Presumably these were bi-layered communities, having a tree canopy and a savanna-like grass-forb understory, since longleaf is not known to reproduce in mesic habitats without a nearly continuous flammable herb layer to carry fire. These complex communities, with all their geographic variation, were never adequately described. Sargent's 1884 maps are unique in that they are the first detailed range maps for a tree species in the South and because they distinguish between two major natural community groups based on different fire regimes.

Natural old-growth longleaf with a minor component of old-growth loblolly exists on lands in Beaufort County South Carolina (pers. obs.), and there is a photo of a similar stand near Slidell, Louisiana (Ware et al. 1993). Other small examples on natural mixed species stands can be found in the Croatan National Forest, and in Pamlico County, North Carolina (LeGrand et al 1992). These natural mixtures include longleaf, loblolly, pond pine, and shortleaf in various combinations depending upon soil texture and moisture (Frost in prep.). Historical examples of each combination were described a century ago in the same region by W.W. Ashe (1894a). The existence of natural mixed species stands has been overshadowed by the remarkable pure longleaf stands that dominated most of the southern uplands, and by the fact that the mixed stands occurred on the moister and finer textured, more fertile soils, the preponderance of which were cleared for farming long ago (Williams 1989).

Hardwoods in presettlement forests. Besides the dominant fire communities, small areas of non-pyrophytic types such as Southern Mixed Hardwood Forest, dominated by beech, magnolia, semi-evergreen oaks and other hardwoods, may have been confined to very limited and specialized habitats within the primary range of longleaf pine (Harper 1911). Old-growth stands can be found on slopes, islands in swamps, and a few upland flats on peninsulas. In many places mesophytic species like beech now are escaping from these fire refugia onto the uplands (Ware 1978). Studies by Delcourt and Delcourt (1977) in the Apalachicola bluffs region of Florida suggest that Southern Mixed Hardwood Forest occupied less than 1% of the presettlement landscape. In the transition region, however, with its more varied topography, there may have been locally extensive stands. Mohr (1884) mentioned one such locality near Vicksburg, Mississippi where "Beyond the Blackwater (Big Black River) in the hilly region of the bluff formation, the great magnolia covers the hillsides...."

Landscape Changes 1565 to 1900

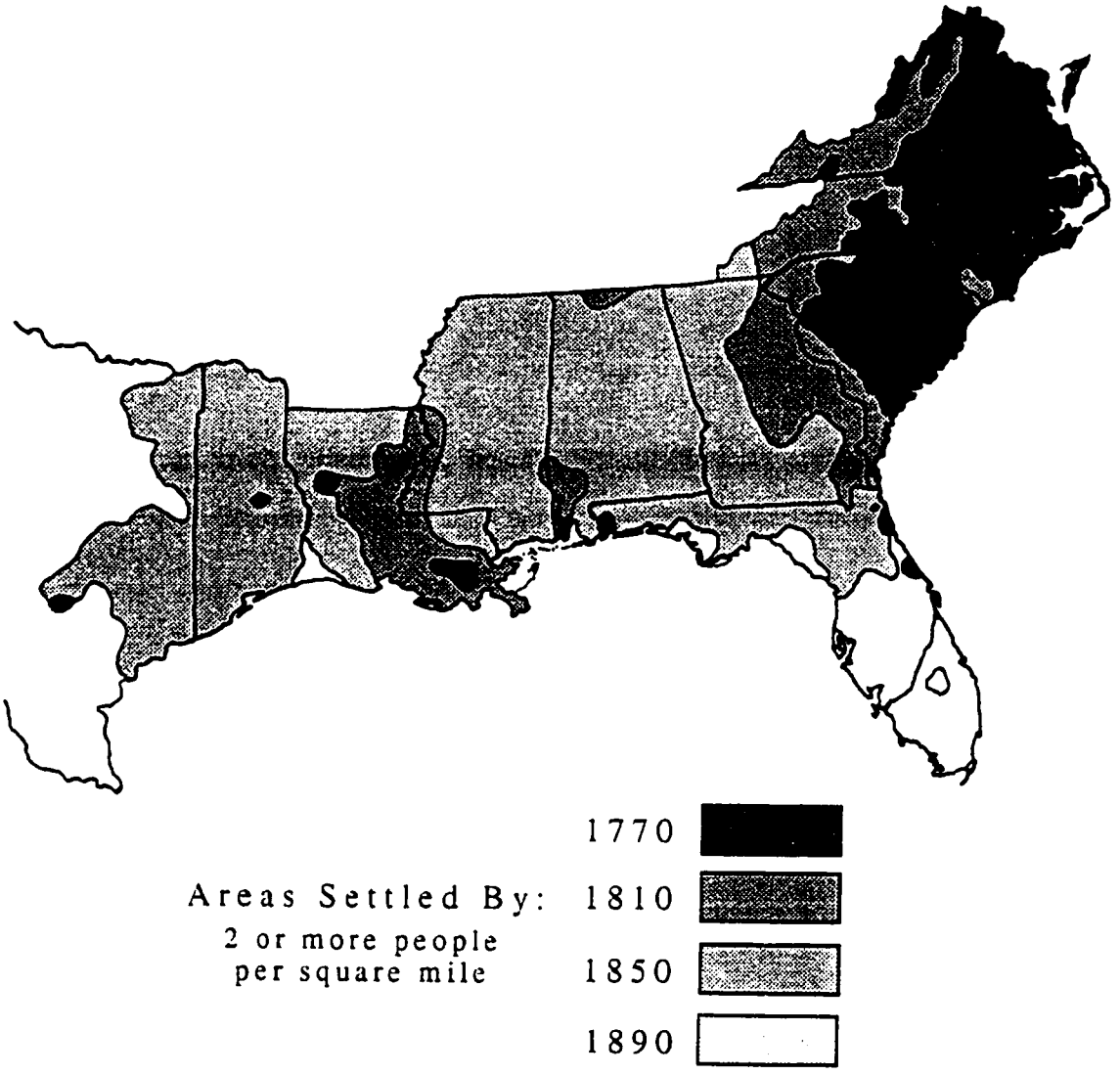
Ecosystem changes in the early Colonial Period. While the landscape that greeted the first two major groups of European settlers, English and Spanish, held immense forest resources, neither were well equipped to exploit them and the two cultures used radically different approaches in exploitation of the New World.

DeSoto set out in 1539 to explore the Gulf Coast interior, an epic overland journey complete with army, horses and droves of hogs, that took him as far north as the Cherokee towns of North Carolina, and west to beyond the Mississippi River (Bakeless 1961). While the Spanish, disappointed with the scarcity of appropriate conquest and pillage, lost interest in the north Gulf interior, they continued to control access to much of the vast region from Florida to Texas. What is significant for landscape history is that during their 256 year tenure, from establishment of St. Augustine in 1565 until cession of Florida to the United States in 1821, the Spanish blocked settlement of the Gulf Coast interior, leaving forests of much of the region in pristine condition well into the 19th century (see Reed 1905). With exception of a handful of coastal villages such as St. Augustine and Pensacola, they never seriously pursued immigration and settlement of the land. At the end of their occupation in 1821, the entire European population of Florida was only a little over 20,000 people, scarcely enough for a reputable town. Note the contrast in settlement patterns between Spanish lands and English settlements along the Atlantic in Figure 3.

In contrast to the Spanish outposts, English settlements were commercial ventures financed by corporations of wealthy stockholders. Backers of the 1607 Jamestown, Virginia expedition under John Smith invested in settlement and domestication of the land, with intent to establish a productive populace from which they could harvest taxes, agricultural produce and whatever natural products the land could supply (Smith 1624).

For the first 150 years, dependence on water for travel and trade limited settlement to the nearest high lands along sounds, bays and the tidal portions of major and minor streams (Hart 1979). The tidewater area included at least 10,000 miles of shoreline from Virginia to Texas and until this distinct coastal zone was thoroughly populated there was little incentive to push inland. Effects of

Figure 3. Pattern of settlement in the Southeast to 1890. Note the three small centers of population in Florida, which comprised most of its sparse population until 1821. With exception of the new cotton plantation regions, most virgin forest of the interior of the six Gulf states remained intact in 1850. Map redrawn from Hammond Inc., Maplewood, NJ.


Areas Settled By:
2 or more people
per square mile
1770
1810
1850
1890

domestication in this settled landscape included land clearing and establishment of saturation densities of open-range hogs and other livestock that fed on longleaf pine seedlings in nearby woods.

In the absence of machinery, timber was essentially worthless except for local use in fencing and log cabin construction. The only milled boards were laboriously sawed by hand with crosscut saws, using one man in a pit and another above (Hindle 1975). A very early exception, a water-powered sawmill built at Henrico on the James River in Virginia in 1611, was destroyed by the Indians a few years later (Hindle 1975). Port records from the British Public Records Office from the early 1600s show that while lumber was a frequent item in ship's cargoes, the quantities were small. Cooperage stock--barrel staves and wooden water pipes made from oak and white cedar, supplied practically the only manufactured items for export for the first hundred years (British Public Records 1607-1783).

The colonists killed trees by girdling and the land was then burned and grazed, or planted in corn and other crops beneath the dead timber (Beverley 1705). The principal early demand for timber was for fencing, and most livestock were allowed to graze on open range in the woods and were fenced out of the small crop patches (Beverley 1705). Of great importance to natural savanna and woodland communities, though little remarked historically, was the introduction of huge numbers of hogs, cattle, horses, mules, sheep and goats onto open range in all of the settled areas. Of these grazing herds, hogs in particular were to play a major part in decline of the longleaf pine ecosystem.

Naval stores and the original northern range of longleaf pine in Virginia. The early history of naval stores and the northern range of longleaf pine have been all but lost, since the species was commercially extirpated by 1850. Even Mohr (1896) states that the naval stores industry began in North Carolina. Such was not the case however; longleaf pine once extended almost to the Maryland border Figure 4), and tar and pitch were produced in Virginia for over 200 years before the boom in North Carolina that gave the Tarheel State its nickname. We know of the early trade, the extent of which has never been thoroughly investigated, only through scattered records.

The southern naval stores industry began in 1608 when John Smith exported the first "tryalls of Pitch and Tarre" (Smith 1624). The next year the Jamestown, Virginia colony exported some 3 or

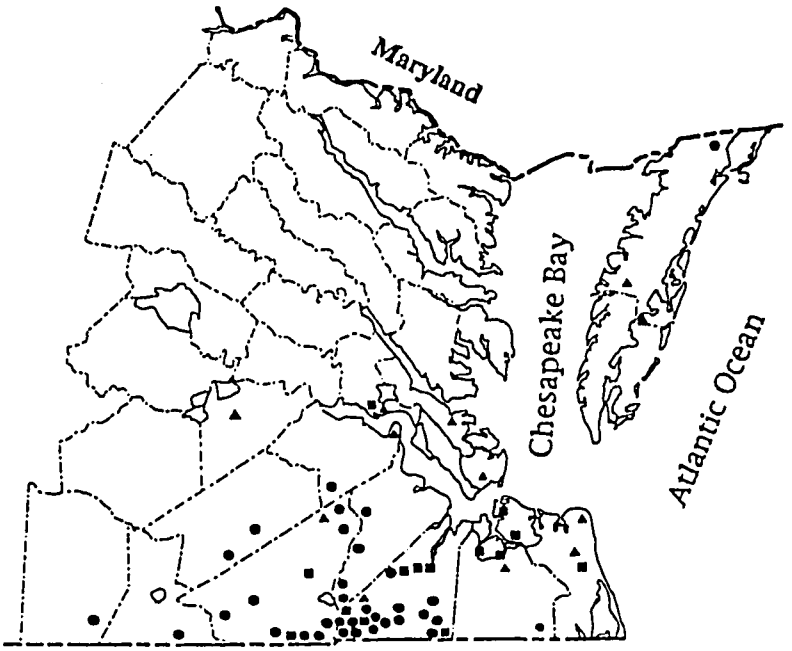
4 dozen barrels to England. To all indications, longleaf was sparse on the north side of the James River where Smith reported finding only a tree here and there "fit for the purpose" [of making naval stores].

Tar, pitch, rosin and turpentine were collectively called naval stores (Ashe 1894a, Mohr 1896) and were produced in the Southeast almost exclusively from longleaf pine[2], although smaller amounts were made from slash pine, shortleaf and sometimes even loblolly (Michaux 1871). These were absolutely essential commodities until the development of petroleum-derived substances in the mid-1800s. Wagons could not move without tar to grease the axles, and ships could not sail without tar and pitch for waterproofing cordage and sails, for caulking leaks, and for coating hulls to prevent destruction by shipworms (Wertenbaker 1931). During the Revolutionary war, a Captain H. Young (1781) wrote to his colonel "...let me entreat you once more to lay before the Council my distressed situation for the want of two Barrels of Tar." "I have offer'd Brown (who is the only one that has Tar) his price in specie, or two barrels of Tar for one, both of which offers he has refused. Our waggons can't run for the want of tar" (Young 1781 [1881]. Colonel Davies had his own problems with the recalcitrant Mr. Brown, while trying to ship 30 cannon to prevent their capture by the British: "Our own vessels are all in readiness, except for some slight repairs, for the finishing of which some small quantity of tar is necessary, tho' not more than a barrel at the utmost-- We cannot procure this quantity under some time unless we obtain it from Mr. Brown, who will not part with it upon any other terms than for specie, of which the State has none to pay" (Davies 1781 [1881].

Early naval stores production concentrated on burning tar kilns for tar and pitch. Tar kilns were earth covered mounds of several cords of collected dead pine "lightwood" which were burned under controlled conditions by carefully regulating the amount of air let into the mound. This sometimes dangerous process took up to 2 weeks of continuous management--from the first drops which did not appear for several days, until the tar ceased to flow into the barrels placed below (Catesby 1731, 1743). The much thicker pitch was simply tar burned down to about 1/3 its original volume. The second, more destructive method was boxing of live trees for the crude gum which was

[2] Smaller amounts were made from slash pine, shortleaf and even loblolly (Michaux 1871).

Figure 4. Documentation of the original range of longleaf pine in Virginia. Circles indicate herbarium specimens or living trees seen from 1960 to 1994, or reported to me by local foresters (also includes two tar kilns visited in Suffolk and Chesapeake). Squares denote clear historical records, some from the early colonial period, but lacking herbarium specimens. Triangles are used for naval stores place names like Pitch Kettle Road, Lightwood Swamp, Pitch and Tar Swamp, tar and Pit Swamp, and Tar Bay. This group also includes uncertain records: exact location not available or uncertain whether tree was native.


Maryland
Chesapeake Bay
Atlantic Ocean
North Carolina

then shipped to New England or Europe for distillation of spirits of turpentine in crude iron retorts. While boxing was practiced as early as 1608 (Smith 1624), the necessity of shipping the bulky crude gum long distances limited the price and demand for the first hundred years.

While tar and pitch were made from 1608 on, most seems to have been consumed locally until around 1700. In 1697, Governor Sir Edmund Andros said that Virginia produced no naval stores for sale except along the Elizabeth River [Norfolk County], where about 1,200 barrels of tar and pitch were made annually" (Pierce 1953). This would have had ready market at the port of Norfolk just a few miles downstream. The industry was carried on by poor men who built their kilns unassisted by servants or slaves, and considered a few dozen barrels a year an excellent output (Wertenberger 1931). F.A. Michaux, writing about his own observations made around 1802, notes that, "toward the north, the Long-leaved Pine first makes its appearance near Norfolk, in Virginia, where the pine-barrens begin" (Michaux, F.A. 1871).

In 1704 Jenings (1704 [1923]) reported some 3,000 barrels of tar produced in Princess Anne and part of Norfolk counties. The disposition was split three ways: between local consumption, sale to ship's masters, and export to the West Indies. Customs records on file for ports from around the Chesapeake Bay list barrels of naval stores as one of the most common exports from the colony from the late 1600s until the Revolution (British Public Records)[3]. In a typical entry, the customs official at Hampton, Virginia noted on April 12, 1745 "Cleared at Hampton, the snow[4] John and Mary, Thomas Bradley, for Liverpool with 106 hhd. tobacco, 500 bbl tar, 60 walnut stocks and 5600 staves." (A snow was a square-rigged sailing vessel, one of the most frequently mentioned trading ship designs in early 18th century records.) The exact site of origin is seldom determinable since ships often stopped at plantations up and down the rivers to pick up cargo and then might be cleared through customs at Hampton or Norfolk. Most tar, pitch and turpentine apparently originated from counties along the south side of the James River and south of Norfolk, where there is evidence of very extensive longleaf pine forests (Frost and Musselman 1987).

[3] I am grateful to the staff of the Colonial Williamsburg Foundation Library, Williamsburg, Virginia for access to the original records on microfilm.

[4] A snow was a square-rigged sailing vessel, one of the most frequently mentioned trading ship designs in early 18th century records.

The export trade had increased 25 years later such that, from March 25 to September 29, 1726, 17 vessels were cleared from Hampton, only one of the ports, with 1,194 barrels of pitch and 6,004 barrels of tar. One ship by itself carried 1,580 barrels of tar and 130 of pitch (microfilm of British Public Records, 1726). By 1791 the port at Norfolk exported 29,376 tons of naval stores (La Rouchefoucauld 1799). By 1803, the number of ships cleared for foreign ports from Norfolk and Portsmouth reached 484, and it was reported that Virginia was no longer able to meet the export demand for yellow pine (Wertenberger 1931). The designation "yellow pine" most often meant lumber from longleaf pine in the early trade.

Early channels of trade in tar and pitch in Virginia were the Elizabeth and Nansemond Rivers, with their tidal tributaries interpenetrating the lands in the interiors of Norfolk and Nansemond Counties. Not a single tree remains within the watersheds of these two stream systems today. The only evidence remaining of this early resource in the vicinity are a few remnants of tar kilns and a few isolated trees in Suffolk. Longleaf forests in Virginia appear to have been largely exhausted by 1840, after which no further naval stores production was listed (U.S. Census Office 1841). The census for that year listed 5,012 barrels produced from five counties. The species no longer occurs in two of these and I was able to find fewer than 50 mature trees left in this state, where once there were around 2,000 square miles dominated by longleaf pine. In 1893, forester B.E. Fernow concluded that, "In Virginia the long-leaf pine is, for all practical purposes, extinct."

In Southampton County Virginia I met a farmer, 84 years old, whose recollection did go back to the days of "longstraw" pine. Perhaps the last person in the state to remember that term from daily use, he took me to see three trees that he had ordered to be left when his land was logged. Longleaf pine has been completely extirpated from 11 of the original 15 counties of its range in Virginia. A few remnant trees can now be found only Isle of Wight, Southampton, Suffolk and Greensville counties.

Southward migration of the naval stores industry, North Carolina to Texas. In 1622, John Pory, traveled overland from Jamestown to the Indian town of Chowanoc, passing through "great forest of Pynes 15. or 16. myle broad and above 60. mile long, which will serve well for Masts for Shipping, and for pitch and tarre, when we shall come to extend our plantations to those borders" (Powell 1977). These were the great pine barrens of western Isle of Wight and Nansemond counties,

Virginia, and Gates and Chowan counties, North Carolina. The first record of naval stores produced in North Carolina was in 1636, 17 years before the first settler set up a house and trading post in 1653. A visitor from Bermuda to the Chowan region was surprised to discover a large number of men there busily producing "sperrits of rosin" (Clay et al. 1975). This was in the vicinity of what has long been called the "Sand Banks" of western Gates County. The crew had apparently come overland from the settlements, only a few years old, along the James River in Virginia. Frost et. al. (1990), were only able to locate about 25 old longleaf trees, most of which occurred in a region in the western part of the county called the Sand Banks. Frost (unpub.) counted annual rings when some of these were logged around 1980. The largest was 308 years old and only 23.5 inches diameter on the stump when cut in 1981.

Schoepf (1788) travelling down the coastal plain from Virginia to South Carolina in observed that "...the greatest and most important part of the immense forests of this fore-county consists of pine....", and commented on "...the opportunity for considerable gain from turpentine, tar, pitch, resin and turpentine-oil". The history of naval stores in North Carolina has been reviewed by Merrens (1964)

In the northern tier of counties besides Gates, only two trees are known to remain in Hertford County, North Carolina, and one tree in Perquimans County. The last stand of longleaf in Northampton County was logged around 1980 and longleaf pine has also been extirpated from Currituck, Pasquotank, Washington and Tyrrell counties.

Fernow (1893) observed that, "in North Carolina, in the division of mixed growth and in the plain between the Albemarle and Pamlico Sound, the long-leaf pine has likewise been almost entirely removed and is replaced with the loblolly." In the central part of the state, there was considerable turpentining activity along the Tar River in the central Coastal Plain by 1732, and by 1850 the state was the world's leading supplier of naval stores (U.S. Census of Manufactures). Agriculturists complained that the entire labor force of the Coastal Plain was employed in the turpentine orchards, to the neglect of agriculture (Ruffin 1861). By 1900 longleaf had been decimated in North Carolina and the industry had passed on to the south, leaving vacant land or scarred survivors. Ashe (1894b) commented, "In North Carolina most of the trees which now bear seed are boxed and have been in this condition for 50-100 years,..."

Introduction of the copper still in 1834 allowed concentration of the final product into distilled "spirits of turpentine" making the process highly efficient, slashing shipping costs, and touching off a wave of commercial exploitation which swept south from North Carolina to Texas decade by decade, decimating the longleaf pine region within 80 years (Mohr 1896). Sargent's state maps (1884) for Louisiana and Texas show the extent of turpentine orcharding being carried into the virgin pine forests. Thomas Gamble (1921) and Thomas Croker, Jr. (1987) have reviewed the history of naval stores for the rest of the South.

Few mature trees escaped the turpentine boxing procedure. Using 19th century methods, virgin stands often produced for only about four years (Mohr 1896). Large trees were boxed on three or even four sides (Schoepf 1788), with deep wedges cut into the base to collect the resin (Figure 5). Crude gum was dipped from the box six to eight times a season and transported by cart or boat to the nearest still (Figures 6,7,8). Casks of distilled spirits of turpentine and barrels of rosin, the residue after distillation, then were shipped to the nearest port (Figure 9). Weakened trees in abandoned turpentine orchards often were blown over or killed when the next ground fire set the residue ablaze in the boxes (Figure 10).

Much of the virgin timber thus was wasted until around 1870, when narrow-gauge logging railroads were extended into upland forests. As forests of each state were exhausted the industry moved south, and by 1890 foresters raised the alarm that without provision for reforestation the turpentine industry would soon come to an end (Ashe 1894b). Mohr (1896) described the situation; "...the forests invaded by turpentine orcharding present, in five or six years after they have been abandoned, a picture of ruin and desolation painful to behold, and in view of the destruction of the seedlings and the younger growth all hope of the reforestation of these magnificent forests is excluded". This grim prediction was largely fulfilled when the last of the virgin forests were depleted in the 1920s.

Figure 5. Boxing trees for turpentine. Bark and cambium were removed and large boxes were chopped into the base to collect the crude gum. Photo courtesy of U.S. National Archives.

Figure 6. Gum was collected every few weeks by dipping with large spoons. Barrels were crafted locally from white oak. Photo courtesy of U.S. National Archives.

Figure 7. Barrels of crude gum were taken by boat or wagon to the nearest still. Photo courtesy of Forest History Society.

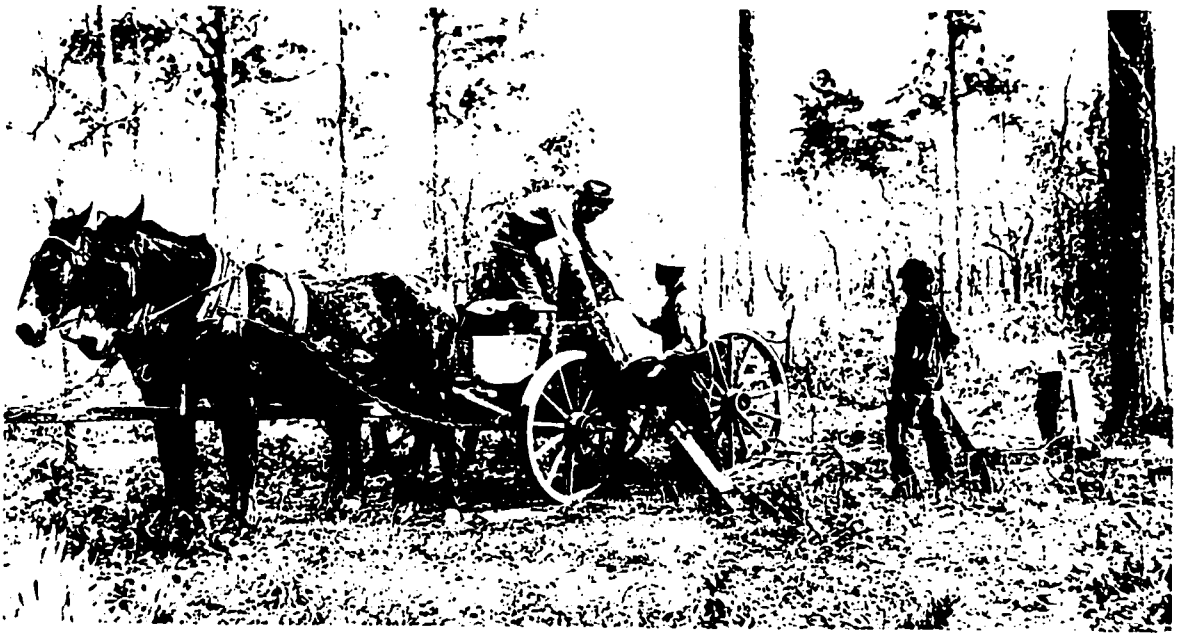


Figure 8. Introduction of the copper still into woods in 1834 permitted reduction of crude gum to spirits of turpentine, saving shipping costs and making the process immensely more profitable. Photo courtesy of U.S. National Archives.

Figure 9. The rosin yards at Savanna, Georgia in 1893. Every 50-gallon barrel of distilled turpentine contained the entire life's production of 33 virgin longleaf pine trees, with a byproduct of 4 barrels of rosin. Net profit per tree was 20 cents (Mohr 1893). Photo courtesy of U.S. national Archives.

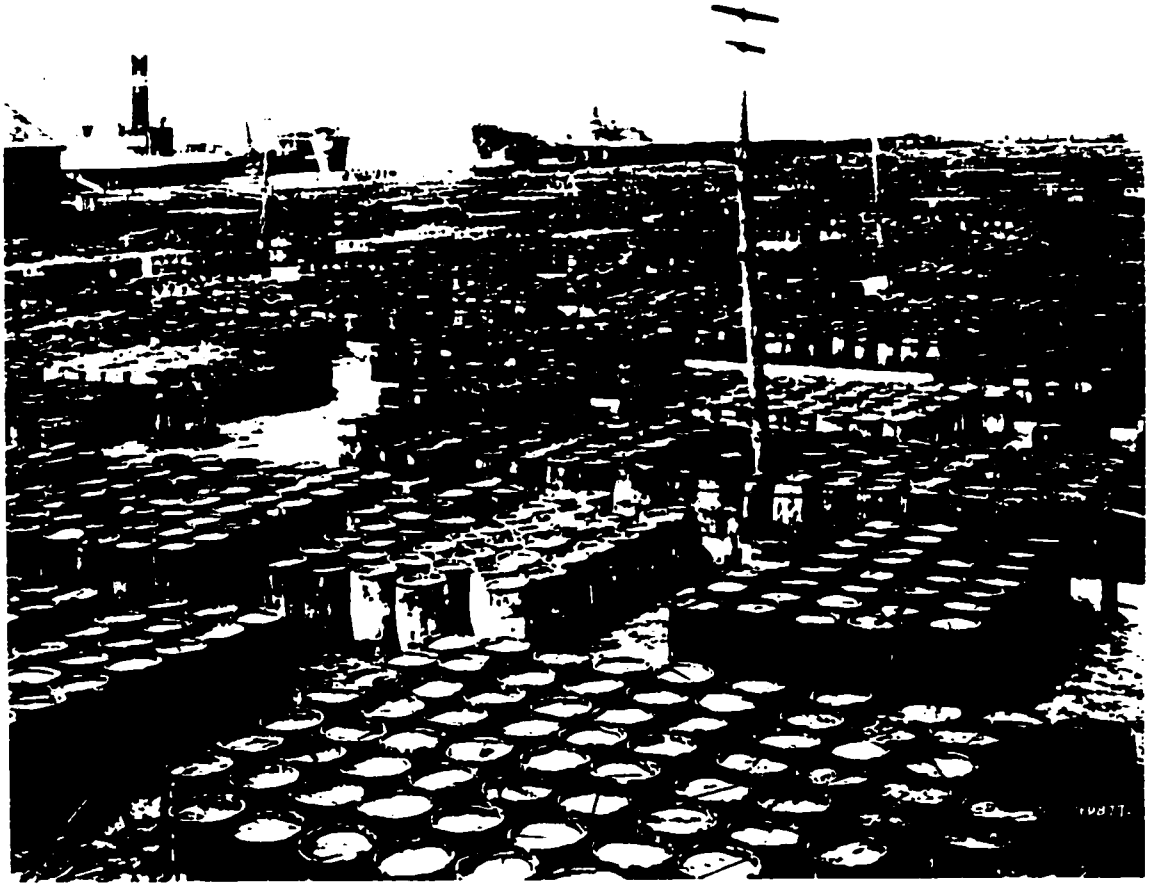
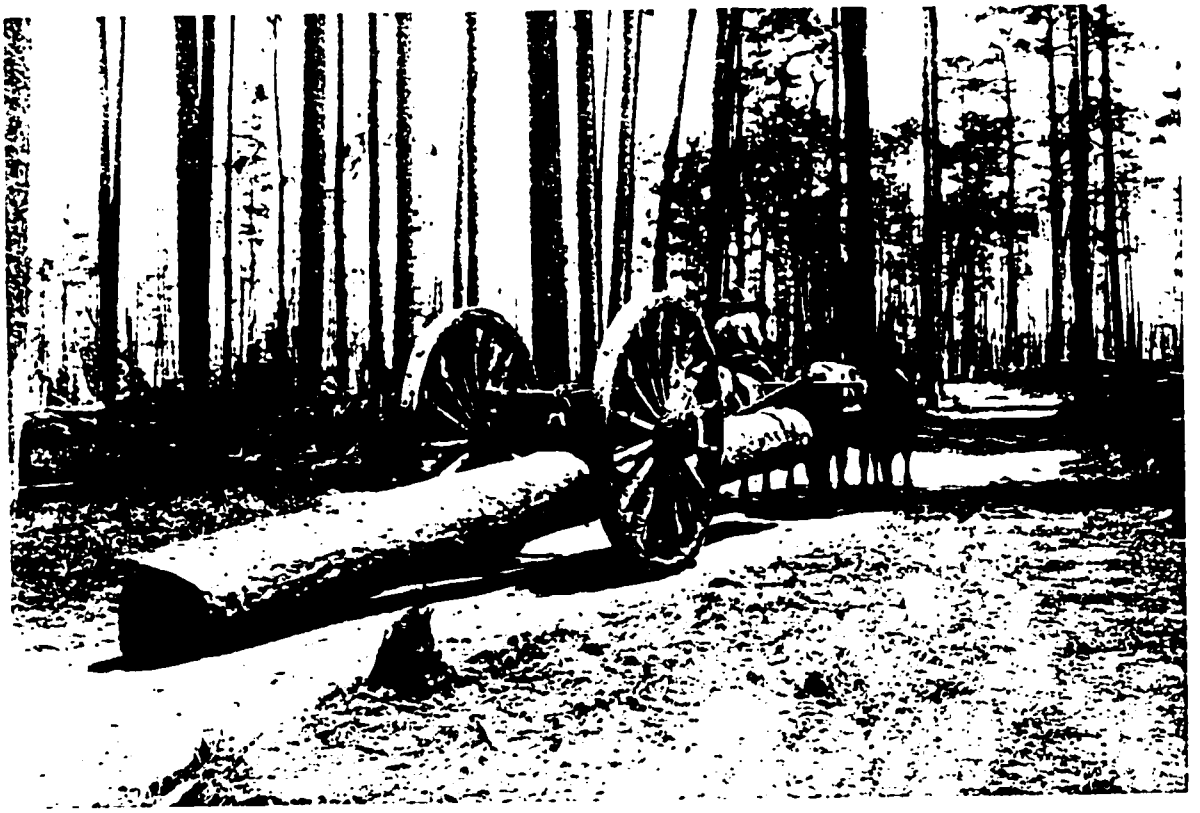


Figure 10. This virgin longleaf stand in Beaufort County, South Carolina had been boxed for turpentine. Fires further weakened the trees by setting the boxes ablaze and in coastal areas, hurricanes often finished the job. Photo, Sherrard 1903.

Figure 11. Virgin longleaf stands of the interior hills of the Piedmont and southern tip of the Appalachians were nearly as open as those of the Coastal Plain. Boxes have just been chopped into the bases of these trees for the turpentine process, which had just reached the hills in 1905. Bibb or Coosa Co., Alabama. Photo Reed 1905.

Figure 12. A "carry-log" drawn by mules. Economical range of this kind of transport was less than 4 miles (Croker 1987). Photo courtesy of U.S. national Archives.

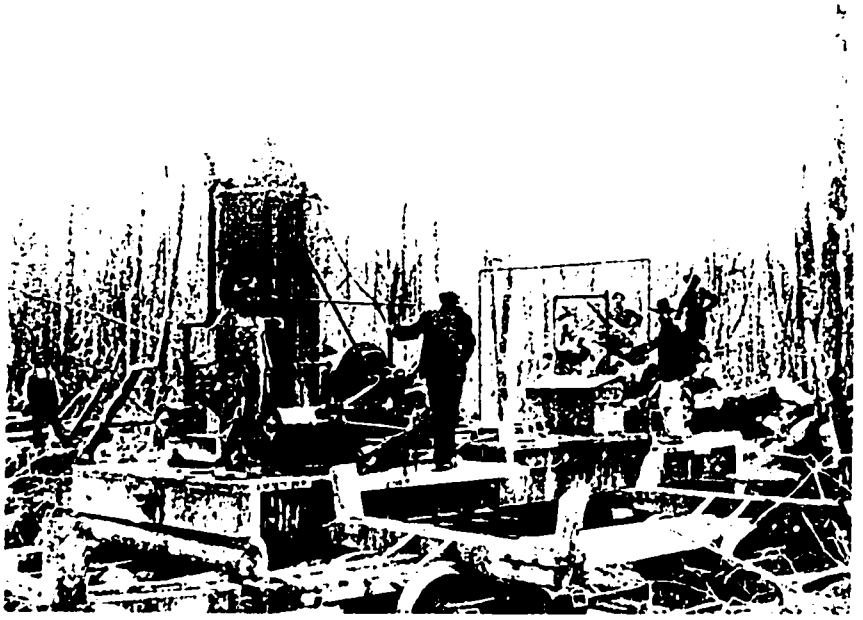


The spread of agriculture in the longleaf pine region. Indians were the first farmers, and the full extent of Indian agriculture in the South has never been delimited. Bartram (1791) described "tallahassees" or Indian old fields from shifting agriculture in north Florida. To the north, the hunter-gatherer cultures of North Carolina and Virginia farmed on a very small scale in patches adjacent to villages, while much of the diet came from fishing and hunting (Harriott 1590, Smith 1624). In the Creek country of Alabama, however, Bartram traversed a region of Indian farmland broken only by small tracts of woods between the outlying agricultural lands of one village and the next (Bartram 1791). Clearly a portion of the longleaf pine region had already been domesticated before arrival of the first Europeans.

Along the Atlantic slope, settlers finally began moving out of the tidewater region in the 1730s (Clay et al. 1964) and, with later waves of immigrants, settled the Piedmont, reaching the foothills of the Appalachians by the 1790s (Figure 3). During the period 1750-1850 virtually all longleaf communities of the more fertile soils were converted to farmland and pasture (Williams 1989). Both the American Revolution and the Civil War interrupted agriculture for a number of years and in 1795 it was reported that "all Tidewater Virginia was full of 'old fields' reverting to timber." (Wertenberger 1922).

The longleaf pine region was fully settled by 1750 with exception of Florida, Texas and the interiors of Alabama and Mississippi (Figure 3). As late as 1820 the vast longleaf forests of the interior of Alabama, Mississippi, Louisiana and east Texas remained essentially untouched. In 1821, however, cession of Florida to the United States by Spain, and major land purchases from the Creek and Choctaw Indians, opened this region to settlement. By 1850 the fertile Black Belt region of central Alabama and Mississippi had been plowed and converted to cotton plantations by large slave-holding planters. A map compiled from the Census of 1840 (Williams, 1980) shows the distribution of major cotton plantations in three dense regions: coastal South Carolina and Georgia, the lower Mississippi River valley, and the Black Belt.

Figure 13. Steam skidders used cables to winch logs out of the woods to loading platforms. Note narrow-gauge logging car in foreground. Juniper Swamp near Roper, Washington County, North Carolina. Photo, American Lumberman 1907.



By the Civil War, nearly all lands optimally suitable for agriculture were in production. By 1900, 30.7 million ac (12.5 million ha) or about (27.0%) of the longleaf pine upland was listed as "improved" farmland, a category that included pasture, roads and buildings as well as cropland (U.S. Census of Agriculture 1902). While there were no separate figures for land in pasture in 1900 (U.S. Census Office 1902), it was necessary to maintain pasture or range on every farm for horses, mules, and oxen used for plowing and transportation, and until around 1880 much livestock was still maintained on open range in the woods.

History of logging, from hand power to water power to steam. Effects of timbering were minor through the early Colonial Period (from 1607 in Virginia, 1565 in Florida) to the mid 1730s, when logging was done by hand, using horses, mules and oxen to drag the logs. Commercial logging was limited to the vicinity of streams where the harvest could be transported. While water power was tried as early as 1611 in Virginia, this technology did not take hold until around a century later, with introduction of water-powered sawmills in Louisiana around 1714 (Hindle 1975) and the Cape Fear region of North Carolina in the 1730s. In 1732, Governor Burrington reported that an abundance of sawmills was being constructed along the Cape Fear River. In 1764 Governor Dobbs reported that forty sawmills had been completed on branches of the Cape Fear, and Governor Tryon reported that the number had risen to 50 by 1766 (Merrens 1964.

Water power opened up the first real possibility of commercial lumber production. Steel saw blades were imported from Holland where the technology had been worked out, and sawmills proliferated rapidly along streams in settled areas. Still, these were slow acting, straight-bladed reciprocating saws (slash saws), with an up and down action, mimicking the human-powered pit saws: the circular saw and band saw were still 100 years away, not coming into general use until after the Civil War (Hindle 1975). Many of these small mills operated only part time--when there was enough water in the mill pond in winter and spring to turn the wheel. Many were plantation-owned, producing boards for local use, with a little surplus shipped downstream to coastal towns.

While water power helped the clapboard house to replace log construction, commercial logging remained a constant but minor industry from 1730 to around 1850. Until that time, most logging was along streams where logs were skidded out in various ways by horses, mules and oxen. The giant wheeled "carry-log" (or "caralog", Figure 12) was important from this time until the late

19th century when it was supplanted by logging railroads and steam skidders. Logs were transported this way to the nearest water and then rafted downstream to mills. The maximum effective distance for this kind of overland transport was only 3 or 4 miles (Croker 1987) and so commercial exploitation was still limited to narrow zones along navigable streams.

Prosperous South Carolinians were fascinated by steam power and in 1833 constructed the first railroad in the United States, connecting Charleston and Hamburg, S.C. In 1856, the first steam-powered dredges were used in Norfolk Co., Virginia, to build the Albemarle and Chesapeake Canal (Ruffin 1861), and the period 1850-1870 saw explosive proliferation of steam technology for logging railroads, steam skidders (Figure 13) and steam powered sawmills (Anon. 1907). By the end of the Civil War, with resumption of intensive turpentining throughout the longleaf forests of North and South Carolina, and with steam logging methods perfected, the stage was set for cataclysmic decimation of the longleaf ecosystem.

After the war, there were sales of huge tracts of southern lands to northern railroad companies (Figure 14), often with subsequent sales by railroads to logging companies. Lands sometimes changed hands at the rate of 100,000 acres or more, at prices of $1.25 per acre (Napier 1985). The decade 1880 to 1890 saw standardization of track sizes and concatenation of isolated railroad lines, making overland transport of lumber cheap and efficient (Anon. 1907, Hale (1883). By 1880, all commercial timber had been removed from lands within a few miles of streams and railroads. Tapping of virgin forests of the interior had just begun, but huge volumes of lumber were being produced. Sargent (Table 2.2) reported an annual cut of over a billion board feet in 1884, increasing to 3.7 billion board feet by 1896 (Mohr 1896). The phase of intensive logging from 1870 to 1930 saw removal of virtually all remaining virgin forest in the South. By 1900, it was apparent that many cutover longleaf areas, particularly those on better soils, were being occupied by scrubby second growth of other species, while others remained open and nearly treeless. Longleaf pine replaced itself only sporadically in a small percentage of its former landscape (Mohr 1896).

Figure 14. Clearing right-of-way through virgin longleaf forest in Mississippi for Natchez, Columbia and Mobil Railroad in 1907. All timber was soon cut within several miles of railroads and more distant lands were sold to logging companies. Photo, American Lumberman 1907.

VIRGIN LONGLEAF PINE REMAINING IN 1880		
	Merchantable Longleaf Pine	Annual Cut
Virginia	No reported commercial production	
North Carolina	5,229,000,000	108,411,000
South Carolina	5,316,000,000	124,492,000
Georgia	16,778,000,000	272,743,000
Florida	6,615,000,000	208,054,000
Alabama	18,885,000,000	245,396,000
Mississippi	18,200,000,000	108,000,000
Louisiana	26,588,000,000	61,882,000
Texas	20,508,000,000	66,450,000
Totals	118,119,000,000	1,194,428,000

Table 2.2. Quantities of virgin longleaf pine remaining, and annual cut in 1880 (board feet). Figures are only for major longleaf pine regions and major logging companies. While virgin growth had been depleted in Virginia and exhaustion in the Carolinas was imminent, stands in Louisiana and Texas still were largely untouched (Sargent 1884).

THE DISAPPEARANCE OF LONGLEAF PINE

Historical records suggest a combination of three factors to explain the disappearance of longleaf pine. First, regenerative failure of longleaf forests may have been due in part to their inherently low rate of restocking under a natural fire regime which, on extreme sites, might take more than 300 years for return to original stand structure after logging. On other sites, however, longleaf may reproduce adequately, even under an annual fire regime (T. Sharpe pers. comm.).

The second factor was the fondness of feral livestock, especially hogs, for the seedlings (Mohr 1896, Hopkins 1947a, 1947b, 1947c). Unlike other pines, longleaf seedlings have a non-resinous, carbohydrate-rich meristem which, while in the grass stage, is vulnerable to grazing for 5 to 7 years or more. Hogs have been observed to feed heavily on longleaf seedlings, consuming up to 400 each in a day (Hopkins 1947a, 1947c). The third and final factor was 20th century fire suppression.

Failure of longleaf pine regeneration after logging. By the 1890s foresters saw clearly that, over large expanses of the landscape, longleaf was not replacing itself after logging (Ashe 1894a, 1894b, Mohr 1884, 1896). Mohr commented, "on the lowlands of the Atlantic coast toward its northern limit this pine is almost invariably replaced by the Loblolly Pine." "In the stronger soil of the upper division of the maritime pine belt, the region of mixed growth, where seedlings of the Longleaf Pine spring up simultaneously with the hard wood trees and the seedlings of the Shortleaf Pine, these latter will eventually gain the supremacy and suppress those of the Longleaf Pine." "It is evident that the offspring of the Longleaf Pine is rarely seen to occupy the place of the parent tree, even in the region most favorable to its natural renewal, and that final extinction of the forests of the Longleaf Pine is inevitable unless proper forest management is applied." To Mohr's mind that meant eliminating all fire and then "bringing in", 15 to 20 years later, shade-tolerant tree species below the longleaf to build up a humus layer "to secure improvement and permanency of favorable soil conditions." These sentiments were echoed by Sherrard (1903). Unfortunately this was a prescription for extirpation of longleaf pine, the herb layer and the two-layered structure typical of fire communities.

The question that dogged foresters was, why didn't longleaf reproduce, at least on those lands where nothing else was done other than logging of the virgin timber? Contemporary with Mohr, one of the first foresters to wrestle with this problem was W.W. Ashe, who noted that not only was the longleaf seed crop produced in irregular mast years, but also that the seeds were descended upon by a variety of predators: "...its large and sweet seeds are eaten in large quantities by fowls of various kinds, rats, squirrels, and by swine, which prefer them to all other kinds of mast, and when there is enough long leaf pine mast become very fat on it" (Ashe 1894b). This had been noticed as early as 1728 by William Byrd during the survey of the Virginia-North Carolina line and Ruffin (1861) commented that "They are so eagerly sought for by hogs that scarcely any are left on the ground to germinate." Ashe was one of the first to report the fondness of hogs for the larger seedlings. "No sooner, however, has the young pine gotten a foot high and its root an inch in diameter than the hog attacks it, this time eating out the roots, which until 2 inches in diameter, are very tender and juicy, pleasantly flavored and free of resinous matter."

Like most foresters of his time, Ashe regarded fire as the unrelenting enemy of forest regeneration, even going so far as to insist that in North Carolina "...the burnings of the present and future, if not soon discontinued, will mean the final extinction of the long leaf pine in this state" (Ashe 1894b). This opinion echoed that of Mohr (1884) and others on the destructive nature of fire. The groundwork for the field of fire ecology had clearly not yet been laid.

After consideration of all factors, Ashe concluded that the chief agencies preventing regrowth of longleaf pine were fire and hogs. While fire destroys first year seedlings and under certain circumstances can even kill mature trees, later authors asserted the actual dependence of the species upon fire to prevent site appropriation by shade-tolerant pines and hardwoods (Harper 1913). When some of the early assertions were tested, longleaf pine was found to be replaced by slash pine when both fire and hogs were excluded (Sherrard 1903), and studies in 1935 showed only 8% fire mortality in two year-old longleaf plantations in Louisiana, versus 53% for seven year-old loblolly (Wakeley 1935). If fire is excused as one of the two principle culprits, that leaves hogs conspicuously in need of closer scrutiny.

In 1539, DeSoto made the first introduction of swine to the South (Bakeless 1961). Later, English settlements brought with them starter livestock (Strachey 1610, Smith 1624). Hogs showed an astounding reproductive potential, and demonstrated an ability to fend entirely for themselves in the woods with no attention from their owners (Beverley 1705, Blakeley 1812 [1910]). The capacity of the landscape to support open range hogs has never been investigated, but there is considerable evidence to suggest that they quickly reached saturation density within a few decades after settlement. By 1617 the log palisades with which the town was walled off were not sufficient to keep the hogs out of the streets of Jamestown, Virginia. Capt. Samuel Argall and James Rolfe on landing there in May of that year commented on the "innumerable numbers of swine" (Smith 1624).

Evidence for early saturation of the landscape by hogs in coastal regions. Both the Spanish and English experiences demonstrated the potential of hogs to increase from a handful to thousands in two or three years under conditions of complete neglect on open range. By 1702 a Swiss visitor to coastal Virginia declared that "Pigs are found there in such numbers that I was astonished" (Michel 1702 [1916]. This was corroborated by Beverley (1705) who stated that, "Hogs swarm like Vermine upon the Earth, and are often accounted such, insomuch that when an Inventory of any considerable

Man's Estate is taken by the Executors, the Hogs are left out, and not listed in the Appraisement. The Hogs run where they list, and find their own Support in the Woods, without any Care of the Owner; and in many Plantations it is well, if the Proprietor can find and catch the Pigs, or any part of a Farrow when they are young, to mark them...."

A few years later, Brickell (1737 [1968]) reported similar conditions in northeastern North Carolina where he saw, "...swine, breeding in vast numbers...." A considerable meat packing business had sprung up in Norfolk, Virginia, the major port in the mid-Atlantic region, to supply salt pork and other provisions to sailing ships. The first direct evidence that hogs had reached saturation density in North Carolina is provided by reports of Governor Barrington in 1733, that about 50,000 hogs were driven annually to the Norfolk market from the Albemarle region of North Carolina (Wertenbaker 1931). The first census figures from these counties, showed no increase from 1840 to the Civil War, indicating that saturation density had been reached, with an average of 14,800 hogs on open range in each of the six counties south of the state line within hog driving range of Norfolk. This gives an average of 10.7 acres per hog (U.S. Census of Agriculture 1841). For the 1890 census only, unique figures were kept for hogs consumed or hogs which died, in addition to total numbers. In Alabama, which still had hogs on open range, an annual number equal to 45% of the total hogs alive were consumed and 23% died. This gives us an approximation for surplus hogs that could be harvested when populations were near capacity (U.S. Census of Agriculture 1895). If the total number of hogs in the six North Carolina counties mentioned above, were at carrying capacity in 1750, the numbers should be nearly the same as in 1840 (88,850 hogs), then the surplus should have been 45% or 40,000 hogs. The fact that the reported surplus of 50,000 fully-grown hogs driven to Virginia exceeds our estimate of 40,000 strongly suggests that carrying capacity had been reached in this region sometime before 1733. These counties were settled between the years of 1655 and 1700 so there had been from 35 to 78 years for hogs to reach saturation density.

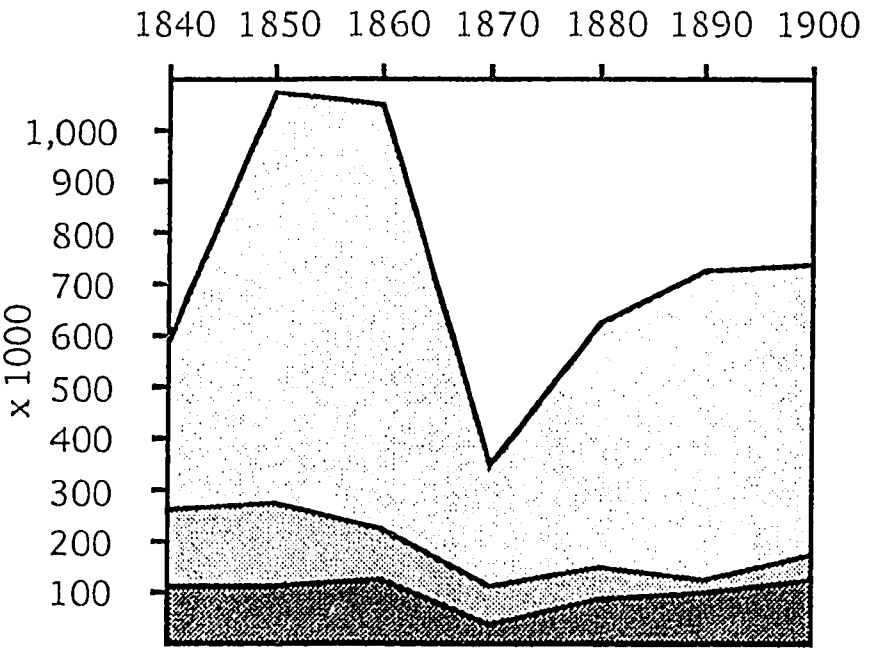
While hogs spread inland from southeastern Virginia and northeastern North Carolina, other introductions were made along the Atlantic and Gulf coasts. Explorers stepping ashore on the barrier island at Cape Fear, North Carolina, in 1663 were astonished at being offered pork for sale by the Indians, livestock having been placed on the islands a few years earlier by stockmen from New England (Lawson 1709 [1967]). Lawson also commented on hogs at the town of Charleston, South Carolina in 1700. Mobile, founded in 1711 (Hamilton 1910 [1976]), was the first permanent city on

the Gulf, and in 1812, free-ranging hogs were kept on three islands of about 4,000 acres each at the head of Mobile Bay. Josiah Blakeley, the owner, wrote that: "Cattle and hogs do well upon them, and no expense. Upon them I have about 30 head of cattle and hundreds of hogs, the hogs wild. I shoot or catch them with a dog (Blakeley 1812 [1910])." There is little evidence, however, that hogs spread very far beyond the frontier, where Indians and other predators may have kept them under control.

From the descriptions above, it seems likely that tidewater Virginia was saturated with hogs by around 1700, and the whole coastal plain of Virginia and the portion of North Carolina north of Albemarle Sound by 1730. The first regularly kept figures, however, were not available until a century later with the 1840 Census of Agriculture. The lower line in Figure 15 shows the total number of hogs from the fifteen Virginia counties within the original range of longleaf pine from 1840 to 1900. The plunge in numbers occasioned by famine during the Civil War is characteristic of all the southern states and is closely paralleled by figures for cattle and other livestock (U.S. Censuses of Agriculture 1840-1900). Note that the population curve for the decades preceding the Civil War is relatively flat, and recovers to a relatively flat slope within two or three decades afterward. This supports the notion that carrying capacity had been reached some time before such records were kept.

In contrast, figures for Alabama indicate that only the coastal region was saturated by 1840. The middle line in Figure15, which parallels that for Virginia, represents the seven old, long-settled coastal counties around and upstream from Mobile. The upper line represents the middle counties. The interior remained Spanish territory until its session to the United States in 1821, when settlers from Georgia and the coast were poised for entry (see Figure 3). By 1840, only 19 years after opening of the territory, immigration was in full swing but the country was as yet sparsely settled. Figure 15 shows increasing numbers of hogs in the central counties, but leveling off after 1850, within 19 years of 1821. The flattening of the curve again suggests carrying capacity had been reached, and suggests that hogs could saturate a vast landscape in about 20 years (the large numbers for the central counties reflects the much greater land area).

Figure 15. Evidence for saturation of the landscape by feral hogs. The lower curves represent stable hog populations in coastal regions long-settled by 1840—more than 200 years for coastal Virginia (bottom line) and over 100 years for coastal Alabama (middle line). The vast regions in central Alabama, only opened to settlement in 1821, had just reached carrying capacity in 1850, with over a million hogs on open range. Data from U.S. Census of Agriculture.


1840
1850
1860
1870
1880
1890
1900
1,000
900
800
700
600
500
400
300
200
100
x 1000

Hogs were not the only competitor for forage on open range however. While hogs were consistently the most abundant livestock species listed, the range was shared by cattle, horses, mules, sheep and goats, whose numbers collectively equaled those of hogs (U.S. Censuses of Agriculture 1841-1902). One writer estimated that 12 to 25 acres of unmanaged woodland was required to support one cow, 2 acres of good pasture would suffice (Gardner 1979).

No figures were ever determined for carrying capacity of southern range for hogs (Grelen 1980). As noted above the apparent saturation density of hogs in 1840 in northeastern North Carolina was 10.7 acres. While this might seem an abundance of land per hog, keep in mind that county areas included water, areas from which hogs were fenced out, and large areas of upland forests where there may have been little forage except for the fall mast crop of acorns and pine seeds. There was stiff competition for the mast crop from birds and other animals (Ashe 1894b, Wahlenberg 1946). Longleaf pine seedlings, on the other hand, were available and vulnerable all year round.

Wakeley (1954) noted that cattle do negligible damage to longleaf pine except where heavy concentrations trample new plantations, and light grazing may reduce fire intensity by removing potential fuel while it is still green. Sheep and goats are more serious, biting out terminal buds, sometimes resulting in more than one stem from a base. Biting retards height growth but does not kill most trees. Nevertheless, densities of one sheep per 47 acres seriously damaged some young longleaf stands, and 1 sheep per 13 acres injured up to 86% of seedlings (Wahlenberg 1946). While birds have been reported to consume from 8% to up to 42% of the longleaf seed crop (Wahlenberg 1946), they do not molest the seedlings, and this much predation must have been tolerable, since birds were a natural part of the landscape in which longleaf pine flourished. Wakeley (1954) considered hogs by far the most serious threat to longleaf: "Where there are many hogs it is foolhardy to plant longleaf pine without fencing.... To this species hogs are infinitely more destructive than fire."

There are several hog and fire exclusion studies to back up this assertion, two of which reported complete failure of stand regeneration on tracts where feral hogs were present. Two experimental tracts at Urania, Louisiana, after five years of protection against hogs, contained an

average of 6,440 longleaf saplings per acre, as compared with an average of only 8 per acre on two similar unprotected tracts (Mattoon 1922). In an area with free-ranging hogs in Georgetown County, South Carolina, hogs were fenced out of 32 1/10 acre plots. After two growing seasons the fenced areas contained 500 fire-resistant seedlings (those with root collar diameters of 1/2 inch or larger) per acre, while unfenced areas again contained only 8 per acre (Lipscomb 1989). The hogs largely ignored small first-year seedlings but focused on those large enough to have accumulated starchy content. Density of hogs was not controlled but was estimated to be about 3 to 6 animals on the 60 ac study area, or 10 to 20 acres per hog. This is comparable to the hog densities of 10.2 acres per hog reported above, on open range in colonial North Carolina, which we have suggested may represent carrying capacity.

Ashe (1894b) and Mohr (1896) both commented on the palatability of longleaf pine seedling roots in the 1/2 to 2 inch diameter range. Wakeley (1954) reported hog consumption of 200-1,000 longleaf seedlings per day, at rates of up to six per minute. Hopkins (1947a, 1947b, 1947c) after observing hogs rooting up hundreds of seedlings a day, analyzed the root starch content and found them to be as nutritious as corn. Little wonder then that hogs would home in on longleaf seedlings, which, in the grass stage, are highly conspicuous and vulnerable for three to seven years. With 10,000 to 40,000 hogs on open range in every settled county in the longleaf region (U.S. Censuses of Agriculture 1840-1900), all that would be required to eliminate reproduction would be for a drove of hogs to happen upon a regenerating plot once every three or four years to largely eliminate the species from the landscape.

Hogs on open range were completely dependent on natural forage, none being provided by their owners (Beverley 1705). If carrying capacity had been reached, survival would be tenuous and occasional disasters could be expected when mast crops or other wild foods failed. A curious example occurred in Illinois when hogs starved in winter after passenger pigeons unexpectedly descended in a local area and ate all the fall mast of acorns, beechnuts, and chestnuts (Bakeless 1961). This raises the question about the reverse situation, that saturation of the landscape with hogs contributed to the extinction of the passenger pigeon. Their summer breeding range extended only as far south as Virginia but from late September to early November the flocks migrated to the winter range from South Carolina to Florida (Bent 1932 [1963]). This coincided with longleaf seed fall, and it has been observed that related birds like mourning doves and quail have crops "crammed"

with longleaf seeds during this time (Wahlenburg 1946). In the South, memory of the species persists only in place names like "Passager Swamp" in Isle of Wight County, VA.

The end of open range. The effects of hogs on longleaf pine were not noticed until the massive wave of logging that followed the Civil War, physically removed the forest. Most of the timber cut in the period 1870-1900 was still virgin forest (Mohr 1896), where the effects of hogs were inconspicuous as long as the trees stood. Note that longleaf had indeed been extirpated from much of the northern range a hundred years before, but the process had taken 200 years, while decimation of the forest using steam logging technology occurred almost overnight. This precipitated an immediate shortage of lumber for fencing (Hale 1883), and forced landowners to look at the problem of livestock on open range. For the first three centuries, crops had been fenced in to protect them from livestock, which had free run of the land. Even if a farmer had little stock of his own, he had no choice but to fence his crops against the animals of his neighbors. As more land came into agriculture demands for fencing increased until the timber shortage made it apparent that it would more economical to fence in the livestock rather than the crops.

In response, fence laws (stock laws) were passed throughout the South, beginning in the 1870s. After the Civil War an act of the legislature in South Carolina allowed each township to determine by vote, "whether the crops or the stock shall be enclosed" (State Board of Agriculture 1883). This option may not have worked, especially along the boundaries of counties with different rules, since by 1883 a statewide law was passed "...making it incumbent upon the owners of live stock to see that they do not trespass on others. The tiller of the soil is no longer compelled to build fences to protect the fruits of his labors from the inroads of his neighbors' cattle, thus saving all cost in building and repairing fences..."(State Board of Agriculture 1883). A respondent to a timber survey, from Anson County, North Carolina commented that, "every man who owns cattle, hogs, sheep, goats or horses in Anson County is now compelled to pasture them on his own land. None are allowed to run at large on the range. This system came into effect in our county about two years ago, and so much is it esteemed already that a return to the old style of fencing the crops against the incursions of stock is next to impossible. This is regarded as the most important single step taken in this county in the last twenty years" (Hale 1883). The process took decades to become effective over the whole South and there are still some areas where hogs run wild (Lipscomb 1989).

LANDSCAPE CHANGES FROM 1900 TO 1990

Fire suppression and the decline of fire as a natural determinant of vegetation. The end of open range should have been a boon to longleaf pine, but while three centuries of open range was drawing to a close[5], a new threat was in the making. Fire was still widespread, but by the Civil War, much of the landscape had been fragmented by agriculture, reducing the size of fire compartments. In central South Carolina there were an average of 50 acres per farm cleared and tilled (State Board of Agriculture 1883). As long as stock raising was the primary source of income the remaining woodlands were burned by the residents to green up forage for livestock. This practice may have perpetuated longleaf pine and its associated flora of wiregrass and savanna herbs, in a landscape where roads, plowed fields and other manmade firebreaks had eliminated landscape-scale fires ignited by lightning. When cattle grazing declined in importance after the Civil War, the practice of spring burning was abandoned in major agricultural areas. Describing the resultant vegetation changes in South Carolina, one writer noted that, "the uplands were covered, as they still are, with a large growth of yellow pine, but a deer might then have been seen, in the vistas made by their smooth stems, a distance of half a mile, where now, since the discontinuance of the spring and autumn fires, it could not be seen fifteen paces, for the thick growth of oak and hickory that has taken the land" (State Board of Agriculture 1883).

On all but the drier lands, longleaf reproduction is completely eliminated by mesophytic pine, hardwood and shrub invasion within a few years after fire exclusion (Sherrard 1903, Frost in prep.). Nowhere in the South can longleaf be seen reinvading the mesophytic mixed pine-hardwood succession that has replaced it.

Modern fire laws and the state apparatus for prevention and suppression of wildfire did not come into being in most of the South until the period 1910-1930. This left a window of some 50 years, between the end of open range and the beginning of 20th century fire suppression, in which longleaf pine could reproduce. Many of the stands which did result have now been logged and most of those naturally-regenerated stands still remaining, date to the end of this window of opportunity.

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[5] The process took decades to becomes effective over the whole South and there are still areas where hogs run wild (Lipscomb 1989).

Fernow (1893) was one of the first to argue for governmental involvement in forestry: "there exist some legislative provisions regarding forest fires in almost every State, but they are rarely if ever carried into execution for lack of proper machinery." Most states remedied this condition in the next 30 years, however. In 1919, Virginia passed laws creating the position of State Forester and provided for forest wardens. The act also imposed fines and a minimum penalty of a year in prison for maliciously starting a forest fire, a far cry from the days when burning was a casual choice.

While early foresters were convinced that both hogs and fire were inimical to longleaf regeneration, the first real demonstration was conducted in 1903. Sherrard (1903) examined a fenced plot from which fire and hogs were excluded. Within a few years a dense stand of slash pine had established itself beneath the longleaf. Sherrard was pleased with the result. Never mind that the new forest would be composed of a new dominant species and of entirely different structure than the open longleaf forests. And curiously, neither he nor Ashe, nor Mohr ever questioned that if fire were the enemy of longleaf, why did its exclusion lead to an entirely different forest type?

Few of the early foresters cared to acknowledge the role of lightning as an ignition source. In South Carolina, Sherrard (1903) blamed all fires on humans, stating that fires were "carelessly set to improve grazing, to clear land, and to protect woods where turpentine is being gathered." Burning in this case was done after first raking pine straw away from the flammable boxes in the bases of the trees. Ashe even believed that one of the reasons longleaf pine was being replaced by loblolly was that it was more sensitive to fire: "the loblolly pine is less injured by fire because its bark is thicker and so offers more protection to the growing wood, --the bark, too, lying closer to the wood in firmly appressed layers, does not so easily take fire." "The chief agencies, then, which prevent a regrowth of long leaf pine on the high sandy lands, are the hogs and the fires..." the burnings of the present and future, if not soon discontinued, will mean the final extinction of the long leaf pine in this State (NC)."(Ashe 1894). Sherrard however, recognized that, "the Longleaf Pine may rightly be called a fireproof species in so far as the survival of scattered groups and patches of second growth and individuals is concerned. But extended areas under forest are impossible under present conditions." He was one of the first to call for a public campaign against fire: "the people must be educated to a sentiment against fires."

Figure 16. The first documented study showing the effects of exclusion of fire and hogs from longleaf pine. A dense forest of slash pine is regenerating in a fenced plot after exclusion of fire and hogs for several years. Old boxed longleaf survivors and scattered slash pine make up the canopy (Sherrard 1903). Sherrard aimed to produce a similar forest on all pine lands in the two counties being studied. Southeastern South Carolina. Photo, Sherrard 1903.

The first voice to clearly distinguish the natural role of fire was Roland Harper who stated, "it can be safely asserted that there is not and never has been a long-leaf pine forest in the United States...which did not show evidences of fire, such as charred bark near the bases of the trees; and furthermore, if it were possible to prevent forest fires absolutely the long-leaf pine-our most useful tree-would soon become extinct" (Harper 1913).

If not admitted by foresters, it was well known to inhabitants of the longleaf pine region as early as the 1830s, that lightning was often responsible for fires in the turpentine orchards. On a large estate in Onslow County, North Carolina, damage to the turpentine crop was prevented by providing log cabins free of rent to poor white families, whose duties included fighting summer lightning fires. "These men are required to do three things: first, they are to guard the orchards from fire, and if a small fire occur, as it often does in the summer time by lightning striking and igniting a resinous pine tree, they and their families must extinguish it. If it gets beyond their control they are to blow horns, summoning the neighboring tenants, sending all around for help, fight the fire until it is put out..." (Gamble 1921). In other areas fire was prevented because it consumed pine straw, which in many parts of the South was sold as stable bedding and "fertilizer on the cotton fields" (Mattoon 1922).

The slow and patchy reproduction characteristic of unmanaged longleaf under conditions of frequent growing season fires was a legitimate concern. Early foresters quickly discovered, however, that exclusion of fire led to establishment of dense loblolly or slash pine understory where longleaf forests had been removed or damaged by turpentining (Sherrard 1903, Figure 16). While it must have been apparent that this kind of succession would eventually lead to replacement of longleaf, it was sufficiently good news in a landscape recently denuded of its primeval forest cover, that within a few years, fire exclusion and a program of educating the public "to a sentiment against fires" became the general forest prescription for the South.

Pine plantation. Pine plantations scarcely existed in 1900. The earliest recorded plantations in the South were three small plots established by farmers in 1892, 1896 and 1907 (Wakeley 1935). The first large attempt at plantation by the U.S. Forest Service, 900 acres on the Choctawhatchee and Ocala National Forests in 1911, proved to be an almost complete failure. Wakeley knew of only 500

acres successfully established by 1919. Problems with technique were soon worked out, however, and Table 2.3 shows the extent of pine plantation in the nine states within the range of longleaf pine by 1931[6]. By this time over 20 lumber and paper companies were involved and accounted for at least 78% of the acreage.

TABLE 2.3. THE FIRST PINE PLANTATIONS: 1892-1931[7]

	Before 1928	1928	1929	1930	1931	TOTAL
Virginia	337	47	349	316	401	1,450
North Carolina	1,525	306	544	270	468	3,113
South Carolina	3,229	------	112	481	745	4,567
Georgia	1,500	6	800	2,542	154	5,002
Florida	966	0	34	1,468	1,867	4,335
Alabama	89	50	328	266	34	767
Mississippi	------	------	------	535	594	1,129
Louisiana	19,540	9,273	10,583	6,556	2,474	49,426
Texas	------	------	------	260	-------	260
						70,049

Fire was a threat to pine plantations, but establishment of increasingly large areas protected from fire in the 1930s and 1940s made it seem feasible to plant loblolly and slash pine as a commercial crop. Pine plantation was expanded by large timber corporations in the 1940s and there were 12,460,000 a (5,046,300 ha) established in the years 1965 to 1967 (Boyce 1979). Forced into more marginal lands by development pressures, timber companies found it increasingly desirable to produce pine pulpwood and sawtimber using intensive management. In the former longleaf region, there are at present about (15,315,000 a) (6,202,000 ha) of pine plantation, primarily loblolly and slash pine, but also some shortleaf and a small amount of longleaf in the former longleaf pine region (Boyce 1979, Outcalt and Outcalt 1994).

[6]A small amount of planted trees were hardwood, something under 5%.

[7] Figures are from Wakeley (1935), with exception of the acreage before 1928 in South Carolina, from Boyce (1979).

Expansion of agriculture and developed land. While much mixed pine-hardwood is now converted to plantation after logging, much is also cleared and converted to cropland, the second largest land use category in the region. While commercial dairy operations have proliferated since 1900, total pasture probably has declined. After World War II mules and horses were retired by tractors, and surplus pasture lands went into cropland or succeeded to loblolly pine (Boyce 1980). The relative percentages of land in cropland and forest are the net result of a complexity of changes which include forest succession of abandoned cropland on small uncompetitive farms between 1940 and 1965, and clearing of new cropland from woodland by large farming operations. The 1982 Census of Agriculture reported 7,814,000 acres in pasture (6.4% of the uplands) and 25,589,000 acres in cropland (20.8% of the uplands) in the 412 counties of the former longleaf pine region (Table 2.1).

The logging boom of the late 19th century left in its wake cutover lands and dense, scrubby second growth, and efforts of crusading fire exclusionists guaranteed that over much of the region, the sunny, open, fire-maintained woodlands would be seen no more. For the inhabitants who lived during the first decades, seeing the forest of centuries fall around them was often a disheartening experience that transformed their world. One respondent to a timber survey in 1882 in Currituck County, North Carolina noted bitterly:

> "The avaricious and insatiable saw mills, together with the desire of every man who could buy a pair of oxen and 'Carry-Log', have demolished and transported nearly all of our pine... This certainly looks like a gloomy report, but more truth than poetry" (Hale 1883).

Still, within the 3% of the landscape that still supports natural longleaf pine today, there is a remarkable galaxy of sites large and small, only one generation away from logging and turpentining, which have recovered nicely. These we may still be able to maintain, and perhaps we can restore more of Bartram's "...expansive, airy pine forests...of the great long-leaved pine...the earth covered with grass, interspersed with an infinite variety of herbaceous plants, and embellished with extensive savannas, always green..."

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APPENDIX. CHRONOLOGY OF SIGNIFICANT EVENTS IN THE DECLINE OF THE LONGLEAF PINE ECOSYSTEM:

1565-1732	Land clearing, hogs and other feral livestock introduced into the woods, small-scale naval stores production.
1714	Introduction of water-powered sawmills. Beginning of sawtimber removal from lands along waterways. By 1764 there were 40 in operation along the Cape Fear River in N.C.
1750	Feral hogs reach saturation density on open range in Virginia and northeastern North Carolina, eliminating much longleaf seedling establishment.
1815	First steamboat in the Carolinas; ten in use in South Carolina by 1826. Introduction of steam power marks the beginning of the Industrial Revolution in the South.
1833	Construction of first railroad in the U.S., between Charleston and Hamburg, South Carolina.
1834	Introduction of the copper still for distillation of turpentine. Beginning of era of massive turpentining operations.
1840	Longleaf pine largely decimated in Virginia after 200 years of small-scale naval stores production as a cottage industry.
1850	Turpentine production peaks in North Carolina, begins to spread south as forests are exhausted.
1860	Feral hogs reach saturation density on open range in most of the range of longleaf pine.

1850-1870	Rapid proliferation of steam technology for logging railroads, steam skidders, steam-powered sawmills.
1865-1870	Large sales of southern lands to northern investors, particularly railroads. Sales of surplus lands by railroads to logging companies after railroad construction.
1880-1890	Beginning of standardization of railroad track sizes and linking of formerly isolated railroad lines, making overland transport of lumber practicable.
1870-1920	Massive logging, powered by steam technology. Most remaining virgin forests in the South logged.
1880-1930	Stock laws and/or fence laws passed in most of the range of longleaf pine. Last major stand regeneration occurs in many areas, in the years between the end of open range grazing and the beginning of modern fire suppression.
1920-1950	Most of the range of longleaf comes under effective fire suppression. Dense second-growth forest succession replaces diversity of savanna, woodland and open fire-maintained forests.
1920-present	Conversion of unmanaged woodlands to pine plantation.
1943	After much debate, U.S. Forest Service gives approval to use of fire in managing woodlands. Many areas on public and private lands, however, are excluded from prescribed fire.
1962-1998	Tall Timbers Fire Ecology Conferences. Growing appreciation of role of fire in maintaining natural ecosystems.

CHAPTER 3

PRESETTLEMENT FIRE REGIMES IN SOUTHEASTERN MARSHES, PEATLANDS AND SWAMPS

ABSTRACT

Presettlement fire regimes in wetland vegetation can be deduced or reconstructed by synthesizing knowledge of fire behavior on adjacent uplands, with information about soils, salinity, landscape factors, remnant vegetation, and historical records. Presettlement fire-return intervals in different parts of the southeastern wetland landscape ranged from nearly annual, up to 300 years, and vegetation was distributed accordingly along this fire frequency gradient. Prediction of vegetation stature and species composition in relation to fire can be made with some confidence in marshes, in the wettest swamps, and on uplands. In large peatlands, however, stochastic factors created a shifting mosaic before European settlement, in which any one of several competing communities could exist for a time on the same soil series, depending upon environmental conditions at time of burn. Before modern fire suppression, peatland vegetation was controlled primarily by master gradients of fire frequency and organic matter depth. There was a third, minor fertility gradient. Distribution of peatland vegetation types along these gradients is complex but is summarized here using a table of 32 cells defined by 8 fire frequency classes and 4 organic soil depths. While many marshes and swamps in the southeast differ little from their presettlement species composition, few peatlands, even those considered natural areas, have escaped major alteration in species dominants. A large percentage of modern pocosin can be shown to be successional from canebrake and other frequent-fire types in the absence of fire. At the other end of the spectrum, in Virginia and North Carolina, large areas now categorized as pocosin were dominated by white cedar (*Chamaecyparis thyoides*), an infrequent-fire type, as late as 1900. In most cases major shifts in vegetation type were selected for unwittingly in the process of fire suppression or logging. When designing a fire management regime in peatlands today the method selected will

determine whether the treatment will perpetuate what is there (the usual choice) or a return to one or more of the presettlement community types.

INTRODUCTION

The landscape that greeted the first settlers in the South was swept and sculpted by fires, with frequencies ranging from as often as every 1 to 3 years, to as infrequent as 300 years. On the Coastal Plain, only a few sites, probably less than 5% of the landscape, were completely protected from fire. Fire shaped vegetation and distributed species into fire-frequency zones and niches. In marshes, fire interacted with two more important gradients, salinity and water depth, to structure vegetation, but in the great peatlands fire shared importance with depth of organic matter as one of the two master influences.

After some years of work it became apparent to me that there could be little understanding of wetland floristics and vegetation structure without considering the pervasive role of fire. The use of tables (see Tables 3.1, 3.2 and 3.3), comparing different fire frequencies with soil factors was an attempt to be rigorous, in order not to miss what might be happening on a particular soil type at a particular fire frequency. A number of unusual communities, such as sweetgum/canebrake (Table 3.2, Cell 12), were thus detected that otherwise might have been overlooked, or passed off as anthropogenic artifacts. Considering that it required 64 cells in Tables 3.2 and 3.3 to relate peatland vegetation to natural fire regimes, it is apparent that complexity of natural wetland vegetation is at least an order of magnitude greater than previously known.

This paper is an interpretation of natural fire regimes in southeastern wetlands, based on some 482 study plots (mostly in North Carolina and Virginia), along with personal observations in all of the nine coastal states from Virginia to Texas. My purpose is to reconstruct presettlement vegetation and presettlement fire regimes in these wetlands, as a guide to managing them and to restoring samples of the most fire-dependent types.

METHODS

The field work and observations presented here are summarized from Frost 1989, Frost et al. 1990, LeGrand et al. 1992, research for a dissertation (Frost 1995a), and studies on presettlement vegetation (Frost 1995b, Frost et al 1986, Ware et al. 1993). Types of data collected include tenth hectare vegetation plots and non-plot vegetation data, soil samples, peat depth measurements, salinity, and information on stand disturbance history. Historical vegetation records, where available, were used in interpreting results. Vegetation was examined and recent fire history determined in 482 plots on 76 different wetland soil series, all either histosols or mineral soils with aquic modifiers. Vascular plant nomenclature follows Kartesz (1994), updated from Radford et al. (1968), which was used throughout the study.

Vegetation and Soil Data—0.1 hectare Plots

118 0.1-ha plots were sampled by laying out a 20 x 50 m plot with 25 herb subplots placed down the centerline. All woody stems greater than 1 m tall were tabulated by species in 2.54 cm (1 in) diameter size classes. This data was used to calculate basal area for all woody species in each plot. In addition several trees, usually pines, were cored in each wooded plot to determine stand age. Within each of the 25 herb subplots, percent cover was estimated for all species below 1 m in height. Soil samples were collected and analyzed for soil nutrients, pH, base saturation, cation exchange capacity (CEC) and weight/volume ratio. Soil texture was determined by the hydrometer method, and soil organic matter content was determined by percent of weight lost on ignition. Soil data, herb and woody cover were used in analyses with TWINSPAN and CANOCO computer programs (see Frost 1995a).

Organic Matter Depth

For all organic soils or soils with organic epipedons, depth to mineral soil was measured for correlation with organic matter depth-dependent vegetation types like canebrake. Since organic matter depth appeared to strongly influence fire behavior and wetland vegetation strongly, peat depth was measured in all marshes, peatlands and swamps. For the deeper soils, 1.1 meter fiberglass rods were used as peat depth probes. Additional rods were screwed on as they were

pushed down into the peat. Fiberglass rods were found to have the fortuitous property of transmitting vibrations so that the grittiness of a sand bottom can be clearly felt while rotating the rod under slight downward pressure, and clay is felt as perfectly smooth rotation, so the underlying substrate several meters down can be readily differentiated into sand, clay, or loam.

Fire Frequency and Fire History Data

Time since last fire, and sometimes 1 or 2 earlier fires, was determined for all plots. This was done in a number of ways. In marshes, fires were dated by using annual bud scale scars on shrubs to age stems in the marsh or at the upland fringe. In peatlands, even-aged size classes of shrub or saplings could be used to date fires occurring within the previous 20 years. Older fires could sometimes be dated by coring fire scars on surviving trees.

Other Stand History

Older trees often predate 20th century fire suppression. Fire scars and tree cores are often revealing of conditions under the earlier fire regime. If the oldest trees are of different species than the younger, a major shift in fire regime may be indicated. Tree stem size-class distribution data were used in estimating previous vegetation on the site, and to help interpret the nature of succession since last fire, logging or other disturbance. In many stands the number and size of old, cut pine stumps were tabulated as evidence of the amount of pine in the previous forest or in the present stand before selective removal of pine. On selected plots the number of wind-thrown trees or trees with broken major limbs was tabulated as evidence of storm disturbance regime. Notes were taken on site on disturbance history, and a final assessment of data was made in the field as to composition of the previous stand. This was used as a first approximation of likely presettlement vegetation type for each plot.

Non-plot Data

In another, less intensive type of sampling, all species were recorded from each soil series in a study area. Species were listed by the layer in which they occurred and dominants were recorded in 6 layers: canopy, subcanopy, shrub layer, herb layer, vines and epiphytes. Cover was

estimated in 5 cover classes. Approximately 364 lists of species were collected and used, along with the 118 1/10 ha plots above, for TWINSPAN classification. This method was not area specific, but length of lists and area covered were very similar to 1/10 ha data. Results of vegetation analysis are reported elsewhere (Frost 1995a).

Historical Data

Around 400 site-specific historical references to original vegetation--mostly trees, but also some shrubs and herbs--were obtained for the region. These and references to community types, such as "canebrake", "pocosin", or "juniper swamp" were used for plotting fire frequency indicator species (Frost 1995a) and communities to assist in mapping presettlement fire frequency. About 150 black and white historical photographs, obtained from various archives and historical publications, were used for interpreting historical fire regimes.

Presettlement Fire Frequency and Vegetation Methods

Specific methods for approximating presettlement fire frequency include use of landscape and environmental factors, historical evidence, and remnant natural vegetation. These methods are covered further in Frost (1995a).

RESULTS AND DISCUSSION

Assumptions About the Natural Fire Environment

On the lower coastal plain terraces, where lightning ignitions were frequent enough to preempt fuel that might otherwise have been ignited by Indians, nearly all presettlement fire should have been growing season burns (Komarek 1964, 1968). The role of Indians in burning the southeastern landscape was probably insignificant on the Coastal Plain and the less-dissected parts of the Piedmont, but may have come into play in more topographically diverse parts of the upper Coastal Plain, Piedmont, and mountain environments, where fire compartments[1] were much smaller and a larger proportion of the landscape would

[1] A unit of the landscape with no natural firebreaks, such that a lightning ignition in one part would be likely to burn the whole unit unless there were a change in weather or fuel conditions (Frost 1995a).

escape lightning fires each year. This differs from Indian effects on the Pacific Coastal Plain where the thunderstorm frequency is much lower than in the Southeast and where frequent Indian burning has been documented from early Spanish records (Timbrook et al. 1982).

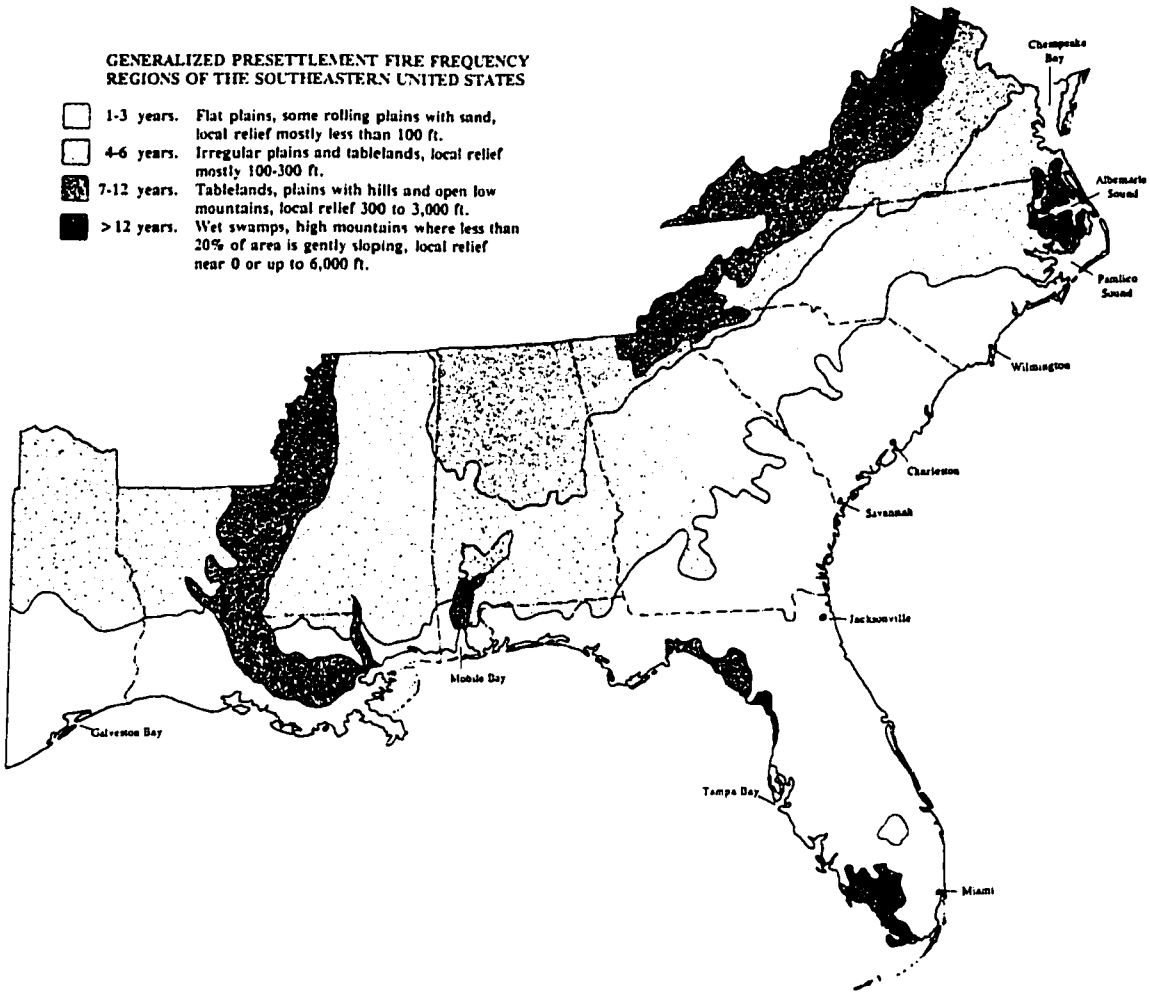
It is also assumed that fire frequency is related to fire compartment size, since a single ignition in a 1,000 km^2 compartment without a natural firebreak could have burned the whole area, while a 1,000 km^2 area with 20 separate fire compartments might require 20 separate ignitions to burn the same amount of land.

Presettlement Fire Frequency Regions

Use of the term "presettlement" refers to vegetation conditions and natural fire regime as they existed at time of first European contact. This varies, since first exposure of the land to European influences came at different times in various parts of the South. Presettlement in east Florida, for instance, means around 1565, in southeastern Virginia it means 1607, in the southern Appalachians it means around 1800, and in central Alabama it was as late as 1821. Figure 3.1 is a first-approximation map of fire frequency regions of the South under the natural presettlement lightning fire regime, along with whatever influence there may have been from the use of fire by Indians. The source of ignition, whether lightning or Indians, is irrelevant, since the fire frequency regions are based on historical records of fire-influenced vegetation that actually existed, whatever the cause. See the classic work of Komarek (1964, 1968) for background on the role of lightning.

Figure 3.1 is a regional fire frequency map, based on a classification of land-surface forms (Hammond 1964, Anon. 1970). Extensive simplification and adjustments for soil and climatic factors were made to the original map. The original was essentially a slope map, coded for the following: 1) percent of the landscape that is flat or only gently sloping, 2) amount of local relief from the stream bottoms to ridge tops, and 3) whether the flat or gently-sloping parts are located on uplands or in bottomlands.

Figure 3.1. Presettlement fire regimes of the southeastern United States. Derived from regional fire compartment size, topography, historical records, climate, vegetation remnants and soils. Frequencies are for the most fire-exposed parts of the landscape. Each region contains variously fire-protected areas with lower incidences of fire.


GENERALIZED PRESETTLEMENT FIRE FREQUENCY
REGIONS OF THE SOUTHEASTERN UNITED STATES
1-3 years. Flat plains, some rolling plains with sand, local relief mostly less than 100 ft.
4-6 years. Irregular plains and tablelands, local relief mostly 100-300 ft.
7-12 years. Tablelands, plains with hills and open low mountains, local relief 300 to 3,000 ft.
> 12 years. Wet swamps, high mountains where less than 20% of area is gently sloping, local relief near 0 or up to 6,000 ft.
Chesapeake Bay
Albemarle Sound
Pamlico Sound
Wilmington
Charleston
Savannah
Jacksonville
Mobile Bay
Galveston Bay
Tampa Bay
Miami

The first characteristic above, the proportion of the landscape that is flat, can be partially correlated with fire compartment size, since in the parts of the landscape that have greater than 80% flat or gently sloping surfaces, the areas without natural firebreaks are quite large. Some, especially in Florida or the Pamlico Terrace of North Carolina, contain more than 2,000 km^2 without a natural firebreak. The third characteristic is also important in interpreting fire behavior because if the flat parts of the landscape are in fluvial bottomlands, the role of fire should be much less important than if they were on upland flats or tablelands.

The basic land-surface form map of Hammond was modified in several ways. Most of the landscape in which more than 80% is flat or only gently sloping was designated as having a fire-return interval of 1 to 3 years. This interpretation is supported by remnant vegetation and numerous historical records (Frost, see publications above). In Virginia, however, where typical southeastern fire vegetation reaches its northern limits, the vegetation described in historical records indicates that fire frequency did not reach the 1 to 3 year class. This may be because of a shorter fire season, and/or lack of fire-facilitating species like wiregrass and longleaf pine. Boundaries between classes were adjusted accordingly. Areas with 50 to 80% of the upland landscape flat or gently sloping were assigned to the 4 to 6 year class, but vegetation in large areas of sands adjacent to more frequent-fire areas in Georgia and the Carolinas, was reassigned to the more frequent fire class. In south Texas these 50 to 80% areas were also upgraded because of the drier climate and the continuity and natural flammability of prairie fuels.

Assignments of fire frequency classes to different parts of the landscape in Figure 3.1 are based on a method in Frost (1995a) which uses field observations, interpretation of historical photographs, and historical occurrences of fire-indicator species and communities. Canebrake, for instance, is an indicator of a general fire frequency of every 4-6 yrs (Table 3.2), and there are numerous historical references to canebrake in the 4-6 yr region in Figure 3.1. The fire frequency classes defined are intended to represent the average regional fire-return interval for the most fire-exposed parts of the landscape, especially flats, uplands, and south slopes. Conversely, varying proportions of the land within each category occur in naturally fire-protected sites. On the Coastal Plain these include islands, peninsulas, wet swamps and some fluvial bottomlands (Harper 1911, 1913, 1914). In the other provinces, fire-safe sites or partially fire-protected sites include north

slopes, large fluvial bottomlands, mountain coves and steep-sided stream valleys. In the original landscape, fire-protected sites may have only occupied about 1-5% of the Coastal Plain, up to 15% of the Piedmont, and 25% of the Mountains.

The 1 to 3 year fire frequency class includes mostly flat plains having 80% to 100% of the landscape flat or gently sloping. Some areas of rolling plains are included where 50-80% of the land is gently sloping and more than 50% of the land surface is covered with sand. Local relief is mostly less than 30 m (100 ft) but some areas with up to 90 m (300 ft) are included, particularly where soils are sandy. Succession on poor, sandy soils is slow, facilitating persistence of grass fuels, and sand is conducive to spread of flammable rhizomatous shrubs which increase in density at lower fire frequencies (Frost 1995a).

The 4 to 6 year fire frequency range covers irregular plains and tablelands which have 50-80% of the uplands flat or gently sloping. Local relief is mostly 30-90 m (100-300 ft) (note that elevation can be much higher than local relief). This includes some upper coastal plain terraces and most of the Atlantic and Gulf Piedmont.

The 7 to 12 year fire frequency class includes plains with hills, tablelands of the southern Appalachians, open high hills and open low mountains. Relief is mostly 90 to 150 m (300 to 500 ft), but may range up to 300 m (1,000 ft) in the Appalachian tablelands of northern Alabama, and up to 915 m (3,000 ft) in the flammable pitch pine communities of the southern Blue Ridge.

Fire-return intervals longer than 12 years occurred in a number of situations. The kinds of vegetation present suggest that high elevation sites in the Appalachians had a lower fire frequency than in the lower mountains. There are also some large coastal swamps that were too wet to burn or had vegetation such as white cedar that seemed to resist all but crown fires, so that the average fire return interval was greater than 12 years (Frost 1995a).

I assume here that the larger the natural fire compartment, the higher the fire frequency, because in large fire compartments there might be several lightning ignitions per year and just one ignition could burn the whole compartment if conditions were right. Moving up from the coastal flats inland, onto older, more dissected coastal plain terraces, the fire compartments decrease in

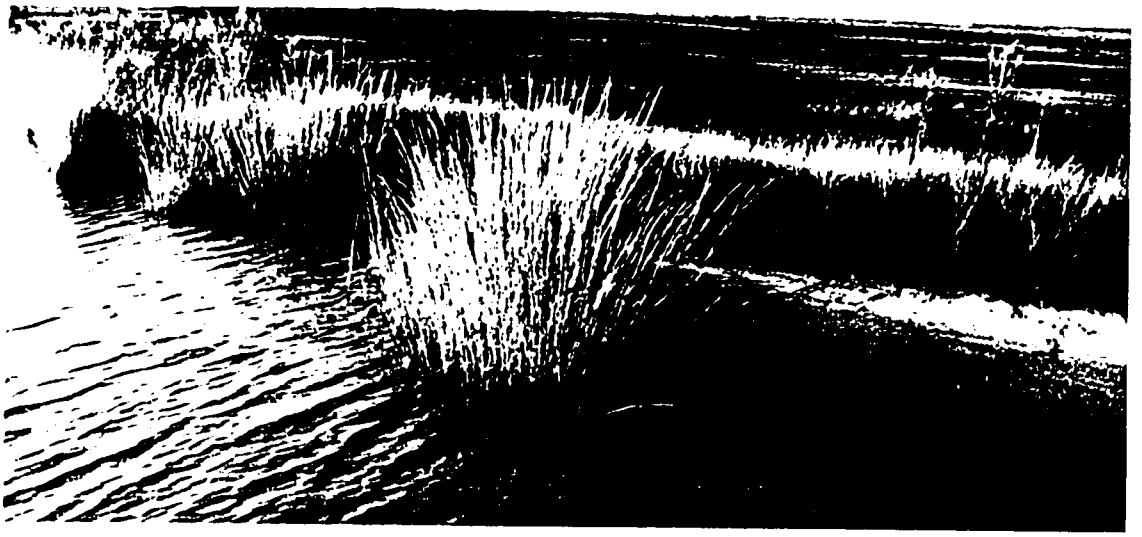
size so that it would take more lightning ignitions to burn the same amount of land. Fire frequency should then decrease. The corresponding decrease in compartment size and fire frequency should be expected to continue on the Piedmont. However, the Piedmont is a dissected plain, and has regions where there are extensive upland flats and gently rolling slopes without significant firebreaks. Topography increases dramatically in the upper Piedmont foothills and lower mountains of the Southern Appalachians, where lightning ignition records indicate that the natural fire frequency was about 7 to 12 years (Frantz and Sutter 1987; Frost 1990; Barden 1977; Barden and Woods 1973). Beyond the Blue Ridge, in the higher mountains extending from Georgia through Virginia, nearly all the land is in slope, and average fire frequency may have been lower. Lightning ignitions in the mountains, however, are still common (Frantz and Sutter 1987; Frost 1990). In summer, 1993, there were three lightning ignitions around 915 m (3000 ft) elevation within a kilometer of one of my study sites on Shortoff Mountain, Burke County, NC, and in my experience, nearly every south slope in the Southern Appalachians shows signs of past fire.

Presettlement Fire Regimes in Marshes

Evidence of past fires can be discovered in nearly all southeastern marshes. The most readily accessible kinds of evidence are even-aged shrub classes, which can be used to date the last fire, and fire char on old woody snags within and on the borders of marshes. Marsh vegetation creates fine-textured fuel and carries fire very efficiently (Figure 3.2). Before European settlement, most marsh fires were probably ignited by fire moving through vegetation on adjacent uplands. Some fires must have originated with lightning strikes in marsh, and there is at least one reported case of spontaneous ignition in Gulf Coast marshes in very hot weather (Viosca 1931).

Table 3.1 shows general successional trends of marsh vegetation under four levels of salinity. Levels are given in parts per thousand of chloride and other salts, determined by refractometer. Salinity ranges for the four levels are as follows: fresh water, 0 to 0.5 PPT; oligohaline, 0.5 to 5 PPT; brackish, 5 to 30 PPT; and saline, over 30 PPT. Two strong master gradients seem to explain most of the variation in plant species distribution in southeastern coastal

Figure 3.2. Brackish marsh dominated by Juncus-Distichlis, salinity 1.1%, photo taken the day after a burn. Marshes are fine-texture fuels; will burn upwind, downwind, and when standing water is on the surface. All above-ground biomass was consumed except for the lower 10 cm of Juncus stems and a narrow strip of Juncus roemerianus and Spartina alterniflora along the shoreline, with Spartina patens on the low sand berm. Scattered tall stems are seaside goldenrod (Solidago sempervirens).



marshes. The salinity gradient is most striking. In some systems like that of Currituck Sound in North Carolina and Virginia, changes in marsh vegetation from freshwater to salt may be followed downstream for some 80 km (50 mi) along the long-attenuated salinity gradient before reaching an outlet to the ocean. The second obvious gradient is the complex master gradient of water depth/frequency of flooding/duration of flooding. The fire frequency gradient is much less important than the preceding two in salt and brackish marshes than in interior peatlands, but is important in regulating succession in fresh and oligohaline marshes. Table 3.1 relates salinity on the vertical axis to fire frequency on the horizontal axis. The water depth gradient is only partly accounted for within cells. For example, in cell 21 the tall marsh species *Spartina cynosuroides, Cladium jamaicense* and *Phragmites australis* persist in wetter sites while drier, interior sites undergo succession to swamp hardwoods, pine, red cedar, cypress, and wax myrtle. Fire and successional effects at intervals greater than 100 years are somewhat hypothetical since few marshes other than those on islands have escaped fire that long, and even islands may have been burned, first by Indians and later by Europeans. The following classification makes no attempt to take into account regional effects of sea level rise and land subsidence.

True Salt Marsh Vegetation
(Table 3.1, Row 1)

While fire has been shown to have a number of effects on nutrient release and productivity increase in marsh (A.A. de la Cruz and C.T. Hackney 1980; C.T. Hackney 1982), it has little impact on floristics in true salt marshes. Plant species diversity is low in true salt marshes because few species are able to tolerate the combination of high salinity and standing water (Sculthorpe 1967). Of 94 marsh communities examined for this study, there were 305 vascular plant species, but only 16 of these occurred in true salt marshes (salinity > 3%). In a similar study in Mississippi, of some 300 marsh species, only 12 were mentioned in saline habitats (Eleuterius 1973). Common dominants in the present study were *Spartina alterniflora* (saltmarsh cordgrass)in wetter sites and *Juncus roemerianus* (black needle-rush) in slightly drier sites across all fire frequencies. In a 0.1-ha plot for this study on a site that was flooded twice daily by the tides, only one vascular plant, *Spartina alterniflora*, could be found.

Table 3.1. Common dominant species under the spectrum of presettlement fire regimes in marshes. Of the two master gradients readily apparent in marshes, the first, the salinity gradient, is represented on the Y-axis. The second major factor, the water depth/frequency of flooding/ duration of flooding complex gradient, is partially accounted for within cells of the table. For example, in Cell 1 *Spartina alterniflora* is found on wetter sites and *Juncus/Distichlis* in drier sites. Under presettlement conditions the fire frequency gradient was third in importance in marshes.

MARSH VEGETATION OF THE SOUTHEASTERN U.S., DISTRIBUTED ALONG MASTER GRADIENTS OF FIRE FREQUENCY AND DEPTH OF ORGANIC SOIL

FIRE FREQUENCY

SALINITY ⇑	1-3 YEARS	4-6 YRS	7-12 YRS	13-25 YRS	26-50 YRS	51-100 YRS	100-300 YRS	NEVER BURNED
SALINE 3-4% (30-40 PPT) ROW 1	SPAL or JURO-DISP CELL 1	SPAL or JURO-DISP CELL 2	SPAL or JURO-DISP CELL 3	SPAL or JURO CELL 4	SPAL or JURO CELL 5	SPAL or JURO CELL 6	SPAL or JURO CELL 7	SPAL or JURO CELL 8
BRACKISH 5-30 PPT ROW 2	JURO-DISP-SPPA with diverse salt marsh herbs CELL 9	JURO-DISP, SPPA, mixed salt marsh herbs CELL 10	JURO-DISP, or CLJA, PHAU, MYCE, IVFR, BAHA CELL 11	JURO or PHAU, CLJA, MYCE, IVFR, BAHA CELL 12	JURO or PHAU, CLJA, MYCE, IVFR, BAHA, JUVI CELL 13	JURO or PHAU, CLJA, MYCE, IVFR, BAHA, JUVI CELL 14	JURO or JUVI, CLJA, PHAU, MYCE, IVFR, BAHA CELL 15	JURO or JUVI, PHAU, CLJA, MYCE, IVFR, BAHA (hypothetical) CELL 16
OLIGOHALINE 0.3-5 PPT ROW 3	Diverse mixed salt marsh, fresh marsh, and swamp species CELL 17	Diverse spp. with patch and zone dominants conspicuous by end of cycle CELL 18	JURO-mixed species with dominants in patches and zones, MYCE CELL 19	JURO, SCAM, TYAN, TYDO TYLA, SPCY PHAU, CLJA in dominant zones, MYCE, PEPA, tree saplings. CELL 20	SPCY, CLJA PHAU or ACRU, PITA, PIEL, PEPA, NYBI, TADI/MYCE CELL 21	SPCY, CLJA, PHAU, or TADI, PITA PIEL, NYBI ACRU, PEPA /MYCE CELL 22	TADI, NYBI ACRU (NYBI is more salt-tolerant than TADI)/swamp forest shrubs and herbs CELL 23	TADI, NYBI, ACRU/swamp forest shrubs and herbs CELL 24
FRESH 0-0.3 PPT ROW 4	Diverse fresh marsh & swamp graminoids & forbs CELL 25	Diverse fresh marsh & swamp graminoids & forbs CELL 26	Diverse species, MYCE, ACRU, CLJA, ferns CELL 27	ACRU, NYBI, TADI, MYCE CLJA, swamp herbs CELL 28	ACRU, NYBI, TADI/ swamp shrubs & herbs CELL 29	TADI, NYBI, ACRU forest, CHTH forest patch mosaic CELL 30	TADI, NYBI forest, CHTH forest patch mosaic CELL 31	TADI/NYAQ, NYBI, ACRU, swamp forest CELL 32

SPECIES ACRONYMS: ACRU: Acer rubrum (Red Maple), BAHA: Baccharis halimifolia (Silverling), CHTH: Chamaecyparis thyoides (Atlantic White Cedar), CLJA: Cladium jamaicense (Sawgrass), DISP: Distichlis spicata (Saltgrass), FRCA: Fraxinus caroliniana (Water Ash), IVFR: Iva frutescens (Marsh Elder), JUVI: Juniperus virginiana (Red Maple), JURO: Juncus roemerianus (Black Needle-rush), MYCE Myrica cerifera (Wax Myrtle), NYAQ: Nyssa aquatica (Tupelo or Water Gum), NYBI: Nyssa biflora (Swamp Black Gum), PEPA: Persea palustris (Red Bay), PHAU: Phragmites australis (communis)(Common Reed), PIEL: Pinus elliottii (Slash Pine), PITA: Pinus taeda (Loblolly Pine), SPAL: Spartina alterniflora (Salt Marsh Cordgrass), SPCY: Spartina cynosuroides (Tall Cordgrass), SPPA: Spartina patens (Saltmeadow Cordgrass), TADI: Taxodium distichum (Baldcypress). TYAN:

Brackish Marsh Vegetation
(Table 3.1, Row 2)

Species diversity increases as salinity decreases, water depth decreases and fire frequency increases. Fire removes the heavy thatch that builds up in 2 to 5 years, opening up habitat for colonization, but in brackish marshes diversity is limited to the relatively small number of species able to tolerate the brackish range. Still, there are enough potential species to give a three-fold increase in species richness when frequent fire maintains habitat open for colonization (Figure 3.3). In addition to the common salt marsh dominants above, other frequent species include the shrubs *Baccharis halimifolia* and *Iva frutescens*; and the herbs *Borrichia frutescens, Spartina patens, Aster tenuifolius, Aster subulatus*, and *Limonium carolinianum*. Fire suppression at higher salinities within the brackish range commonly leads to heavy dominance by juncus (Figure 3.4), while shrubs may invade the less saline areas. Red cedar (*Juniperus virginiana*, sometimes called var. *silicicola*) may become established at lower fire frequencies (Figure 3.5), especially on lenses of sandy soils in marshes and around the periphery (Table 3.1, cells 12-16).

Oligohaline Marsh Vegetation
(Table 3.1, Row 3)

Frequently-burned oligohaline marshes maintain high species richness by drawing on four pools of species. First are the true salt marsh species, which may still turn up as scattered individuals or patches in marshes that have little measurable salinity. Second are fresh marsh species, some of which have some tolerance for salt. Third are swamp herbs like *Ptilimnium capillaceum, Peltandra virginica* and several polygonums, which also find suitable microhabitats in oligohaline marshes. Fourth are species limited to or reaching their best development in the oligohaline range like *Sagittaria lancifolia, Triglochin striata* and *Cladium mariscoides*. Unusual dominants like *Eryngium aquaticum* or *Eleocharis rostellata* may sometimes be found under the two most frequent fire classes. Zonation of marsh dominants is least evident in the 1 to 3 year fire frequency class, where regular removal of thatch allows constant establishment of shade-intolerant

Figure 3.3. Frequently burned brackish marsh with 25 species per 1/10 ha--relatively high diversity for brackish marsh (Cedar Island National Wildlife Refuge, North Carolina).

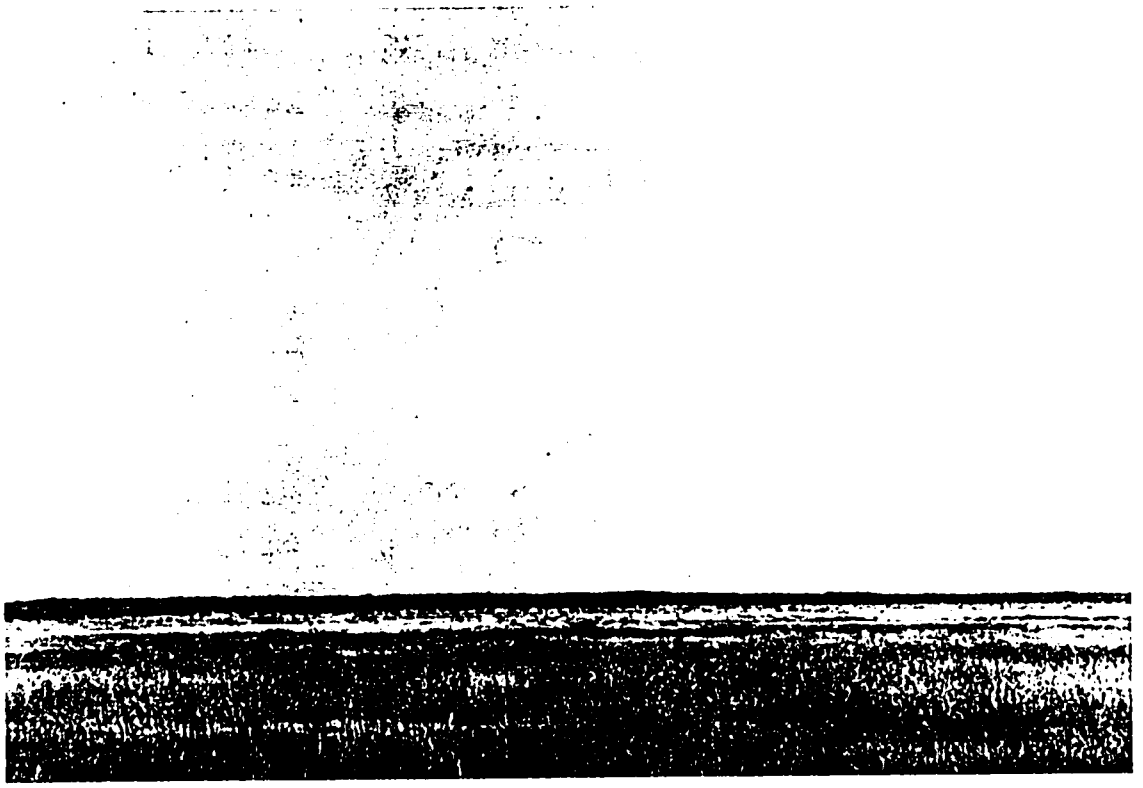


Figure 3.4. Fire suppressed marsh, on opposite side of road from that in Figure 3.3. Heavily dominated by black needle-rush with only 8 species per 1/10 ha and 98.8% cover of Juncus and Distichlis. Juncus roemerianus (black needle-rush) builds up a deep thatch of dead stems, penetrable only by its own spears, perhaps the reason for the needle-tips.

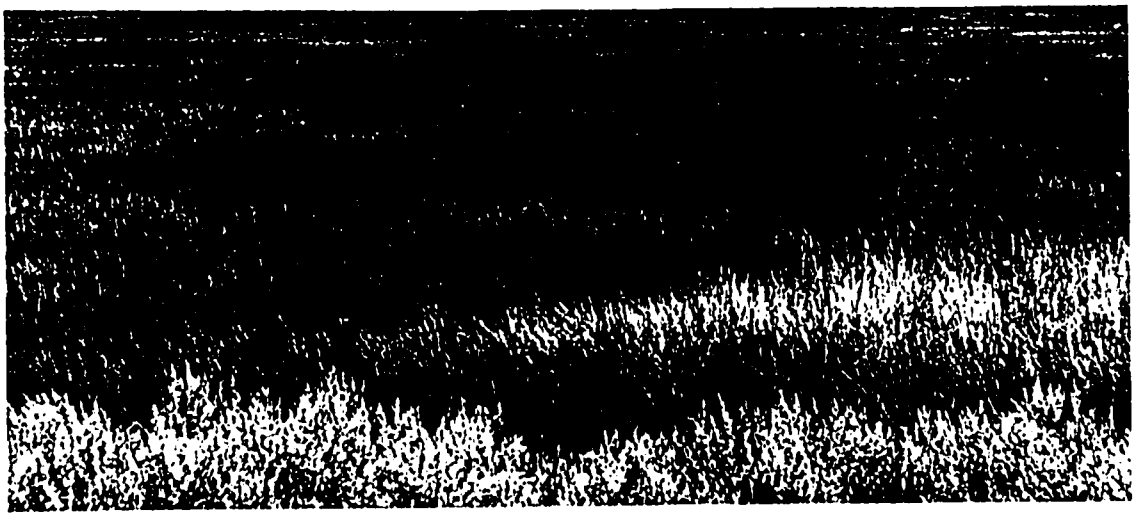


Figure 3.5. Woody succession in fire-suppressed brackish marsh, Salinity 5-10 PPT. Red cedar, loblolly pine, red maple and shrubs like wax myrtle and Baccharis halimifolia are replacing tall sawgrass and Juncus, which in turn probably replaced more diverse marsh graminoids and forbs under the original fire regime; about every 4-6 years on adjacent uplands. In more exposed coastal locations such succession may be prevented or retarded by storm-driven salt water intrusion (Conner and Askew 1993).

herbs, maintaining diversity. Reduction of fire frequency to intervals longer than four years leads to increasing patch dominance (Frost 1995a). Successive reduction in fire frequency, as has happened throughout the South, leads to dominance of oligohaline marshes by a few tall marsh species and *Juncus roemerianus*. The sites with lower salinity or shallower water undergo succession to red maple, wax myrtle, pine and cypress. Such succession is slower in oligohaline sites, however, than in freshwater sites, and is subject to being reset by fire or saltwater incursion during major storms (Frost 1995a).

True Fresh Water Marsh Vegetation
(Table 3.1, Row 4)

True fresh marshes in the South are largely restricted to Florida, but may sometimes be found elsewhere along freshwater rivers at sea level, where sediment deposition creates new substrate that is colonized by marsh vegetation. These marshes may in turn succeed to red maple and swamp forest in the absence of fire.

Presettlement Fire Regimes and Recent Succession in Peatlands

Tables 3.2 and 3.3 each summarize the variation in southeastern peatlands that can be attributed to the two master gradients of fire frequency and organic matter depth. Each row of cells may also be taken in part as a successional series. For instance the community found in cell 18, on soil that is not too infertile, with organic matter one meter deep, and with a fire frequency of 4 to 6 years, most commonly may be expected to be canebrake. Under presettlement conditions this may have been essentially a stable community, except for drift in fire frequency resulting from fluctuations in climatic conditions over decades or centuries. Any reduction of fire frequency would be expected to result in a shift to the next community to the right. In the case of canebrake, reduction of fires from every 4 to 6 years to 7 to 12 years would allow the establishment of pocosin shrubs which would overtop and suppress the cane before the next fire. Further reduction to 13 to 25 years would lead to high pocosin with a substantial canopy of low trees by the end of each cycle. Total fire exclusion, initiated at any cell in the table, should initiate simple succession leading eventually to the cell farthest to the right.

Canebrake, as used here, refers to any stand with a dominant layer of *Arundinaria gigantea* having at least 50% cover. The term pocosin, as used by the Algonquian Indians, referred to any natural wetland opening in the forested landscape. In ecological terms it has come to be limited to sclerophyllous evergreen shrub bog. Canebrake in large peatlands may be treeless but both canebrake and pocosin commonly have pond pine (*Pinus serotina*), in +any density from scattered single trees to closed-canopy patches. See Weakley and Schafale (1991) for a classification of pocosins in the Carolinas.

Most of this landscape has undergone a series of fire frequency shifts in the twentieth century, one or more steps to the right in Tables 3.1, 3.2 and 3.3. This shift to less fire-frequent vegetation complicates the interpretation of southeastern wetland vegetation. Changes resulting from reduction in fire frequency, however, must be taken into account in any attempt to manage natural vegetation. Using these tables, historical records, soil maps and remnant vegetation, it is possible to get an approximation of where modern sites fit in the multidimensional fire landscape.

Tables 3.2 and 3.3 may be thought of as overlays, each having depth of organic matter on the vertical (Y) axis and fire frequency on the horizontal (X) axis. With Table 3.2, the slightly more fertile sites, on "top", and Table 3.3, the most oligotrophic sites, on "bottom", the Z axis then represents the fertility gradient. Each of the three axes are master gradients named for what appears to be the most important component gradient. The fire frequency gradient, for instance, subsumes season of burn, a secondary gradient. Actual frequency of fire is easiest to study in the field, since the date of last fire can almost always be determined on site, and frequency alone seems adequate to explain most of the variation in the tables that is attributed to fire. It should be noted, however, that stand-destroying fires in certain types of peatland vegetation probably occurred only during the spring/summer lightning season, perhaps at times when foliar moisture was low (see white cedar mosaics in cells 22, 23, 30 and 31).

The organic matter depth master gradient subsumes hydroperiod, which seems less important in peatlands than in marshes or swamps, since saturation with standing water for much of the year is a prerequisite for peat accumulation. Most southern peatlands would be lakes if the peat were removed and the ditches or underlying drainages were blocked. Peat exposed by

drainage oxidizes and disappears over years or decades (Ruffin 1861, Frost 1987). The assumption about subsuming hydroperiod under the organic matter depth gradient, however, holds only for peatlands, not for swamps. For a discussion of hydrologic relations of fluvial swamps see Wharton et al. (1982), and for an illustration of the relationship of fire frequency and hydroperiod in Florida swamps see Ewel (1990).

While recent fire history and depth of organic matter were determined for all sites studied, the fertility gradient is less readily apparent and far less accessible for study, as has been observed by others (Christensen 1977, Walbridge 1986). The "fertility" master gradient used here subsumes several putative gradients. Soils with higher pH, slightly greater nutrient availability, and shallower organics, are classified here as more fertile. Also, organic soils overlying sandy aquifers seem to be more fertile, perhaps because of subsurface transport of nutrients from uplands. While soil samples were collected and analyzed for texture, pH, CEC, and several nutrients at many sites, the assessment of fertility was largely based on landscape position, vegetation stature, and apparent access to or isolation from nutrient sources. For example, many large peatlands show radial drainage, with rainfall the only source of nutrient input. Vegetation on such sites often takes on a bowl-like structure, with dwarfed shrubby vegetation in the center (see Cells 58 to 60 in Appendix) and increasingly taller vegetation radiating outward in all directions to the contact with mineral soil. In the case of one large peat dome, potassium has been shown to be the limiting nutrient in the center of the vegetation bowl (Walbridge 1986).

Fertility was also assessed, in part, on the behavior of individual species in different habitat and landscape situations. Cane (*Arundinaria gigantea*), for instance, is absent from the most oligotrophic peat domes, but it may form extensive, pure stands on shallow histosols where pH of the underlying substrate is moderate, and in small stream bottomlands. Also subsumed under fertility, are any considerations about the chemical and physical composition of peat or muck, the plant species from which peat was originally formed, the amount of mineral matter incorporated, and the texture of underlying substrate.

In addition to providing a description of presettlement vegetation, Tables 3.2 and 3.3 also may be used to map natural vegetation, and determine original natural vegetation and fire regime for restoration of a specific site. If, for example, you have a historical record of canebrake but it

no longer occurs on the site, find canebrake in cells 10, 11, 18 and 19 to get the most likely fire regimes of 4 to 6 and 7 to 12 years for this community type. Then, since these communities occur most commonly on soils with organic matter 10 cm to 1 m in depth, use current soil maps to locate soils in the site with the appropriate range of characteristics. The portions of these soils that are not naturally fire-protected by streams, steep slopes or swamps are the most likely sites to restore canebrake on the management unit.

Where there are no historical records, the table may be used with a soil map and topographic map to determine the most likely type or range of wetland vegetation under the presettlement fire regime. Use Figure 3.1 to find the regional fire frequency. Then look at topography and landscape factors. If there are no steep slopes, lakes or streams large enough to act as natural firebreaks, accept the regional frequency. Then for each soil type find the appropriate vegetation cell or cells. If substantial firebreaks are present, adjust vegetation one or more cells to the right.

Presettlement Natural Vegetation Types on Moderately Fertile Sites

Table 3.2 (Cells 1-32) illustrates these vegetation types (see Appendix 1 for details on vegetation of each cell). Species lists and plot data are available elsewhere for many cells (Frost 1995a).

Despite the designation "fertile" as used here, and with exception of sites like calcareous marl prairies in Florida (Figure 3.6) or wetlands receiving runoff from uplands with fine-textured soils, vegetation in Table 3.2 is found on soils that are typically acid and relatively infertile. The difference between this and Table 3.3 is that soils in Table 3.2 are less disastrously acid and infertile, in agricultural terms, than those in Table 3.3, which include the most nutrient-limited soils in the southeastern landscape. The gradient of fertility, while less striking than fire frequency or organic matter depth, is necessary to explain adequately the diversity of southeastern peatland vegetation.

Table 3.2. Peatland vegetation and fire on moderately fertile sites. Cells show common dominants for each combination of fire frequency and organic matter depth. Local dominants vary with the geographic range of each species and, for Row 1, with difference in soil texture. See text and Appendix 1 for further cell descriptions.

PRESETTLEMENT DISTRIBUTION OF PEATLAND VEGETATION OF THE SOUTHEASTERN U.S. ALONG MASTER GRADIENTS OF FIRE FREQUENCY AND DEPTH OF ORGANIC SOIL

CELLS 1-32: MODERATELY FERTILE SITES

FIRE FREQUENCY

⇐ ORGANIC MATTER DEPTH	1-3 YEARS	4-6 YRS	7-12 YRS	13-25 YRS	26-50 YRS	51-100 YRS	100-300 YRS	NEVER BURNED
Seasonally wet mineral soils ROW 1	Species-rich wet prairie with graminoids and grass-leaved forbs CELL 1	Species-rich wet prairie, with dwarf shrubs CELL 2	ANGL, ARGI, CLJA, ILGL, CYRA, CLMO, tree saplings CELL 3	Small ACRU, NYBI, LIST, PISE, PITA, PIEL, TAAS CELL 4	Dense ACRU, NYBI, TAAS, LIST, PISE, PITA, PIEL/ ARGI, Shrubs CELL 5	PITA, PIEL, TAAS, QUMI, PISE, ACRU, LIST/ sparse ARGI, ferns CELL 6	TADI, FRPE, LIST, ACRU, NYBI, QUMI other bottomland oaks/mesophytic herbs CELL 7	TADI, NYBI, FRPE, LIST, ACRU, bottom-land oaks CELL 8
Soils with thin organic layers, 10-30 cm thick ROW 2	Wet prairie and bog graminoids and forbs, patches of ARGI, ANGL CELL 9	Dense canebrake CELL 10	Alternating canebrake and pocosin CELL 11	PISE, ACRU, PITA, PIEL, TAAS, LIST/ ARGI CELL 12	PISE, PITA, PIEL, TAAS, LIST, NYBI/ PEPA, MAVI CELL 13	PISE forest, PITA, PIEL, TAAS, bottomland hardwoods, bay forest CELL 14	TADI, NYBI, FRPE, LIST, PITA/ ACRU, FRCA/ Carex, swamp herbs CELL 15	TADI, NYAQ, NYBI/ ACRU, FRCA, ULAM/ swamp shrubs, herbs CELL 16
Shallow histosols, 30-100 cm thick ROW 3	Open bog with dwarf shrubs, graminoids, pitcher plants, short cane, mosses CELL 17	Dense canebrake CELL 18	Alternating canebrake and pocosin CELL 19	PISE/ canebrake, alternating with PISE-ACRU tall pocosin CELL 20	Patch mosaic: PISE forest, ACRU forest, CHTH forest, bay forest with PEPA, MAVI CELL 21	Patch mosaic: CHTH forest, TADI/ACRU forest, PISE forest, NYBI forest, bay for. CELL 22	Extensive CHTH forest and patch mosaic as in Cell 22 CELL 23	TADI in wet swamps, cycling ACRU forest in peatlands (hypothetical) CELL 24
Deep histosols, peat deeper than 1 m ROW 4	Open bog with low shrubs, pitcher plants, grasses and sedges CELL 25	Canebrake or Low pocosin with ANGL, and bog herbs CELL 26	Alternating canebrake and pocosin, or medium to tall pocosin CELL 27	Tall pocosin with PISE, GOLA, ACRU; PISE forest, bay forest, CHTH patch mosaic CELL 28	Patch mosaic of types seen in Cell 22 CELL 29	Extensive CHTH forests and patch mosaic of types seen in cell 22 CELL 30	Extensive old growth CHTH forests and patch mosaic of types in cell 22 CELL 31	TADI in wet swamps, cycling ACRU forest in peatlands (hypothetical) CELL 32

SPECIES ACRONYMS: ACRU: Acer rubrum (Red Maple), ANGL: Andropogon glomeratus, ARGI: Arundinaria gigantea (Cane), CHTH: Chamaecyparis thyoides (Atlantic White Cedar), CLJA: Cladium jamaicense (Sawgrass), CLMO Cliftonia monophylla (Black Titi), CYRA: Cyrilla racemiflora (Titi), FRCA: Fraxinus caroliniana (Water Ash), FRPE: Fraxinus pennsylvanica Red Ash), GOLA: Gordonia lasianthus (Loblolly Bay), ILGL: Ilex glabra (Gallberry), LIST: Liquidambar styraciflua (Sweet Gum), MAVI: Magnolia virginiana (Sweet Bay), MYCE: Myrica cerifera (Wax Myrtle), NYAQ: Nyssa aquatica (Tupelo or Water Gum), NYBI: Nyssa biflora (Swamp Black Gum), PEPA: Persea palustris (Red Bay), PIEL: Pinus elliottii (Slash Pine), PITA: Pinus taeda (Loblolly Pine), TAAS: Taxodium ascendens (Pond Cypress), TADI: Taxodium distichum (Baldcypress).

Figure 3.6. Wet prairie zone between slightly drier pine rockland on the left and slightly wetter cypress head in Florida (Table 3.2, Cells 1 & 2). Similar treeless zones are found rangewide where frequently-burned longleaf pine savannas contact pocosin wetlands (Table 3.3, Cells 33 & 34).

Seasonally Wet Mineral Soils
(Table 3.2, Row 1, Cells 1-6)

Row 1 shows the nature of vegetation in transition from peatlands to wet mineral soils and upland vegetation. Soils are mostly Aquults, Aquepts, Aquods, Aquents and Aqualfs. Each cell of this row condenses much more complexity than those below because these transitional communities are distributed along the clay, loam, sand complex gradient of soil texture which, along with fire frequency, becomes one of the two master gradients required to explain original natural vegetation of uplands. Row 1 does not attempt to explain all the variation on wet mineral soils but is included to show some of the principal types on peatland margins. Soils are those just down slope from soils dry enough to support wet longleaf pine savanna.

Soils with Thin Organic Layers
(Table 3.2, Row 2, Cells 9-16)

Vegetation occurs on soils with thin organic epipedons 10-30 cm thick. These soils occur sometimes only in narrow bands, sometimes in broad zones, where deep organics feather out onto wet mineral soils, or contact upland slopes. The great canebrakes of the South, recorded in numerous historical accounts, were centered in Cells 10 and 18, with fire frequency around every 5 yrs. In addition, large portions of the peatlands with a slightly lower fire frequency, experienced a cycle of alternating canebrake and pocosin (Cells 11 and 19). In this situation, cane dominates for 3 or 4 years after fire and pocosin dominates after 7-8 years. This phenomenon, apparently widespread in original peatlands, has never been described. The site has the appearance of pure canebrake in the years immediately following fire (Figure 3.7). Within its range, pond pine is usually the only tree to survive canebrake fire. Pocosin shrubs resprout after fire but are suppressed by the dense cane, which may reach 2 m in the first full growing season. The shrubs are very slow to regain their pre-burn stature. Eventually, however, toward the end of the fire cycle, shrubs overtop and suppress the cane, and the community aspect becomes that of pond pine pocosin, although cane stems are common upon closer inspection (Figure 3.8). The next fire resets the process. In one pair of 0.1- ha plots on either side of a fire line in this type, the plot burned in the preceding year had 567,200 cane stems per ha, while the side which had grown for 8

years since last fire had 67,200 stems per ha, or about 0.1 as many. The immediate dominance of cane seen after a burn suggests that only 10% of the potential stems have the ability to maintain the entire rhizome mat until the next burn. With further reduction in fire frequency, succession proceeds to various kinds of forest communities and cane is almost entirely eliminated by 26-50 years. One unusual variant, where peat soils feather out onto low mineral flats (Cells 12 and 5), is sweetgum/canebrake (see Appendix for dynamics of this and other communities).

Shallow Histosols
(Table 3.2, Row 3, Cells 17-24)

These communities occur on soils with intermediate organic matter depth, mostly shallow histosols (Terric Medisaprists). With frequent fire these soils are typical of the great peatland canebrakes. With less frequent fire, Cells, 22 and 23, along with Cells 29, 30 and 31 of the next row, appear to provide the optimum organic soil depths and fire regimes for maintenance of white cedar in pure stands. Patch dynamics become complicated, however, and the same site has the potential to support pure white cedar, pure *Taxodium* or various mixtures with *Nyssa biflora*, red maple, red bay and sweet bay. The patch mosaic may shift on a scale ranging from decades to centuries (Figure 3.9). The species that assume dominance on a particular site after stand-replacing fire appears to depend upon stochastic processes and conditions at time of fire (Frost 1987. These include depth to water table, foliar moisture (Blackmarr and Flanner 1968), wind velocity, and time since last fire. If the stand is killed but peat is too moist to burn, white cedar is likely to seize the site quickly with a dense blanket of new seedlings from the seed bank (Akerman 1923; Korstian 1924). On the other hand, if evapotranspiration has drawn down the water table a half meter or more, the surface peat can burn and the seed bank will be destroyed. If the peat burn is deep, a stand of *Taxodium ascendens* may seed in and the site may be pooled when the water table returns to its seasonal high level. After a century or two, peat rebuilds to the general land surface and the next fire has the potential to return the site to white cedar. Most of these processes were documented in the virgin pyromosaic communities of Figure 3.9.

Figure 3.7. Alternating canebrake and pocosin, canebrake phase, taken 3 months after wildfire. Community is composed of two clear dominants, pond pine and cane (Table 3.2, Cell 19). Unburned pocosin on the other side of a fire plow line can be seen in the background.

Figure 3.8. Alternating canebrake and pocosin, tall pocosin phase 8 years after fire (Table 3.2, Cell 19). Site is immediately adjacent to the canebrake seen in Figure 3.7, separated only by the fire plow line that stopped the fire. Cane stems are still common, although only 10% of the number in the adjacent canebrake, and are inconspicuous among the tall pocosin foliage. Quick return to dominance after a fire indicates that a relatively small number of cane stems are able to maintain the rhizome mat until fire returns.

Soils with Deep Peat
(Table 3.2, Row 4, Cells 25-32)

Organic matter in this class most commonly ranges from 1 to 2.5 meters. Peat thicker than 2.5 meters is only occasionally found, since the great peatlands mostly are formed on poorly-drained upland flats or very slight bowl-shaped depressions. Deeper organics occur where V-shaped drainages lead out of peatlands, and in estuarine swamps bordering rivers and sounds where organic accumulation keeps pace with rising sea level. Some deep peat deposits have standing water at least part of the year in peat burnouts near their centers. This may be due in part to the poor drainage, which leads to slight peat doming, with higher peat accumulation in the center than around the periphery. Elevated peat is subject to water table drawdown by evapotranspiration during summer drought. Summer drawdown of more than a meter has been reported (Ingram and Otte 1982), and a fire during such a time may burn into the peat. The vegetation sequence under different fire regimes is very similar to that for Row 3. Canebrake is less common because deep peats tend to be more acid and infertile. Examples of canebrake, however, on peat more than 2 m deep were seen where the underlying substrate was nonacid.

One feature of this row, best developed in Cells 25 and 26 is pyrophytic low pocosin, not previously described. Some classifications (Schafale and Weakly 1990) only designate a community low pocosin when woody stature is limited by severe nutrient deficiency. In the original landscape, however, some pocosins that were part of large fire compartments would have been ignited frequently by fires in adjacent longleaf pine savannas. Some areas would have been maintained in low pocosin just because of the fire frequency. Thus two low pocosin community types probably occurred in presettlement vegetation, trophic low pocosin and pyrophytic low pocosin. The second type required fires on such a large landscape scale that it can no longer be found in the fire-suppressed landscape. The significance of both types of low pocosin, in terms of species richness, is that they both permit coexistence of a variety of graminoids, orchids, pitcher plants, and other bog species that are excluded from pocosin in larger stature classes. The orchids and graminoids that often appear after a pocosin burn are probably remnants, indicating a higher fire frequency in the past.

Figure 3.9. White cedar patch mosaic (Table 3.2, Cells 21, 22, 23, 29, 30, 31). This remarkable infrared image shows a virgin pyrophytic patch mosaic with trees up to 300 years old, perhaps the best remaining example in the South. The light colored 2-lobed "mitten" in center is an area invaded by a wind-driven crown fire from the south (right side of photo) 2 or 3 decades ago. This is superimposed on a white cedar stand (black patches), dating from a crown fire also driven from the south about 90 years ago. Immediately adjacent areas have Taxodium/red maple stands (white dots are tree crowns) dating to fires 200 and 300 years ago which apparently burned deep enough into the peat to pool water, creating habitat for pure cypress stands. Other patch elements are Nyssa biflora forest, and tall pocosin (in the more frequently burned interior, beyond top edge of photo). Black area at bottom left is the Alligator River (Alligator River National Wildlife Refuge, North Carolina).

Presettlement natural Vegetation Types on Severely Nutrient-Limited Sites
(Table 3.3, Cells 33-64)

Some of the stands in this table may represent the most infertile extremes in the southeastern wetland landscape (Walbridge 1986). Such sites are less common than those in Table 3.2 but this may not have always been the case. Much of the existing wild landscape has been fertilized by nitrogen fixed by automobile engines; by input of phosphorus and potassium from wind deflation of agricultural fields in the spring after plowing and fertilization; and by sulfur from industries. Nutrient data are available to support the assertion of infertility in some cases (see cells 57 and 61), but, as mentioned earlier, most interpretation of fertility is based on observations of species behavior and robustness in different habitats.

Seasonally Wet Mineral Soils
(Table 3.3, Row 1, Cells 33-40)

As in Table 3.2, Row 1 shows the nature of vegetation transitional from peatlands to wet mineral soils and considers only part of the variation on these soils which are just barely too wet to support moist longleaf pine savanna. One difference over more fertile sites seen in Table 3.2, is the persistence of open communities like wet savanna and prairie without frequent fire. Most of the best remaining examples of this type are in Florida in sites like the oval moist prairies in Apalachicola National Forest. The best examples outside Florida are the wet prairies interspersed with longleaf pine savannas at Grand Bay Savanna on the Alabama-Mississippi state line and on the Sandhill Crane National Wildlife Refuge in Mississippi. These include sites with the highest species density known in the South, with up to 40 species per square meter or 100 species per 100 square meters (Norquist 1984, Peet and Allard 1995). Dominants include a variety of graminoids such as wiregrass (*Aristida stricta*) and toothache grass (*Ctenium aromaticum*); rare endemics including *Sporobolus teretifolius* of the mid-Atlantic coast or cutthroat grass (*Panicum abcissum*) in south central Florida (Myers and Ewel 1990); and grass-leaved members of the lily family such as *Pleea tenuifolia* and *Tofieldia racemosa*. Examples were originally found as far north as the former Burgaw Savanna in North Carolina (Wells 1932), now destroyed. On fine-textured wet soils frequent fire was probably of only secondary importance in maintaining the community. The

combination of long hydroperiod and clayey soils seems to be deadly to most woody species. Even so, an occasional fire is still needed, since even these sites are slowly colonized by shrubs and saplings of wetland trees. Extreme fire frequency was a coincidence of the landscape setting rather than a requirement for sustaining the prairie community. On the other hand, wet loamy or sandy soils, readily permeable to roots and rhizomes, are subject to more rapid woody invasion, and open remnants are rare. The only large areas with circumannual fire today are found on several military bases in the South. Intermediate succession across Row 1 leads to more pocosin-like forests than those of Table 3.2.

Soils with Thin Organic Layers
(Table 3.3, Row 2, Cells 41-48)

At high fire frequency, Cell 41 and Cell 33 of the Row above provide a characteristic soil and fire regime combination for some of the rarest and most fire-dependent plants, including unusual species like Venus's flytrap (*Dionaea muscipula), Sarracenia psitticina*, and rare and endangered species such as *Lysimachia asperulaefolia, Asclepias pedicellata*, and *Parnassia caroliniana*. Reduction of fire frequency leads to dominance by pocosin shrubs and then dense wetland forest, with almost complete disappearance of the herb species.

Shallow Histosols
(Table 3.3, Row 3, Cells 49-56)

Cells in this group differ from the corresponding row in Table 3.2 by the absence of cane. Most communities have the classic appearance of low or medium pocosin. Only with the longer fire-return intervals do forests develop. While white cedar may be found occasionally, more typical components of the patch mosaic are pond pine-*Gordonia* forest or bay forests dominated by sweet bay, red bay and red maple.

Table 3.3. Peatland vegetation and fire on severely nutrient-limited sites. See text and Appendix 1 for descriptions of vegetation in each cell.

PRESETTLEMENT DISTRIBUTION OF PEATLAND VEGETATION OF THE SOUTHEASTERN UNITED STATES ALONG MASTER GRADIENTS OF FIRE FREQUENCY AND DEPTH OF ORGANIC SOIL

CELLS 33-64: SEVERELY NUTRIENT-LIMITED SITES

FIRE FREQUENCY

⇐ ORGANIC MATTER DEPTH	1-3 YEARS	4-6 YRS	7-12 YRS	13-25 YRS	26-50 YRS	51-100 YRS	100-300 YRS	NEVER BURNED
Seasonally wet mineral soils ROW 1	Species-rich wet prairie sim. cell 1. ARST, PLTE, SPTE, CTAR, TORA CELL 33	Species-rich wet prairie, dwarf shrubs CELL 34	Wet prairie, MYCE, ILGL CELL 35	Thicket of dense, small PISE, PIEL, NYBI, bay forest/shrubs CELL 36	Dense ACRU,NYBI, LIST, PISE, PIEL/MAVI, PEPA/Shrubs CELL 37	PISE forest, PIEL, ACRU, LIST/MAVI, PEPA/ ferns CELL 38	TADI, ACRU, NYBI, swamp herbs CELL 39	TADI, NYBI, ACRU CELL 40
Soils with thin organic layers, 10-30 cm thick ROW 2	Diverse wet prairie and bog gramin-oids, forbs, and insectivorous plants CELL 41	Wet prairie with insectivorous plants and dwarf shrubs CELL 42	Low or medium pocosin CELL 43	Medium pocosin CELL 44	Tall pocosin, PISE forest, bay forest CELL 45	PISE forest, NYBI & ACRU forest, bay forest CELL 46	TADI, NYBI/ swamp herbs CELL 47	TADI, NYBI/ swamp herbs CELL 48
Shallow histosols, 30-100 cm thick ROW 3	Open bog with pitcher plants, dwarf shrubs, graminoids CELL 49	Low pocosin with pitcher plants, other bog species. CELL 50	Low or medium pocosin CELL 51	Scrubby PISE/ medium pocosin CELL 52	PISE-GOLA forest, bay forest with PEPA, MAVI, ACRU CELL 53	Patch mosaic: PISE-GOLA forest, CHTH forest, TADI/ ACRU, NYBI forest, bay for. CELL 54	Patch mosaic: CHTH forest, TADI/ACRU forest, NYBI forest, bay forest CELL 55	TADI in wet swamps, cycling ACRU forest in peatlands (hypothetical) CELL 56
Deep histosols, peat deeper than 1 m ROW 4	Open bog with pitcher plants, grassca and sedges, dwarf shrubs CELL 57	Low pocosin, with pitcher plants, other bog species CELL 58	Low pocosin CELL 59	Low pocosin CELL 60	Low or medium pocosin CELL 61	Medium pocosin (hypothetical) CELL 62	Tall pocosin, PISE-GOLA forest, bay forest (hypothetical) CELL 63	TADI in wet swamps, cycling red maple forest in peatlands (hypothetical) CELL 64

SPECIES ACRONYMS: ACRU: Acer rubrum (Red Maple), ANGL: Andropogon glomeratus, ARGI: Arundinaria gigantea (Cane), ARST: Aristida stricta (Wiregrass), CHTH: Chamaecyparis thyoides (Atlantic White Cedar), CLJA: Cladium jamaicense (Sawgrass), CLMO Cliftonia monophylla (Black Titi), CTAR: Ctenium aromaticum (Toothache Grass), CYRA: Cyrilla racemiflora (Titi), FRCA: Fraxinus caroliniana (Water Ash), FRPE: Fraxinus pennsylvanica (Red Ash), GOLA Gordonia lasianthus (Loblolly Bay), ILGL: Ilex glabra (Gallberry), LIST: Liquidambar styraciflua (Sweet Gum), MAVI: Magnolia virginiana (Sweet Bay), MYCE: Myrica cerifera (Wax Myrtle), NYAQ: Nyssa aquatica (Tupelo or Water Gum), NYBI: Nyssa biflora (Swamp Black Gum), PEPA: (Persea palustris (Red Bay), PIEL: Pinus elliottii (Slash Pine), PITA: Pinus taeda (Loblolly Pine), PLTE: Pleea tenuifolia, SPTE: Sporobolus teretifolius, TAAS: Taxodium ascendens (Pond Cypress), TADI: Taxodium distichum (Baldcypress) TORA: Tofieldia racemosa (False Asphodel).

Deep Histosols
(Table 3.3, Row 4, Cells 57-64)

Cells in this row constitute the true ombrotrophic low pocosins, which are able to maintain their low stature without fire. Nevertheless, some large areas of in this category did burn at a nearly annual rate. Those that did seem to have been open bogs rather than low pocosin. One annually-burned peatland of some 325 km^2 (200 mi^2), was described in 1852 as being covered with "coarse grasses" (Emmons 1860). A second visitor to the same site in 1856 said it was dominated by *Andropogon glomeratus* and low shrubs with *Sarracenia flava* and *S. purpurea* (Ruffin 1861). No frequently burned sites are presently available for study since no large peatlands still burn at this frequency. It would be very valuable if a site could be found where this fire regime could be experimentally reestablished.

True ombrotrophic pocosins may persist for decades without fire. Sheep Ridge Low Pocosin in the Croatan National Forest, NC is the longest-persisting low pocosin known, with vegetation still only around waist high after more than 30 years of fire exclusion (Figure 3.10). Here, on deep, oligotrophic peat, phosphorus has been demonstrated to be the limiting nutrient, with nearly all of the supply tied up in vegetation and micro-organisms (Walbridge 1986). Titi (*Cyrilla racemiflora*), *Zenobia pulverulenta*, red bay and *Lyonia lucida* are dominant, along with nine other pocosin shrubs. Herbs are limited to *Scleria*, a few clumps of *Andropogon glomeratus*, scattered pitcher plants (*Sarracenia flava* and *S. purpurea*) and a few other species of pocosins and wet savannas, which are able to persist in the interstices between the low shrubs. Particularly interesting species are *Cassandra calyculata* and *Lilium catesbaei*. The persistence of low pocosin for more than three decades suggests that this is one of the most infertile sites in the Southeast.

Cells 62 through 64 show hypothetical vegetation under continued fire exclusion. It is unlikely that natural vegetation occurred under these conditions without fire. Longer fire-return intervals are possible on more fertile peatlands because white cedar and other forests appear to have considerable resistance to all but wind-driven crown fires. On severely nutrient-limited sites,

Figure 3.10. Possibly the most nutrient-limited site in the Southeast, Sheep Ridge Low Pocosin is still only waist high after more than 30 years of fire exclusion. Trees are pond pine (Table 3.3, Cell 61). Walbridge (1986) has shown phosphorus to be the limiting nutrient (Croatan National Forest, North Carolina).

however, the low sclerophyll shrub layer is simply too susceptible to fire. The probability of very infertile sites, which retain the flammable low pocosin physiognomy, escaping fire for more than 13-25 years seems remote under the regional natural fire regimes (Figure 3.1). The hypothetical future vegetation under long-term fire exclusion should be medium pocosin, high pocosin with scrubby pond pine, *Gordonia* and red maple forest, as vegetation slowly accumulates additional phosphorus from atmospheric input. In large peatlands, ultimate succession in the absence of fire is hypothetical, but some stands excluded from fire for 75 years seem to be approaching a cycling red maple climax.

CONCLUSION

Peatlands of the southeastern U.S. once experienced landscape-scale fires that burned for weeks or months (Figure 3.11). Fire frequency and peat depth were the two master gradients governing presettlement peatland vegetation. Lightning ignition, which once sustained the master fire gradient, is clearly no longer a significant factor in the landscape. Except in the most remote areas, fires are extinguished before they can burn as much as a hectare (Jennings 1989). As a consequence, the Southeast's original vegetation, structurally complex and diverse, is undergoing massive simplification, as dominant vegetation shifts to the right in the three fire frequency tables.

On uplands, longleaf pine communities have been reduced to less than 3% of their original extent (Frost 1995b). In peatlands, both canebrake and white cedar have been eliminated from all but 1% of their original habitat (Frost 1987).

Fresh and oligohaline marshes show decline in species richness, and loss of certain rare, fire-dependent types like *Eryngium aquaticum* and *Eleocharis rostellata* marsh, while brackish and salt marsh have been little affected. The great peatland and fluvial canebrakes of the South have been almost entirely replaced by pocosin, bay forest and the various scrub and forest communities described in cells 12, 13, 20, 21 and 28. In turn, much, perhaps 50% or more, of our existing "pocosin" communities were something else (open bogs, canebrakes and white cedar) under the original fire regimes. Only the true ombrotrophic pocosins seem to have remained unchanged.

Figure 3.11. Litter fire in dry Nyssa biflora swamp, still creeping 2 weeks after a hot, wind-driven wildfire that burned more than 90,000 acres of canebrake and pocosin. In presettlement times, fires in wetlands may have burned all summer, creeping through swamps, smoldering in peat, and flaring up when more flammable vegetation was reached or conditions of humidity and wind reached critical thresholds. Ferns being consumed are Woodwardia areolata. (Allen Road fire of April 1985, Hyde, Tyrrell and Dare Counties, NC).

Many rare plants are now limited to pocosin/savanna ecotones. Some of these species were probably originally native to pyrophytic low pocosin--pocosin kept low by frequent fire--which was may have been more widespread than trophic low pocosin--those sites kept low by extreme nutrient limitation. Other rare species sites in peatland interiors benefitted by fires that traversed wetlands to reach sand lenses and other islands of habitats now isolated from fire. It is critical to understand the pervasive role of fire in shaping natural vegetation of southeastern wetlands, in order to manage and restore natural areas, and preserve rare species dependent upon fire. Understanding the regional fire regime permits reconstruction of fire history on a site-by-site basis. The possibilities that open up include the ability to accurately delineate presettlement vegetation; learning how to conduct landscape-scale fires in wetlands; and the restoration of marshes, bogs, canebrakes and white cedar forests. The renewed interest in fire ecology, and the individuals pioneering efforts in burning large or difficult-to-manage wetlands offer hope for protection and restoration of the original spectrum of species and community diversity in southeastern wetlands.

APPENDIX 1: Descriptions of peatland vegetation to accompany Tables 3.2 and 3.3, vegetation cells 1-64.

CELLS 1-32. MODERATELY FERTILE SITES:

Cell 1. Wet prairie with a nearly annual (1 to 3 yrs) fire frequency. Most communities in this class are addressed in cell 33 in the table for more infertile sites. The few wet prairie sites with higher nutrient status may include the marl prairies of south Florida, which are dominated by species like Muhlenbergia filipes, sawgrass (Cladium jamaicense), Rhynchospora and Xyris, and the numerous other species found in treeless areas between pine rocklands and cypress heads (Figure 3.6). In the Carolinas, this cell is represented by rare wet savannas which have marl near the surface in an otherwise acid landscape, and have site-limited rare species like Oxypolis canbyi (e.g. Lanier Quarry Savanna). As discussed in cell 33, fire frequency as high as 1 to 3 years was probably not a requirement for maintenance of these wet sites, but a consequence of the regional fire regime.

Cell 2. Wet prairie with 4 to 6 yr fire frequency. This group occurred in portions of the landscape with smaller fire compartment sizes, slightly more topography, or adjacent to vegetation slightly less conducive to fire spread. Small examples can be found in a number of areas managed with controlled fire, including Florida's Apalachicola National Forest and several southern military bases. Dominants on clayey soils are similar to those in cell 1. On loams and sands low forms of pocosin shrubs such as Myrica, gallberry (Ilex glabra), Clethra and Cyrilla may be conspicuous toward the end of each fire cycle. Regional variation in dominants, and with different degrees of wetness, may include Andropogon glomeratus, Pleea tenuifolia, Ctenium aromaticum, Sporobolus spp., and sparse or patchy cane (Arundinaria), along with a great variety of other species of wet savannas and bogs. In Virginia, one of the northernmost such sites, now vanished, was dominated by Tofieldia racemosa (Fernald 1940).

Cell 3. Wet mineral soils with 7-12 yr fire frequency. On all but the wettest sites, reduction of fire frequency to this level allows firm establishment of regionally prevalent wetland shrubs such as Myrica, titi (Cyrilla racemiflora), black titi (Cliftonia monophylla), Ilex, Vaccinium, and any of the other pocosin species. Larger grasses like Andropogon glomeratus, Panicum virgatum, cane, or sawgrass may increase in importance, and the site may have the appearance of a prairie-shrub patch mosaic.

Cell 4. Wet mineral soils with 13 to 25 yr fire frequency. Small trees of red maple (Acer rubrum), swamp black gum (Nyssa biflora), sweet gum (Liquidambar styraciflua, pond pine (Pinus serotina), loblolly (Pinus taeda) or slash pine (P. elliottii) form a scrubby wetland forest toward the end of the cycle. Most stems are killed by fire and the resulting sprout community is similar in appearance to high pocosin but red maple sprouts quickly dominate. Where soil is loamy or sandy, cane may be important. Herbs may be almost nonexistent in the dense canopy shade for most of the cycle.

Cell 5. Wet mineral soils with 26 to 50 yr fire frequency. Woody stems on such sites are dense, with dominant subcanopy and shrub layers. Canopy trees regionally include red maple, loblolly pine, slash pine or even white oak and other hardwoods, often with cane, gallberry or other shrubs as dominants. Fire at around 26 years may kill most stems to the ground while many pines and hardwoods may survive at the longer end of the cycle. Much stochastic variation in survival and

dominant canopy species is possible depending upon wind, density of understory and other conditions at time of burn. An interesting phenomenon of this phase is that cane may become abundant or even dominant in the understory following accumulation of 5 to 15 cm of organic matter, but it may then be eliminated by a growing season burn that removes the organic surface layer.

Cell 6. Wet mineral soils with 51 to 100 yr fire frequency. With this fire-return interval, wetland trees like slash pine, loblolly pine, red maple and bottomland oaks have time to become large enough to resist fire, thus shading out much of the potentially flammable understory. So, when fire does occur, fewer trees are killed and the principal effect is elimination of the smaller size classes of understory stems. In contrast with the thickets in Cell 4, these stands are often quite open beneath the canopy. Scattered cane stems and patches are found in some stands. Accumulated deep pine needle litter smothers the herb layer except for a few tall species like cinnamon fern (Osmunda cinnamomea) and royal fern (O. regalis).

Cell 7. Wet mineral soils with 100 to 300 yr fire frequency. As pines are replaced by shade-tolerant wetland hardwoods like red maple, Nyssa biflora, and swamp chestnut oak (Quercus michauxii, the pine needle duff layer is replaced by herbs, typically swamp species of Carex and broadleaved herbs. Fires have little effect other than damaging exposed roots and leaving basal scars on some of the trees.

Cell 8. Wet mineral soils completely protected from fire. Natural examples can be found on small islands in wet swamps surrounded by permanently saturated soil or standing water, and with no understory vegetation capable of carrying fire to the site. Such sites may be dominated by baldcypress (Taxodium distichum) and Nyssa biflora, and slightly higher areas may support nearly pure stands of beech or beech-magnolia.

Cell 9. Thin organic soils with 1 to 3 yr fire frequency. These are open, wet prairie and bog sites, sometimes with very dwarfed shrubs in the herb layer. They may be dominated by very diverse wet prairie and bog graminoids and forbs, with species richness similar to or slightly lower than that for cell 1. Shrubs may out-compete some herbs at the 3 year frequency. Examples of stream bottom canebrakes in this category may be seen on Fort Bragg in North Carolina, where fires have

passed through bottomlands about every 2 years in recent times. Such communities, common in historical accounts, are now quite rare.

Cell 10. Thin organic soils with 4 to 6 yr fire frequency. Good conditions for canebrake, especially at the 30 cm depth. See cell 18 for further discussion of canebrake at this frequency.

Cell 11. Thin organic soils with 7 to 12 yr fire frequency. These are alternating canebrake and pocosin sites, especially at the 30 cm depth (see Figures 3.7 and 3.8).

Cell 12. Thin organic soils with 13 to 25 yr fire frequency. At this frequency an open canopy of pond pine and red maple reduces density of understory shrubs and intensity of fires. Loblolly pine, slash pine or sweet gum can then become established. Variations include stands dominated by sweet gum with a cane understory of light to medium density. In these sites, coexistence of cane--ordinarily conducive to high-intensity tree-killing fires--and the tree canopy, is maintained in a precarious dynamic balance in which the shading canopy is just thick enough to keep cane density just thin enough so that the trees are not killed by fire. Conversely, cane density is still sufficient to carry fire and maintain an understory largely clear of other species.

Cell 13. Thin organic soils with 26 to 50 yr fire frequency. With continued suppression of the understory, forest stands may form closed canopies of sweet gum, pond pine, slash pine, or red maple in large peatlands, or loblolly or slash pine and hardwoods at peatland/upland contacts and in fluvial bottomlands. There may be occasional canopy or subcanopy stems of red bay (Persea palustris) and sweet bay (Magnolia virginiana). The understory may be very sparse, consisting of scattered shrubs and patches of cane. Sites in small stream swamps may have narrow zones of white cedar downslope from more frequently burned pine savannas, especially where slopes are steep.

Cell 14. Thin organic soils with 51 to 100 yr fire frequency. This interval permits formation of mature pond pine forest in large peatlands, or various mixtures of loblolly pine, slash pine, sweetgum and bottomland hardwoods elsewhere. Subcanopy is often well-developed, with only scattered stems of cane or shrubs such as gallberry, Myrica, Ilex coriacea, and Lyonia lucida. The herb layer may be almost nonexistent but for tall ferns like Osmunda cinnamomea and O. regalis.

Cell 15. Thin organic soils with 100 to 300 yr fire frequency. This uncommon type is most often encountered as a narrow band bordering riverine swamps or in the interiors of large swamps where shade and channels quell most fires moving in from outside. Tall canopy dominants may include baldcypress, pine, Nyssa biflora, Fraxinus pensylvanica, and sweet gum with occasional white cedar. Red maple and Fraxinus caroliniana may be common in the subcanopy. Shrubs are typically sparse but there may be a well-developed herb layer of Carex, grasses, and other swamp herbs.

Cell 16. Thin organic soils completely protected from fire. This type can occur in portions of swamps cut off from the mainland or from large wetland fire compartments by oxbows and stream channels. It occurs as a multi-storied community dominated by bald cypress as old as 1,000 years in virgin stands, most often with a high subcanopy of Nyssa (N. biflora on slightly drier microsites and N. aquatica in the wetter areas). It is characterized by an open, low subcanopy of wetland saplings like red maple, water ash or elm (Ulmus americana), an open shrub layer, and a layer of swamp forest herbs.

Cell 17. Organic matter 30 cm to 1 m deep with 1 to 3 yr fire frequency. These are open bogs, with pitcher plants and other insectivorous species, dwarf shrubs, low graminoids, and sometimes cane. One such site was described in the 1930s as covered by vast carpets of fire-following mosses like Funaria hygrometrica after each fire (Anderson, pers. comm.), along with Andropogon glomeratus, dwarf shrubs, and sphagnum.

Cell 18. Organic matter 30 cm to 1 m deep with 4 to 6 yr fire frequency. These are the classic canebrake soils. Cane rebounds to a height of 1.5 to 2 meters or more within a few months after a fire. Because of the high fire frequency, shrubs have inadequate time between fires to become established in the shade of the tall cane, and cane may be practically the only species present. One such site examined for this study in North Carolina had only 10 species per 1/10 ha: there was 100% cane cover and a density of 450,800 stems per ha. Besides the cane there were ten stems/ha of pond pine, and a few scattered stems of poison sumac (Toxicodendron vernix), Rhus copallina, Aralia spinosa, Prunus serotina, Rubus hispidus, Phytolacca americana, Ilex glabra,

Toxicodendron radicans, and Smilax glauca. Combined cover of all species other than pine and cane was less than 1%.

Cell 19. Organic matter 30 cm to 1 m deep with 7 to 12 yr fire frequency. The dynamics of alternating canebrake and pocosin are discussed in the text. This alternating community pair is best developed on soils of this depth, and was probably extensive in peatlands under the presettlement fire regime.

Cell 20. Organic matter 30 cm to 1 m deep with 13 to 25 yr fire frequency. At this frequency, pond pine may form a nearly closed canopy. Shrubs may dominate the understory for much of the cycle. Red maple may dominate in sites or patches where pond pine is lacking. Immediately after fire, cane may recapture the understory and nearly all biomass in the resulting bilayered community consists of pond pine in the canopy and cane below. Shrubs resprout in the shade of these two dominants but are unable to regain more than about 50% of the understory cover until near the end of the cycle. Pine shade may reduce intensity of fires by reducing density of understory shrubs.

Cell 21. Organic matter 30 cm to 1 m deep with 26 to 50 yr fire frequency. Reduction of fire frequency to this level can produce tall, straight pond pine forest. Under the closed canopy are scattered evergreen bay species, including Persea and Magnolia. Scattered stems of cane persist, and shrubs like Myrica, gallberry, and fetterbush (Lyonia lucida) are common but do not usually form a closed layer. Because of the shade and deep pine needle accumulation, sometimes as much as 30 cm on the forest floor, herb cover is almost nonexistent. Good examples are rare now, since the tall, straight, dense pond pine stands have all been logged, and few are being regenerated with fire. Logged stands have been replaced by red maple or bay forest. On a landscape level, such stands sometimes occur in a patch mosaic with white cedar. Pure Gordonia stands can sometimes be found.

Cell 22. Organic matter 30 cm to 1 m deep with 51 to 100 yr fire frequency. See text and Figure 3.9 for discussion of the white cedar patch mosaic of which this cell is a part.

Cell 23. Organic matter 30 cm to 1 m deep with 100 to 300 yr fire frequency. Such sites have similar species and operate with dynamics like those in Cell 22. Three hundred years approaches the documented upper limit for age of white cedar, but only a few remnant Chamaecyparis may be adequate to maintain the seed bank until the next fire.

Cell 24. Organic matter 30 cm to 1 m deep completely protected from fire. As in cell 16, this situation is not known to occur in the great peatlands. However, completely fire-protected sites can be found in fluvial swamps, with baldcypress dominant. In Virginia and North Carolina, long settled and farmed, there are sites where fire has been completely excluded for 75 years. Among three such sites, one had a few pond pine, and another had a remnant patch of white cedar on the fringe; but all three were heavily dominated by red maple. The maple stands had red maple in the canopy, subcanopy, shrub and herb layers. There was a pocosin-like shrub layer, but no other woody stem was present that could be a candidate for the canopy. On such sites, it appears that the ultimate forest under existing climate with continued fire exclusion will be cycling red maple.

Cell 25. Deep peat soils, greater than 1 m in depth with 1 to 3 yr fire frequency. Plant cover is similar to cell 17, but this type was probably much less extensive, since deep peat zones are often surrounded by pocosin vegetation on shallow peat and pocosin is less likely to carry every fire that passes through upland savannas, into the deep peat communities.

Cell 26. Deep peat soils, greater than 1 meter in depth with 4 to 6 yr fire frequency. Bog herbs and low pocosin shrubs are predominant. Canebrake may occasionally be found in peatlands with organic matter 2 or more m deep where the underlying mineral soil is nonacid. One such site, Light Ground Pocosin in Pamlico County, NC, once had extensive canebrakes on its east side near the contact with an unusual zone of Alfisols, circumneutral soils being very uncommon in the region. Only small patches remain of extensive canebrakes visible on old aerial photos. In some areas the ground is littered with old canes where no living stem persists today. The canopy after 40 years of fire exclusion is a patch mosaic with stands of pure red maple, and mixed stands of pond pine, loblolly pine and Gordonia.

Cell 27. Deep peat soils, greater than 1 meter in depth with 7 to 12 yr fire frequency. Such sites have medium to tall pocosin, or in sites with circumneutral basement substrate, alternating

canebrake and pocosin. Depending upon site nutrient status, pocosin typically bounces back quickly to a certain height within a year or two after a burn and then increases very slowly. This fire frequency allows pocosin vegetation that is not severely nutrient-limited to reach heights of 3 to 5 m. Herbs are rare except for Woodwardia virginica which may be a codominant in the year or two after a burn. W. virginica, along with Lyonia lucida, often forms an understory beneath the dominant shrub canopy.

Cell 28. Deep peat soils, greater than 1 meter in depth with 13 to 25 yr fire frequency. Tall pocosin is common, with emergent pond pine, red maple and Gordonia lasianthus, or pure pond pine forests of shorter, more twisted stature than those of cells 13 and 14. Perhaps because they have more time for building root systems, the tree species produce emergent saplings within a few years rather than remaining for an extensive time in the pocosin shrub layer. These communities form impenetrable thickets tied together with cat-brier (Smilax laurifolia), but toward the end of the cycle the tree canopy may be 10 m in height. Red bay and sweet bay add an evergreen component to the understory that can emerge as bay forest with further reduction in fire frequency. Areas in this cell adjacent to white cedar stands may be colonized by white cedar after a fire, forming pure or mixed stands.

Cell 29. Deep peat soils, greater than 1 m in depth with 26 to 50 yr fire frequency. As in cells 21,22,23,30, and 31, this fire-return interval is conducive to patch mosaic formation, better illustrated in the next cell. Patch elements are pond pine-red maple forests, white cedar forest, bay forest, and the others discussed below.

Cell 30. Deep peat soils, greater than 1 m in depth with 51 to 100 yr fire frequency. Within its geographic range, this interval is optimal for Atlantic white cedar, occurring during the most vigorous part of its life cycle and allowing time for massive seed bank accumulation in the wet peat. As with cell 22, pure cypress stands (both T. distichum and T. ascendens) can become established in pools created by peat burnouts. Other elements of the mosaic include pond pine-red maple forest, Nyssa biflora forest, red maple forest, and bay forest. While any of these can occur naturally, most existing examples of Nyssa, red maple and bay forest are the incidental result of removal of white cedar. Until the past decade, nearly all logging of white cedar left the logging slash on the ground, inhibiting or completely preventing cedar seedling regeneration. The local

understory species took over and formed a new canopy. Some variation of this has occurred nearly everywhere that white cedar formerly was found, and the species now occupies only about 1% of its original range (Frost 1987). White cedar is conspicuously absent from some of the largest peat domes, which include some of the most sterile of peat habitats (see cells 57-64). Most sites with white cedar appear to have a supplemental nutrient source. Sea-level stands adjacent to fresh or brackish water receive occasional storm inundation and more regular aerosol deposition. Stands in small stream systems downslope from uplands can receive nutrients in runoff and ground water, and may also be occasionally flooded. The Dismal Swamp white cedar, historically the largest known stand in the range of the species, at an estimated 112,000 acres (45,000 ha)(Akerman 1923), lies at the toe of the 8 m (25 ft) high Suffolk Scarp and is underlain with a sandy aquifer which could supply subsurface nutrients from the upland plateau to the west (Oaks and DuBar 1974).

Cell 31. Deep peat soils, greater than 1 m in depth with 100 to 300 yr fire frequency. White cedar stands up to 300 years of age are known to have dominated the most fire-inaccessible central interior of the Dismal Swamp (Frost 1987, 1989). Even-aged stands of baldcypress 200 years old can still be found in large peatlands (Figure 3.9). In the latter, red maple may be nearly the only understory tree. In peatlands the life span of red maple seems to be only about 100 years. On part of the site studied in Figure 3.9, the 200 year-old cypress canopy overtops a well-developed secondary canopy of red maple, the only other substantial layer present. The oldest maple stems present are about 100 years old. Also present are dead trunks, and all size classes of maple replacement stems. The picture clearly presented is a pure cypress canopy, probably originating in a peat burnout during a dry summer 200 years ago. The cypress has persisted for centuries, with the red maple below, completing its life span and replacing itself on a 100 year cycle.

Cell 32. Deep peat soils, greater than 1 m in depth in completely fire-protected sites. Such sites probably do not exist in the big peatlands. There are riverine islands of deep peat which support old-growth baldcypress.

Cells 33-64. SEVERELY NUTRIENT-LIMITED SITES

Cell 33. Wet prairie with a 1 to 3 yr fire frequency. Flora is similar to cell 1.

Cell 34. Wet prairie with 4 to 6 yr fire frequency. This group is similar to cell 2 except that in more infertile sites, species richness may be higher because of less rapid exclusion by bunch grasses. Shrubs are fewer and of smaller stature than those in cell 2 between burns.

Cell 35. Wet mineral soils with 7 to 12 yr fire frequency. On sterile sites with fine-textured soils, moist prairie vegetation persists, but single stems and patches of low shrubs like gallberry, Myrica, and along the Gulf Coast, shrubby Hypericum may occur. Cane and other species that require higher fertility are lacking. Various fire-suppressed successional examples are common in the Mississippi coastal meadows.

Cell 36. Wet mineral soils with 13 to 25 yr fire frequency. On sites with clayey soils, moist prairie with shrubs may persist. On sandy soils, readily penetrated by roots and rhizomes, dense thickets may form. Canopy species may be pond pine, Nyssa biflora or red maple, with pocosin and bay species in the understory. Typically there is little differentiation into vegetation strata, the whole being one continuous vertical thatch of stems. The appearance after fire is that of medium pocosin, but with numerous emergent dead stems and trunks.

Cell 37. Wet mineral soils with 26 to 50 yr fire frequency. Pure pine forest or forests with various mixtures of pond pine, slash pine, Nyssa biflora, and red maple may occur. The understory remains thick, and consists of red bay, sweet bay, and the more shade-tolerant pocosin shrubs like Ilex glabra, I. coriacea, Myrica cerifera and M. heterophylla. Herbs are nearly absent. Many hardwood stems are killed by fire. Canopy pond pine often survives, tending to maintain its dominance. Resprouting stems of other trees are relegated to canopy gaps.

Cell 38. Wet mineral soils with 51 to 100 yr fire frequency. These communities consist of pine forest, Nyssa biflora forest sometimes with Taxodium, and red maple forest. Many of these commonly have sclerophyllous evergreen understory with red bay and sweet bay. Herbs, other than a few ferns, are typically lacking.

Cell 39. Wet mineral soils with 100 to 300 yr fire frequency. Very sterile sites in this category are hard to find. Fire is in part responsible for enforcing infertility by driving off nitrogen, while

poor sites that go this long without fire are likely to accumulate nutrients just from atmospheric deposition. Also, sites so sheltered from fire are usually in swamps or bottomlands where nutrient transport from uplands or by water comes into play. Some stands of Taxodium along acid blackwater streams may fit this category.

Cell 40. Wet mineral soils completely protected from fire. The same comments as for cell 39 apply here. Old-growth Taxodium along small, sandy blackwater streams isolated from fire by oxbows and channels are the only candidates. Larger rivers and streams carry nutrients that would shift this cell to Table 3.2.

Cell 41. Thin organics with 1-3 yr fire frequency. These are open wet prairie and bog sites similar to those in cell 9, except that cane is absent and shrub growth is somewhat lower in nutrient-stressed sites. Herb species diversity remains very high. This and Cell 33 provide a characteristic soil and fire regime combination for some of the rarest and most fire-dependent plants, including unusual species like Venus's flytrap (Dionaea muscipula), Sarracenia psitticina, and rare and endangered species such as Lysimachia asperulaefolia, Asclepias pedicellata, and Parnassia caroliniana. Dominants, which vary greatly on a local and regional basis, include Pleea tenuifolia, Sporobolus, Ctenium, and Tofieldia racemosa. Most of the locally available pocosin shrubs can be found, but usually in dwarfed form.

Cell 42. Thin organics with 4 to 6 yr fire frequency. Vegetation and species richness for cells 42, 43, 50 and 51 are drastically different from the corresponding block of cells from Table 3.2. These soils, apparently too sterile for cane, may have a rich herb flora interspersed with dwarf shrubs. They also include most of the rare species discussed in cell 41 above.

Cell 43. Thin organics with 7 to 12 yr fire frequency. On sterile sites the alternating canebrake and pocosin phenomenon of cell 11 is replaced simply with low or medium pocosin. Species diversity is typically low, limited to 10 or 12 pocosin shrub species as well as Smilax laurifolia and Woodwardia virginica. Other herbs are sparse, and include a few pitcher plants, orchids, Xyris, Rhynchospora or Carex.

Cell 44. Thin organics with 13 to 25 yr fire frequency. On sterile sites, medium or high pocosin with pond pine develops over the fire-return interval. Toward the longer cycle, some sites with intermediate fertility also produce emergent Gordonia, sweet bay, Nyssa biflora and red maple, which are reduced to resprouting stems after fire. Stems of scrubby pond pine may survive into the next cycle.

Cell 45. Thin organics with 26 to 50 yr fire frequency. This interval is long enough for formation of pond pine forest, but the trees are of the characteristically picturesque crooked form, lacking the straight tall trunks of pond pine forest seen in the corresponding cell 21. Because establishment of pine is irregular in this and the preceding cells, pine forest is often interspersed in a matrix of tall pocosin or bay forest in which the canopy dominant is often Gordonia lasianthus, with red bay and sweet bay forming most of the subcanopy. Smilax and pocosin shrubs make the understory impassable.

Cell 46. Thin organics with 51 to 100 yr fire frequency. These forests resemble those of cell 45, but Nyssa biflora and red maple may become components of the canopy and subcanopy. Both species are tolerant of shade and very poor soils, but have spindly, twisted trunks when found on such sites. The dominants in this class sometimes form a patch mosaic with white cedar.

Cell 47. Thin organics with 100 to 300 yr fire frequency. As with other cells in this fire frequency class, it is most often encountered as a narrow band bordering riverine swamps, in this case those bordering acid blackwater rivers. The community may have old baldcypress of reduced stature or Nyssa biflora and bay forest species. Gordonia is not known to live long enough to survive into this age class and does not reproduce in shade. White cedar is occasionally found.

Cell 48. Thin organics completely protected from fire. This type is limited to small, acid blackwater stream systems. A baldcypress stand along the Black River, a tributary of the Cape Fear River in North Carolina, has been identified as the oldest in the eastern U.S., with trees up to 1,200 years old. These occur on wet, sterile, acid soils. There is nothing in the understory to carry fire, despite the fact that nearby uplands were subject to the highest fire frequency regime.

Cell 49. Organic matter 30 cm to 1 m deep with 1 to 3 yr fire frequency. These are open bogs with pitcher plants, dwarf shrubs, graminoids, especially Andropogon glomeratus as described for cell 17, but without cane.

Cell 50. Organic matter 30 cm to 1 m deep with 4 to 6 yr fire frequency. These sites support only low pocosin, maintained by a combination of infertility and frequent fire. Shrub stature is kept low enough to permit a diversity of pitcher plants and other bog species in the interstices.

Cell 51. Organic matter 30 cm to 1 m deep with 7 to 12 yr fire frequency. This is low to medium pocosin with sparse, crooked pond pine emergent over shrubs. Woodwardia virginica may be virtually the only herb.

Cell 52. Organic matter 30 cm to 1 m deep with 13 to 25 yr fire frequency. Scrubby pond pines are emergent over medium pocosin with very low species diversity, largely limited to 9 or 10 pocosin shrub species plus Smilax laurifolia and Woodwardia virginica.

Cell 53. Organic matter 30 cm to 1 m deep with 26 to 50 yr fire frequency. Tall pocosin or scrubby pond pine-Gordonia forest with red bay, sweet bay and tall pocosin shrubs, thick and relatively undifferentiated into layers.

Cell 54. Organic matter 30 cm to 1 m deep with 51 to 100 yr fire frequency. As in many of the other cells in the 50-100 year fire frequency class, this fire regime is conducive to formation of a patch mosaic, with different communities depending upon fire behavior and environmental conditions at time of burn. Components of the mosaic include pond pine-Gordonia forest. The pines are gnarled and crooked. White cedar forest may occur on less infertile sites. Nyssa biflora forest or pond cypress (Taxodium ascendens) forest, the trees often straight but small, may also be found.

Cell 55. Organic matter 30 cm to 1 m deep with 100 to 300 yr fire frequency. Similar forest types can be found as in cell 23. Taxodium ascendens, in particular, has a great range of tolerance for site fertility. One site examined during this study had a pure cypress canopy about 200 years old, probably dating to a peat burnout. The trees were only 16 to 18 inches in diameter, with very

regularly spaced growth rings, most only about 1 mm wide. While cypress is typically slow growing, in fertile river bottomlands it can have growth rings several mm wide in the early years, and two to three times the diameter of those in large oligotrophic peatlands.

Cell 56. Organic matter 30 cm to 1 m deep completely protected from fire. Sites in large peatlands probably do not occur. Very old Taxodium distichum may be found on organic soils in acid blackwater stream systems, as described in cells 31 and 47. The hypothetical community in peatlands, should fire continue to be successfully excluded until pines or cypress die off, would be cycling red maple.

Cell 57. Deep peat soils, greater than 1 m in depth with 1 to 3 yr fire frequency. Open bogs with pitcher plants, sundews, Andropogon glomeratus and sedges like Scleria ciliata, and Carex. While there are historical descriptions of such communities (see text), no examples remain.

Cell 58. Deep peat soils, greater than 1 meter in depth with 4 to 6 yr fire frequency. These are herb bogs, similar to Cell 57, but with low pocosin shrubs. Few, if any, large peatlands still burn at this rate.

Cell 59. Deep peat soils, greater than 1 m in depth with 7 to 12 yr fire frequency. These are true ombrotrophic low pocosins with sparse, bonsai pond pine. There are still a few large peatlands which experience wildfire at this rate.

Cell 60. Deep peat soils, greater than 1 m in depth with 13 to 25 yr fire frequency. This cell contains low pocosin with shrub cover dense enough to exclude bog herbs, except for those in small openings between woody plants.

Cell 61. Deep peat soils, greater than 1 m in depth with 26 to 50 yr fire frequency. These very infertile sites may remain in low pocosin for many years without fire (Figure 3.10).

Cell 62. Deep peat soils, greater than 1 meter in depth with 51 to 100 yr fire frequency. This is the hypothetical extension of existing communities of cell 61, and consists of open pond pine with low or medium pocosin. While large white cedar wetlands may withstand fire for up to 300 years

(cells 23, 31), no large, severely nutrient-limited peatlands are known with fire-return intervals as long as that in Cells 61-64.

Cell 63. Deep peat soils, greater than 1 m in depth with 100-300 yr. fire frequency. This type is unknown in nature on extremely sterile sites. Hypothetical vegetation is discussed in the text.
Cell 64. Deep peat soils, greater than 1 m in depth in completely fire-protected sites. As with cell 63, no sites are known. Without fire it seems likely that trees would continue to accumulate enough nutrients to increase stature of vegetation. Based on observations discussed above, hypothetical vegetation, after death of pine and Gordonia, would be cycling red maple.

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CHAPTER 4

PRESETTLEMENT FIRE FREQUENCY REGIMES OF THE UNITED STATES: A FIRST APPROXIMATION

ABSTRACT

It is now apparent that fire once played some role in shaping all but the wettest, the most arid, or the most fire-sheltered plant communities of the United States. Understanding the role of fire in structuring vegetation is critical for land management choices that will, for example, prevent extinction of rare species and natural vegetation types. Pre-European fire frequency can be reconstructed in two main ways. First is by dating fire scars on old trees, using a composite fire scar chronology. Where old fire-scarred trees are lacking, as in much of the eastern U.S., a second approach is possible. This is a landscape method, using a synthesis of physiographic factors such as topography and land surface form, along with fire compartment size, historical vegetation records, fire frequency indicator species, lightning ignition data, and remnant natural vegetation. Such kinds of information, along with a survey of published fire history studies, were used to construct a map of presettlement fire frequency regions of the conterminous U.S. The map represents frequency in the most fire-exposed parts of the landscape. Original fire-return intervals in different parts of the U.S. ranged from nearly every year to more than 700 years. Vegetation types were distributed accordingly along the fire frequency master gradient. A fire regime classification system is proposed that involves, rather than a focus on trees, a consideration of all vegetation layers.

KEY WORDS: Fire history, fire regime classification, presettlement fire frequency, site fire frequency, fire compartments, fire frequency mapping, fire effects, presettlement vegetation, rare plant species.

INTRODUCTION

The most important applications of fire history research are in land and timber management, restoration of natural communities, and restoration of habitat required by endangered species. Fire history is critical for understanding natural vegetation, and is a prerequisite for being able to map presettlement vegetation.

The Wisconsin glaciation ended some 10,000 years ago, and a climate with warm winters, similar to those we now experience, stabilized around 8,000 years ago. Most modern plant assemblages finished responding to these changes and have remained relatively stable for the past 6,000 years (Webb 1988). Vegetation is dynamic and periods of drier or wetter climate, accompanied by higher or lower fire frequency have oscillated over the past 3,000 years (Swetnam 1993), and seasonality of fire has varied in some regions (Grissino-Mayer and Swetnam 1995), but these and minor Holocene climatic fluctuations such as the "little ice age," a slightly cooler period from AD 1450 to 1850, produced no substantial shifts in major plant formations (Webb 1988). The plant and animal communities found by the first European explorers, then, had been in place for several thousand years. It seems reasonable that these are the natural communities we would want to perpetuate. Fire history research can complement this goal.

The primary object of this paper is to construct a map of fire frequency regions of the United States as they existed in one window of time, the era of European settlement. The intention is to begin to visually relate fire history studies across the country in order to further appreciation of the pervasive role of fire in natural vegetation. The secondary objective is to classify fire regimes in terms of their effects on whole vegetation communities: the canopy, midstory, shrub and herb strata.

METHODS

Using Land Surface Form for Mapping Landscape Fire Regimes

Two steps were used in construction of the fire frequency map. First, information was compiled from fire history studies from across the country. Second, I used a map of land surface forms (Hammond 1964) as a starting point to put boundaries on presettlement fire frequency regions. Hammond's mapping units are shown in Table 4.1. Land surface form is essentially slope mapping, coded for the following: 1) percent of the landscape which is flat or only gently sloping, 2) amount of local relief from the stream bottoms to ridge tops, and 3) whether the flat or gently sloping parts are located on uplands or in bottomlands. Hammond used these categories to classify landscape in the U.S. into 27 surface form categories (Table 4.2).

Hammond's land surface form map is uniquely useful in fire frequency mapping because the land surface units permit interpretation of the size of fire compartments and of the density of impediments to fire flow in the landscape. For example, his categories A1 (flat plains) and A2 (smooth plains) cover much of the southeastern coastal plain and the central prairie region where there were once vast areas without a single firebreak. In contrast, some regions classified D4--such as the Ridge and Valley Province of the Appalachian Mountains--have dramatic relief of ravines and valleys with numerous streams to serve as firebreaks, so that the expected fire frequency would be much lower.

On the other hand, land surface form does not provide much information about ignition rates, fire-return intervals, or variation in fire frequency due to latitude, climatic regions and ignition factors. These, however, are accounted for in the actual fire-return intervals determined by fire history studies in the various parts of the country. The land surface form polygons do circumscribe regions of relatively uniform types of relief, in which fire ignition rates, rates of spread and other characteristics may be expected to be remain within certain bounds. This permits approximate boundaries to be put on fire frequency regions.

TABLE 4.1. LAND SURFACE FORM CLASSIFICATION (Hammond 1964)

UNITS IN CLASSIFICATION SCHEME

SLOPE (Capital letter)			
A	More than 80% of area gently sloping	C	20-50% of area gently sloping
B	50-80% of area gently sloping	D	Less than 20% of area gently sloping
LOCAL RELIEF (Numeral)			
1	0-30 meters	4	150-300 meters
2	30-90 meters	5	300-900 meters
3	90-150 meters	6	Over 900 meters
PROFILE TYPE (Lower case letter)			
a	More than 75% of gentle slope is in lowland	c	50-75% of gentle slope is on upland
b	50-75% of gentle slope is in lowland	d	More than 75% of gentle slope is on upland

Fire history studies, historical records, and my own experience with remnant natural vegetation, were used to assign fire frequency values to the map polygons. The studies used for mapping include many of those mentioned in Wright and Bailey (1982), Agee (1993), Brown et al. (1995b), Frost (1995), and Frost (1998). Where specific fire history studies were lacking, values were assigned using evidence of the kinds listed in Table 4.3. Where studies on adjacent polygons on the Hammond map showed the same type of fire regime, the polygons were merged.

The basic land surface form map of Hammond (1964) was further modified in several ways. Some boundary adjustments were made for the influence of soils and climate. Küchler's (1964) vegetation map units 40 (saltbush-greasewood), 43 (paloverde-cactus) and 46 (desert, vegetation largely absent) were added to distinguish barren desert and arid lands with fuel insufficient to carry fire. A map by Myers (Myers and Ewel 1990) was used to delimit infrequently burned sand pine scrub in Florida. Little's Atlas of North American Trees, Vol. 1 (1971) was consulted for ranges of fire frequency indicator tree species such as jack pine (*Pinus banksiana*), and a forest vegetation map based on satellite imagery (Zhu et al. 1993) was consulted for verification of major vegetation types.

TABLE 4.2. CLASSES OF LAND SURFACE FORM (Hammond 1964)

PLAINS			
A1	Flat plains	A2	Smooth plains
B1	Irregular plains	B2	Irregular plains, high relief
TABLELANDS			
B3c,d	Tablelands, moderate relief	B5c,d	Tablelands, high relief
B4c,d	Tablelands, considerable relief	B6c,d	Tablelands, very high relief
PLAINS WITH HILLS OR MOUNTAINS			
A,B3a,b	Plains with hills	B5a,b	Plains with low mountains
B4a,b	Plains with high hills	B6a,b	Plains with high mountains
OPEN HILLS AND PLAINS			
C2	Open low hills	C5	Open low mountains
C3	Open hills	C6	Open high mountains
C4	Open high hills		
HILLS AND MOUNTAINS			
D3	Hills	D5	Low mountains
D4	High hills	D6	High mountains

Fire Compartment Size and Fire Frequency

A fire compartment is defined here as an element of the landscape with continuous fuel and no natural firebreaks, such that an ignition in one part would be likely to burn the whole. In developing the fire frequency map, I assumed that the larger the local fire compartments, the higher the fire frequency, since in large compartments there might be several lightning ignitions per year, yet any one ignition had the potential to burn the entire compartment. Many fire compartments, especially in Florida and the Midwestern prairies, once contained more than 1,000 square kilometers without a natural firebreak. Before the fire landscape was partitioned by roads, ditches and farms, some of these regions experienced nearly annual fire (Frost 1995, 1996, 1997). In more rugged topography, the fire compartments are much smaller, so that it would take

many more ignitions to burn the same amount of land that might burn from a single ignition in flatter topography. As a result, expected fire frequency would be much lower.

Distinguishing Point Fire Frequencies, Area Frequencies and Site Frequencies

Fire frequency is expressed as the average number of years between fires (mean fire-return interval). Agee (1993) pointed out that such figures are meaningless unless an indication is given of the size of the area being sampled. A point sample, such as the dates obtained from fire scars on a single tree, might yield a 10 year mean fire-return interval. This point frequency would likely be an underestimate, however, because very few trees are scarred by every fire (Kilgore and Taylor (1979), Swetnam et al 1988, Caprio and Swetnam 1995). Since peculiarities of fuel distribution or wind affect whether or not a particular fire might scar a particular tree, standard fire history methodology uses scars from clusters of old trees and correlates the scar dates between trees into a composite fire scar chronology to give a more accurate picture of fire history.

Expanding the sampled area to the size of a state would add many more fires, giving fire-return intervals in weeks or months. Agee (1993) called these area samples or area frequencies. Area frequencies are useful on large sites, such as national forests, where they might predict that there will be, for example, an average of 3.2 fires per year on the forest. But for determining the fire frequency necessary to maintain a particular forest structure or to meet the needs of a fire-dependent rare plant species, a more ecologically significant measure of fire frequency is needed.

The fire frequency classes used in developing the fire map are neither point nor area frequencies, but are what I will call site frequencies. Ecologically, the local site or fire compartment is the most important level of scale. In terms of species biology, the mean fire-return interval for fire-dependent plants on a particular south slope is more important than the regional area frequency, since this is the true recurrence of fire experienced by those plants. Instead of using point or area frequencies, then, I will define site as a fire compartment, so a site frequency is the mean fire-return interval for a particular fire compartment.

TABLE 4.3. LINES OF EVIDENCE FOR APPROXIMATING PRESETTLEMENT FIRE FREQUENCY AND PRESETTLEMENT VEGETATION

Asterisks suggest degree of usefulness, with three being most valuable. Usefulness of different kinds of evidence varies in different parts of the country.

LANDSCAPE AND ENVIRONMENTAL EVIDENCE:

*** Original fire compartment size.
** Landscape factors which resist flow of fire between compartments (steep slopes, soils, water bodies).
** Soil maps and observations of fire behavior on different soil types.
** Charcoal deposition in varved lake sediments.
** Lightning ignition records.
** Records of size of areas burned by wildfires without suppression.
* Charcoal deposition in soils or peat.

HISTORICAL EVIDENCE:

*** Historical records mentioning fire frequency indicator species and fire frequency indicator vegetation types.
*** U.S. General Land Office Survey witness tree records.
** Historical references to fire or fire frequency.
** Oral history (where land settled in past century).
** Vegetation on old photos and aerial photos.
** Tree species on old land survey plats.

VEGETATION EVIDENCE:

*** Fire scar analysis with tree ring chronologies.
*** Presence of remnant fire frequency indicator species.
** Presence of remnant fire frequency indicator communities.
** Observations of vegetation under known fire regimes.
** Vegetation response to reintroduction of fire.
** Vegetation response to fire exclusion.
** Studies of succession on specific soil series under fire exclusion.
* Degree of fuel continuity.

Details in some published studies are adequate to determine whether or not the results are site frequencies. Guyette and Cutter (1991) compiled a fire scar chronology of an area of post oak savanna in Missouri about 2.5 square kilometers in size. Their maps of widely spaced trees scarred by the same fires over this whole landscape indicate that this was part of a single fire compartment, perhaps much larger than the study area. Later studies by Guyette and Dey

(1995) on a 1 square kilometer site, by Dey and Guyette (1996) on a 1/2 square kilometer area of a white pine (*Pinus strobus*)-red pine (*Pinus resinosa*)-red oak (*Quercus rubra*) stand in Ontario, and by Caprio and Swetnam (1995) in individual giant sequoia (*Sequoiadendron giganteum*) groves, also appear to be site frequencies.

Classifying Ecological Fire Regime Types

Heinselman (1973) used a combination of fire frequency and severity to define seven fire regimes, with emphasis on crown fires of the kinds experienced in the Boundary Waters Canoe Area of Minnesota. Agee (1981) applied this system to forests of the Pacific Northwest and related fire severity to percent basal area of trees removed. Barrett and Arno (1991) used a different system to classify fire regimes on the Selway-Bitterroot Wilderness in relation to vegetation type and topography. More recently, to facilitate communication among foresters, a simplified classification of fires was made into 3 categories; nonlethal, stand replacement, and a mixture of these two, a "mixed fire regime" (Brown 1995, Brown et al. 1995a). Previous fire regime classifications have been mostly concerned with effects on timber species (Barrett and Arno 1981, Brown 1995). I have attempted here a more detailed ecological classification of fire regimes according to factors that appear to be of importance in determining vegetation structure and in maintaining habitat for understory species, including fire-dependent rare plants. Each fire regime is identified by a four-character code, including characters for periodicity, season of burn, frequency, and ecological fire effects (Table 4.4).

Periodicity. In this category, fire-return intervals are classified roughly into nonrandom (regular or predictable), irregular, and polycyclic. A limited number of published studies to date (Bragg 1991, Touchan et al. 1995), report standard error for the variation around the mean fire-return interval, which would be useful for distinguishing between regular and irregular fire-return intervals. In the absence of such statistics from the majority of studies, I have classified these categories subjectively and tentatively. On the face of it, fire-return intervals may appear to be irregular but sometimes are more or less tightly clustered around a mean. This might be expected since it may take a certain number of years for fuel patches in xeric ecosystems to coalesce to provide continuity for fire, or for a particular community to accumulate enough cured fuel to carry fire. I analyzed a cross-section of pyrophytic baldcypress (*Taxodium distichum*) from a

peatland in Pamlico County, North Carolina that dated from the year 1262 and had 729 rings. Fire scars and ring width measurements indicated a fairly regular fire-return interval in the pre-European era. The range was 4 to 25 years but most fires were clustered around the 12.8 year mean fire-return interval. In this case, a degree of regularity may have been imposed by the time required for fuel development in the fire source, a large, flammable pocosin that graded into the cypress stand. More work is needed on the relationship of fuel development to fire-return interval.

The term polycyclic was coined to describe communities with two or more kinds of fire cycle. In the southern Appalachians, fire history work with pitch pine (*Pinus rigida*)-Table Mountain pine (*P. pungens*) stands (Frantz and Sutter 1987, Sutherland et al. 1995), along with my own unpublished work in Linville Gorge, show that the typical fire regime on dry south slopes consists of a short cycle of fairly regular understory shrub-reduction fires, about 5-7 years apart, interrupted periodically by the long cycle of catastrophic stand-replacing fires about 75 years apart. Heinselman (1981) reported stands of red pine in the Lake States that were subject to three kinds of fire cycle on the same site: light, nonlethal understory fires; hotter, canopy-thinning understory fires, and stand-replacing fires. These cycles within cycles also account for much of the variability in some mixed-species northern and western conifer stands (Barrett and Arno 1991, Brown 1995).

Season of burn. Communities were also coded for primary season of burn. In the Southeast, fire season begins in February-March in Florida (Myers and Ewel 1990), while to the north, in the southern Appalachians, the frequency of lightning ignitions, as well as the amount of land burned, both peak in May (Barden and Woods 1973). Bragg (1982) found the highest probability of fire in Nebraska prairies to peak in midsummer, with potential fires any time during the lightning season from March through November. Spring has been reported as the principal fire season in the Southwest (Pyne 1982), although large lightning fires are often ignited by summer thunderstorms.

In summer, convection storms create a background of lightning ignitions across most of the country and this may be the peak fire season in many areas. Swetnam et al. (1988) found the dominant presettlement fire season to be early or mid growing season at a site in southeastern

Arizona, and Grissino-Mayer and Swetnam (1995) found that fires occurred throughout the growing season in southwestern New Mexico. In parts of the West, fire season culminates in August and September when senescent vegetation cures and becomes increasingly flammable. High temperatures and extreme low humidities then create severe burning conditions (National Wildfire Coordinating Group 1981).

Fire frequency. Polygons were classified by the frequency with which fire occurred. Fire-return intervals were divided into seven classes: 1-3 years, 4-6 years, 7-12 years, 13-25 years, 26-100 years, 100 to over 500 years, and never burned. The more frequent classes are more finely divided because there are many herb layer species, especially some rare plants, which appear to be limited to specific frequent-fire regimes (Frost 1995, Frost 1998).

Ecological fire effects. The fourth letter in the fire regimes code represents ecological effects of fire. Previous classifications of fire regimes have focussed largely on fire effects on trees. Most species diversity, however, occurs in the herb layer. The herb stratum provides habitat for the overwhelming majority of rare plants, and much of the species diversity used as food by wildlife. The following classification emphasizes fire effects on total vegetation structure. The ten fire effects categories are arranged roughly in order of increasing magnitude of ecological consequences.

a. Nonpyrophytic communities includes those that are completely fireproof, such as tupelo swamps (*Nyssa aquatica*) with standing water, sparse vegetation clumps above treeline, talus slopes, rock outcrops, lava flows in the pioneer stages of succession, and completely barren deserts, playas and salt flats. It also includes some arid land vegetation lacking sufficient fuel continuity to carry fire.

b. Oligopyric sites ordinarily do not burn because of wetness or lack of fuel continuity, but may carry a surface fire under extraordinary conditions of wind or drought. This includes arid land vegetation a little denser than in nonpyrophytic sites, or wet sites like some swamp black gum (*Nyssa biflora*) swamps, where prolonged drought can dry out leaf litter enough to carry surface fire.

TABLE 4.4. CODING FOR FOUR COMPONENTS OF FIRE REGIMES

Fire regimes are assigned 4-character codes according to the scheme below. For example, the fire regime for Ponderosa pine stands on the east slopes of the Oregon Cascades might be designated Ns2c: this could describe a particular site (fire compartment) where fairly regular late summer fires have occurred approximately 5 years apart, and the fires are typically light surface fires, reducing grass, shrubs and litter, while leaving trees intact. Where information was lacking in the original report I have estimated the seasonality, season of burn, or fire effects components. Fuel models refer to those of the ***National Wildfire Coordinating Group (1981). Note that ecological fire effects don't correlate well with fuel models***

Codes for Periodicity of the Fire Cycle:[1]

N Nonrandom (clustered around a mean fire-return interval)
I Irregular (tending toward random fire intervals)
P Polycyclic (more than one kind of cycle)

Codes for Primary Season of Burn:

p Spring
s Summer
f Fall
w Winter

Codes for Fire Frequency Classes (site mean fire-return intervals):

1 1-3 years
2 4-6
3 7-12
4 13-25
5 26-100
6 100-500+
7 Never burned

Codes for Ecological Fire Effects on Vegetation:

a Nonpyrophytic (No fuel model).
b Oligopyric (No fuel model)
c Light surface fire, trees present (Fuel models 1, 2, 8, 9)
d Grass reduction (Fuel models 1, 3).
e Understory thinning (Fuel models 9, 10).
f Understory reduction (Fuel models 7, 9, 10)
g Shrub reduction (Fuel models 4, 5, 6)
h Canopy thinning (Fuel models 4, 6, 7,)
i Stand replacing (Fuel models 6, 10).
j Ground fire (Beneath fuel models 1, 4, 6, 10).

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[1]Sites with mean fire-return interval more frequent than 10 years were arbitrarily assigned to the clustered category.

c. Light surface fire refers to fires in hardwood leaf litter, thin grass, some forb-dominated communities, and light conifer litter. Typical situations include eastern oak-hickory forests with closed or partly open canopies, arid grasslands, frequently burned longleaf pine (*Pinus palustris*) and ponderosa pine (*Pinus ponderosa*) forests, and some Douglas-fir (*Pseudotsuga menziesii*) and larch (*Larix occidentalis*) stands. Effects include removal of litter, reduction of grass and small woody stems (reduction means removal of aboveground biomass or killing stems to ground, whether or not they resprout). If frequent, they lead to bilayered stands with only tree canopy and herb layer.

d. Grass reduction refers to fires in grass-forb dominated communities like marshes, shortgrass and tallgrass prairie, eastern piedmont prairie, and western intermontane valley prairie, longleaf pine savannas (sparse trees), mountain grassy balds and meadows. Most are dominated by perennial grasses and forbs that are reduced to the ground but quickly resprout from belowground rhizomes and other storage structures. Intensity can vary highly but is of little ecological importance since the result is the same--the stand is burned to the ground. Most live and dead fuel is consumed down to the mineral or wet muck substrate, even in marshes.

e. Understory thinning fires may be very light, only removing shrub and sapling stems up to 2 or 3 centimeters diameter, or they may burn hot enough to remove selected large subcanopy stems. If frequent, they dramatically restructure the community into bilayered stands with a tree canopy over a rich herb layer.

f. Understory reduction occurs in stands with flammable shrubs or heavy woody fuel accumulations in the understory. Fires are sufficiently intense to clean out everything but the canopy trees, most of which survive but may be heavily scorched. Some understory species may be killed outright while others resprout. Examples are pitch pine/ericad shrub communities of the New Jersey Pine Barrens, Table Mountain pine/ericad communities in the southern Appalachians, longleaf pine/*Serenoa repens* flatwoods in the southern Atlantic coastal plain and *Sequoiadendron giganteum-Pinus lambertiana/shrub* communities in California.

g. Shrub reduction describes shrub-dominated communities in which fires are typically intense and all stems are reduced to the ground. These include chamise, chaparral, some sagebrush

types, canebrakes, low pocosin and high pocosin. Most eastern species are prolific resprouters, while western shrublands include some species that do not resprout.

h. Canopy thinning occurs when fuel loadings, fuel moisture and wind create prolonged or severe fire behavior but fall short of initiating crown fire. This is seen in communities dominated by Douglas-fir and many other western conifers (Wright and Bailey 1982, Barrett and Arno 1991), red pine in the Lake States (Heinselman 1981) and I have seen this effect in pitch pine/Table Mountain pine stands in the southern Appalachians.

i. Stand replacing fire includes both crown fires and lethal understory fires (Barrett and Arno 1991). In either case, canopy stems are killed to the ground. Most trees are killed outright, while a few species, like pond pine (*Pinus serotina*), quaking aspen (*Populus tremuloides*), and many other hardwoods, can resprout from the ground.

j. Ground fire. Whatever the surface vegetation and fuel, fires sometimes ignite organic substrate. Peaty material may burn down to expose mineral soil, or may initiate ponding, followed by a decades- or centuries-long succession of plant communities while new peat is formed.

Fire spread. The mean extent of area burned by fires is another significant variable in fire regime. The fire compartment is the most accessible unit of area in defining the typical area burned. Under severe burning conditions, however, with fires accompanied by low humidity, low fuel moisture, high temperature and high winds, all bets are off, and fire may easily flow through topographic and vegetation features that would serve as firebreaks under ordinary conditions. Fires once burned multi-state areas as large as the 282 kilometer fire across the landscape of Kansas and Texas reported in 1885 (Haley 1929, in Bragg 1995). Determining spread of presettlement fires requires constructing master fire chronologies by cross dating fire scars on trees scattered over a broad landscape. Composite fire scar chronologies developed by Baisan and Swetnam (1995), Caprio and Swetnam (1995), and Touchan et al. (1995), in the Southwest, show a pattern of frequent fires of limited extent, perhaps compartment fires, punctuated at longer intervals by fires that spread over the larger landscape. Because of the paucity of studies with composite fire chronologies in most of the U.S, however, no attempt was

made to assign fire spread values to the studies in Table 4.5.

RESULTS AND DISCUSSION

Table 4.5 is a sampling of fire history work reported in the literature, to which has been added the fire regime classification according to the scheme above. Values in the table were those reported by the original authors or were interpreted from data presented. Missing information was sometimes inferred from other work in the same region. The map was based largely on the studies cited.

Fire Frequency Map

Figure 5.1 represents local site fire-return intervals for the most fire-exposed parts of the landscape, especially flats, dry uplands and south slopes. This should not be taken, however, to mean that the whole landscape burned at those frequencies. Varying proportions of the land within each map polygon were sites naturally protected from fire. Fire-safe sites in lowlands, for example, include islands, peninsulas (Harper 1911), some swamps and some fluvial bottomlands. On uplands, naturally fire-sheltered sites include north slopes, mountain coves, ravines and steep-sided stream valleys, and portions of the landscape where waterways block fires swept by prevailing winds.

The map represents the highest fire frequencies commonly found within each region. For a particular fire frequency to be assigned to a polygon on the map, at least 10% of the landscape had to be judged to have had presettlement fire frequency that high. In some areas, such as tallgrass prairie or the southeastern coastal plain, the frequencies shown probably applied to 50% to 90% of the landscape. In some of the lower fire frequency polygons there are small areas that had higher frequency but did not seem extensive enough to meet the 10% criterion. The reason for emphasis on the higher fire frequencies that might be found in each region was to draw attention to the widespread distribution of landscapes with high presettlement fire frequency, and to the pervasive effects this had on woody vegetation structure, the herb layer, and habitat for species that are now rare.

TABLE 4.5. SITE FIRE FREQUENCIES REPORTED FOR PRESETTLEMENT VEGETATION TYPES

REPORTED FIRE FREQUENCY	FIRE REGIME TYPE	VEGETATION TYPE, AUTHOR, STATE
1	Np1g	Low pocosin/bog (Emmons 1860, Ruffin 1861, NC)
1-2	Np1d	Wet savannas--Venus flytrap sites (Frost, 1998, NC)
1.8	Np1d	Ponderosa pine (Dieterich 1980, AZ)
2	Np1g	Sandhills canebrakes (Hoffman, personal communication, NC)
1-3	Np1d	Longleaf pine savanna (Chapman 1926, LA)
1-5	Np1d	Oligohaline marsh (Frost 1995, VA, NC)
1-5	Np1g	Peatland canebrakes (Hughes 1966, NC)
2.2-13	Ns1c	Giant sequoia (AD 1000-1300, Swetnam 1993, CA)
3.2	Ns1c	Cedar glade (Guyette and McGinnes 1982, MO)
3.4	Ns1c	Mixed oak forest (Sutherland, 1997, OH, historic period)
4.3	Ns2d	Post oak savanna (Guyette and Cutter 1991, MO)
4.8	Ns2d	Sandhills prairie (Bragg 1991, NE)
3-7	Np2d	Ponderosa pine (Boucher and Moody, 1998, NM)
5	Ns2e	Table Mountain pine (Sutherland 1995, VA)
4-6	Np2d	Brackish marsh (Frost 1995, NC)
4-6	Ns2c	Pyrophytic oak-hickory woodland (Frost 1995, 1996, NC, SC)
5.4	Ns2c	Ponderosa pine (Baisan and Swetnam 1995, MEX)
5.5	Ns2c	Ponderosa pine (Kilgore and Taylor 1979, CA)
5.7	Ns2d	Ponderosa pine (Grissino-Mayer and Swetnam 1995, NM)
7/75	Pp3f/Ps5i	(Polycyclic) Appalachian pitch pine (Frost, 1998, NC)
7.5	Np3d	Ponderosa pine (Jenkins et al., 1998, UT)
4.8-11.9	Np3d	Ponderosa pine (Weaver 1951, AZ, NM)
6-11	Ns3c	Douglas-fir (Arno 1976, MT Bitterroot Valley)
6-11	Ns3c	Ponderosa pine (Arno 1976, MT Bitterroot Valley)
7-10	Np3d	Aspen/grass (Baker 1925, UT)
9	Is3c	Lodgepole pine (Wright and Bailey 1982, Rocky Mountains)
~9/~43	Ps3c/Ps5i	(Polycyclic) Ponderosa pine (Baisan and Swetnam 1995, NM)
9.2	Ns3c	Giant sequoia (Kilgore and Taylor 1979, CA)
10	Ns3d	Desert grassland (Leopold 1924, southern AZ)
10.8	Ip3c	Douglas-fir (Wright and Bailey 1982, AZ)
10.9	Is3c	Incense cedar-sugar pine (Kilgore and Taylor 1979, CA)
11.8	Is3c	Red pine (Guyette and Dey 1995, Ontario)
10-18	Is4f	Giant sequoia (Kilgore and Taylor 1979, CA)
5-30	Ip4d	Grass-sedge fens (Heinselman 1981, MN)
10-30	Is4h	Pinyon-juniper (Leopold 1924, southern Arizona)
15-30	Is4h	Douglas-fir (Arno 1976, northern Rockies)
25	Is4f	Coast redwood (Fritz 1931 CA)
20-30	If4d	White pine (Wright and Bailey 1982, Lake States)
20-30	Ns4g	California chaparral (chamise) (Sweeney 1956, CA)
20+	Ns5g	Arizona chaparral (Cable 1975, AZ)
36/160	Ps5f/Ps6i	Red pine-white pine (Heinselman 1981, MN)

1-25/26-99/100-300	Ps4f/Ps5h/Ps6i	(3 kinds of cycles) Red pine (Heinselman 1981, Lake States)
25-40	Is5i	Black spruce (Wright and Bailey 1982, Lake States)
29-37	Is5f	Red pine (Burgess and Methven 1977, Ontario)
17-41	Is5g	Sagebrush-grass (Houston 1973, Yellowstone, WY)
25-50	Is5f	Lodgepole pine (Arno 1980, Northern Rockies)
20-60	Is5i	Sand pine (Cox and Roberts, 1998, FL)
43/117	Is5h/Is6i	Lodgepole pine-subalpine fir (Barrett and Arno 1991, ID- MT)
50	Is5i	Jack pine (Van Wagner 1978, MN)
72/181	Is5h/Is6i	Whitebark pine-subalpine fir (Barrett and Arno 1991, ID- MT)
50-300	Is6i	Peatland baldcypress (Frost 1995, NC)
25-300	Is6i	Peatland Atlantic white cedar (Frost 1987, 1995, VA, NC)
150-500	Is6i	Douglas-fir (Franklin et al. 1981, West Coast)
200	Is6i	Western hemlock (Wright and Bailey 1982, West Coast)
700-800	Is6i	Sitka spruce (Wright and Bailey 1982, northwest coast)
700-800	Is6i	Pacific silver fir (Schmidt 1957, Pacific Northwest coast)

Wherever possible, published fire scar chronologies were used for mapping, since these represent real data points in the landscape. Paradoxically, in the most frequently burned areas, fire scar dating is not always instructive since the resulting low-intensity fires may not produce any scarring. The more frequently a community is burned, the less intense will be the fires. For example, in Gates County, North Carolina, I examined a stand of 300-year-old longleaf pine that had experienced perhaps 100 fires over their lifetime, but not a single tree was scarred. By extension, underestimates may also occur with the most frequently burned ponderosa pine, larch and other species, especially in lands where Indians carried out annual burns (Timbrook 1982). It seems likely that the fire-return intervals shown on the map are conservative. Thus, some of the areas mapped as having fire at 7-12 year intervals, may in reality have burned as frequently as 4-6 years, and some of the areas mapped 4-6 years may have burned at the 1-3 year interval. In prairies, Bragg (1982) found that areas burned in March accumulated enough fuel for a second fire in October or November, raising at least the possibility of a greater than annual fire frequency.

At the other end of the fire frequency spectrum, stand-replacing fires occurred at intervals ranging from 25 years (Heinselman 1981, Frost 1995) to more than 700 years (Schmidt 1957). Heinselman divided these into three interval classes in the Lake States, and examples may also be found in many other parts of the country:

1) short return interval (25-100 years). In the East this includes jack pine, sand pine (*P. clausa*),

black spruce (*Picea mariana*) and some pitch pine and Table Mountain pine. It also includes some Atlantic white cedar (*Chamaecyparis thyoides*) stands, especially those on the margins of the great peat bogs of northeastern North Carolina (Frost 1995). In the West, it includes aspen and a variety of mixed conifer stands (Agee 1981).

2) long return interval (100-300 years). In the eastern U.S. this interval occurred in white cedar of the interior of the Great Dismal Swamp of Virginia and North Carolina (Frost 1995), and in a few small areas of white pine in various mixtures with eastern hemlock (*Tsuga canadensis*), white spruce (*Picea glauca*), red spruce (*Picea rubra*), red pine, balsam fir (*Abies balsamea*), sugar maple (*Acer saccharum*), beech (*Fagus grandifolia*), yellow birch (*Betula lutea*) and red maple (*Acer rubrum*), along the northern U.S. border from Michigan to Maine (Heinselman 1981).

3) very long interval (more than 300 years). No intervals much longer than 300 years have been reported from the eastern U.S. In the West, however, a number of late seral conifers like Pacific silver fir (*Abies amabilis*), may be associated with catastrophic fire intervals up to 700-800 years (Wright and Bailey 1982).

Contrasts Between Eastern and Western Fire Ecology

In comparing fire ecology of vegetation of the eastern and western U.S., salient differences arise in terms of stand-replacing fires and in the periodicity of shrub fires. Stand replacement is the primary mode of regeneration for a number of conifers. In the East, the majority of natural stands of jack pine, black spruce, sand pine, pitch pine, Table Mountain pine and Atlantic white cedar were initiated by crown fires in previous stands of the same species. In western conifers, where fire regimes are more polycyclic, a variety of kinds of nonlethal understory fires may occur before a stand is killed by a catastrophic fire. Stand-replacing fires are often reported in upland stands of lodgepole pine (*Pinus contorta*), some Douglas-fir stands, Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), western redcedar (*Thuja plicata*) and grand fir (*Abies grandis*)(Barrett and Arno 1991).

In another striking contrast between East and West, the eastern species listed above

usually replace themselves immediately from seed, so that all fire does is replace an even-aged old stand with an even-aged new stand of the same species (jack pine, black spruce, sand pine, white cedar). In contrast, crown fire in western conifers often initiates a long succession beginning with early seral species, which are replaced by late seral species as the stand ages and the early species die out. In the minority, quaking aspen resprouts from the roots after fire (Fowells 1965), and a parallel occurs in the East with pond pine, which resprouts from the base after intense pocosin fires.

Behavior and frequency of fire in shrub communities also differ between East and West. Chamise (*Adenostoma fasciculatum*) in California chaparral has been reported to require about 20 years between fires in order to accumulate enough size and dead wood to carry fire (Sweeney 1956). In contrast, southeastern canebrakes and some pocosins can burn every year or two (Emmons 1860, Hoffman 1994, Frost 1995). Chamise and chaparral burn with varying intensity depending upon shrub density, fuel moisture, humidity, temperature and wind. In canebrake and pocosin, fires either go or they don't. When they go they burn hot, and flame lengths of 12 meters are not uncommon.

Pre-European Ignition Sources: Lightning Versus Native Americans

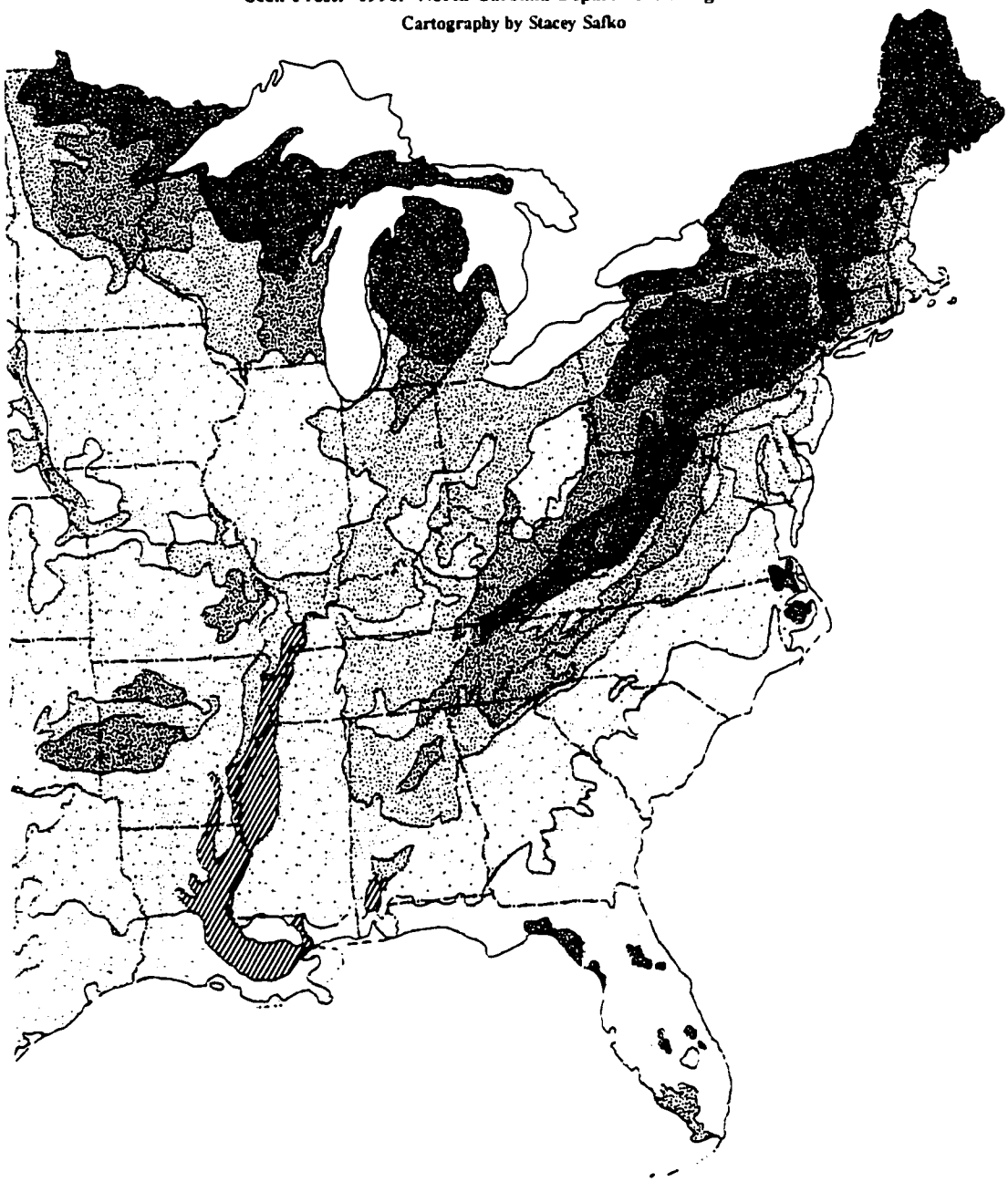
Figure 5.1 shows fire frequency regions of the U.S. under the natural presettlement lightning fire regime, augmented in many places by Indian burning. The work by Komarek (1964, 1968, 1974) provided background on the role of lightning, and Pyne (1982) summarized the evidence for the Indian component. While there are many records of Indian burning, there is no consensus yet on the relative effects of Indian fires versus lightning ignitions. It seems likely that the effects of Indian burning varied drastically, and that whether or not Native Americans significantly influenced the local fire regime depended upon the background lightning fire regime associated with the landscape they lived in. This ranged from landscapes in which lightning ignitions are so frequent that effects of any Indian burning may have been negligible, such as the southeastern coastal plain, to lightning-infrequent regions where dense forest may have prevailed but for regular Indian burning, such as the Willamette Valley of Oregon (Agee 1993), or coastal California (Timbrook 1982).

Figure 4.1. First approximation map of presettlement fire frequency regions of the U.S. The frequencies illustrated represent the higher fire-return intervals to be found in each landscape unit.

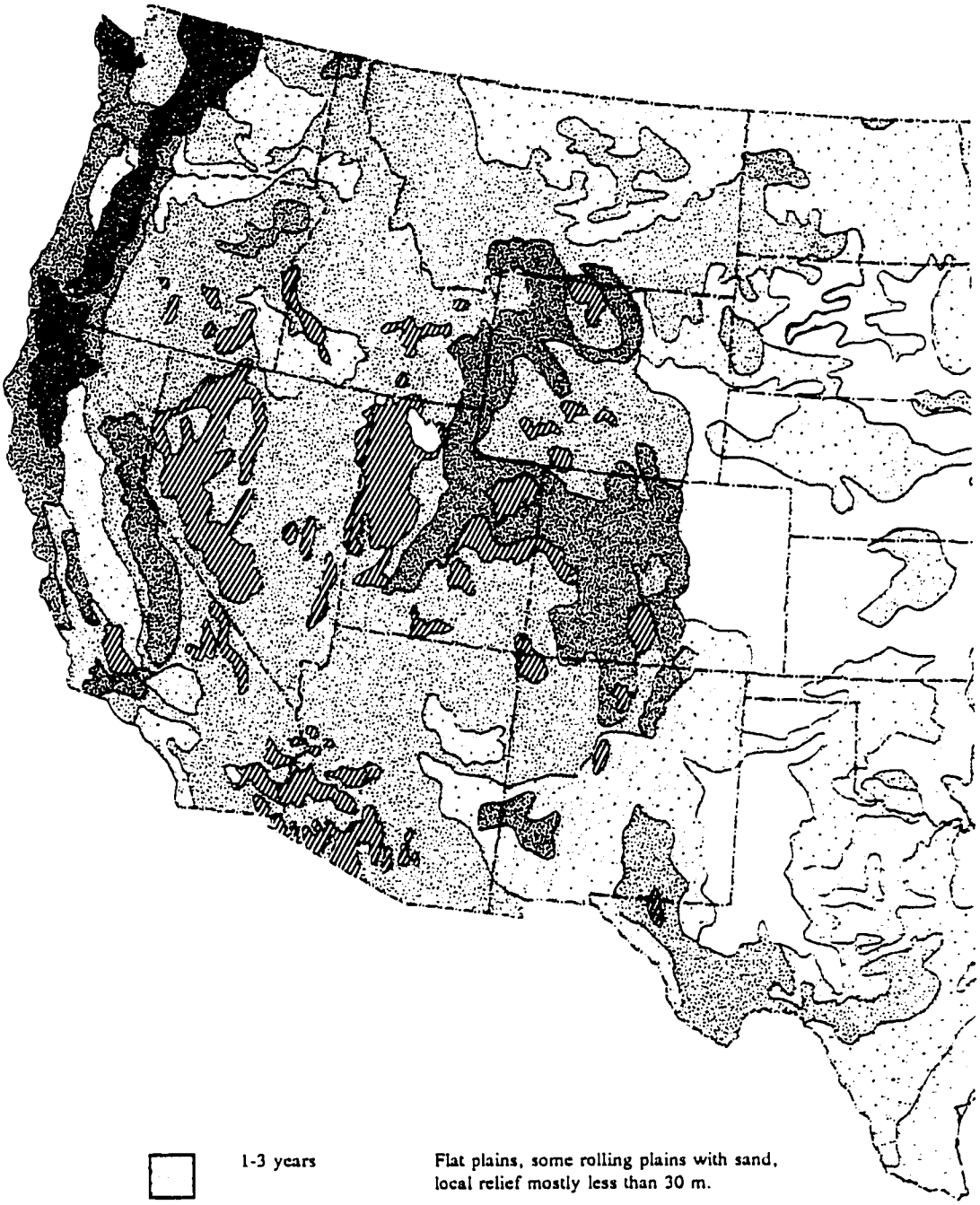
PRESETTLEMENT FIRE FREQUENCY REGIONS OF THE UNITED STATES

Cecil Frost. 1996. North Carolina Department of Agriculture

Cartography by Stacey Safko



■	100-500+ years	Vegetation that is topographically fire-sheltered and ordinarily too moist to support fire. Fire is the result of rare climatic events such as prolonged drought in combination with hot, dry winds. Found on land-surface form extremes from flat plains (peatlands) to high mountains.
▨	Nonpyrophytic	The wettest cypress and tupelo swamps, some bottomland hardwoods, barren deserts, salt flats, playas, cactus and xerophytic vegetation too sparse to carry fire. Also a variety of sites too small to map, such as dunes, talus slopes above treeline and rock outcrops. Found on the land surface-form extremes of flat plains (swamps, deserts) and high mountains. Some have small components that burn.



1-3 years	Flat plains, some rolling plains with sand, local relief mostly less than 30 m.
4-6 years	Irregular plains and tablelands, local relief mostly 30-90 m.
7-12 years	Tablelands, plains with hills and open low mountains, local relief 90-900 m, but also some high mountains in dry regions.
13-25 years	Plains with hills or low mountains, tablelands with moderate relief, fire-tension zones between frequently burned and fire-sheltered vegetation, vegetation with fuel development structure that discourages frequent burns.
26-100 years	Low mountains, some high mountains with high rainfall, northern spruce-fir lowlands, hills where all the land is in slope and rainfall is moderate to high.

Native Americans appear to have shifted the seasonality the fire in many areas (Bragg 1995). In northern mixed-grass prairie of the Dakotas, over 70% of lightning fires occur during July and August (Higgins 1984), but fires ignited by Native Americans from 1630 to 1920 exhibited two peaks, one in April and the second in October (Higgins 1986). In the southern mixed-grass prairie, however, the burning peak by Indians in mid- to late summer coincided with the lightning ignition peak (Moore 1972). In pre-European times, any post-lightning season fires in fall and winter would have been the result of burning by Native Americans. Byrd (1728) described the smoke from late fall Indian fires while surveying the Piedmont portion of the boundary line between Virginia and North Carolina.

The Atlantic and Gulf coastal plains were regions of almost annual fires over a large part of the landscape (Frost 1995), and it seems likely that in most years lightning preempted the fuel that Indians might have used. This also is the region with the most clearly fire-dependent plant species. Despite some skepticism (Agee 1993), there do seem to be distinctly fire-dependent species, and in the southeastern U.S. some, like *Lilium iridollae*, *Lysimachia asperulifolia*, *Parnassia caroliniana* and many other rare species, seem to require a 1-3 year fire-return interval (Frost 1995). My ongoing plot studies in the Green Swamp of North Carolina indicate that one of the most fire-dependent species, Venus's flytrap (*Dionaea muscipula*), dies out when fire-return intervals become longer than 3 years.

Since any dependency on fire must involve evolutionary time, it seems unlikely that any rare species in the U.S. were dependent upon Native American burning. Indians have occupied North America only since the last glaciation--a relatively short time in evolutionary terms. Some long-lived species such as the redwoods have only undergone a few generations in that time. It follows that any truly fire-dependent species are lightning-ignition dependent. The remarkable adaptations of extreme frequent-fire species like longleaf pine and Venus's flytrap are unlikely to have appeared in the 10,000 years since the end of the Wisconsin glaciation, and may well have taken hundreds of thousands of years to evolve during previous interglacials. The existence of highly fire-adapted species is, in fact, a line of evidence for the greater importance of lightning ignitions over Indian burning in the in the southeastern coastal plain (Komarek 1964). It remains to be demonstrated whether there are any species that are truly dependent upon frequent fire in

the West.

On the other side, the relative importance of Indian fires should be expected to increase in topographically complex areas where fire compartments are smaller, and in regions with infrequent lightning ignitions. There are documented instances of changes in fire regime associated with Native American movements in such areas. In Missouri post oak savanna, fire frequency decreased after 1820 when the Osage and other Indian tribes began leaving in advance of European settlement (Guyette and Cutter 1991). In the giant sequoia-mixed conifer forests of California, there was also a drop in fire-scarring after elimination of burning by the Yokut and Monache Indians in the early 1870's (Kilgore and Taylor 1979). Conversely, an increase in fire with the appearance of Iroquois settlements between 1360 and 1650 has been inferred by charcoal deposition detected in annually laminated lake sediments (Clark et al. 1996).

Native Americans were probably the more important ignition factor in at least the northeastern U.S. and the Pacific coastal fringe. In some places, regular Indian burning created isolated grasslands where forest otherwise would have prevailed. Examples are as widely scattered across the country as the Willamette Valley of Oregon (Agee 1993), the Shenandoah Valley of Virginia (Pyne 1982) and piedmont prairies of the Carolinas (Logan 1859).

Native American burning across the U.S. was carried out against a background of lightning ignitions, and the lightning pattern on the landscape is complex (MacGorman et al. 1984). Hot spots occur in places like isolated mountain ranges while ignitions may be rare in the surrounding lowlands (Agee 1993:29). In the southeastern U.S. there are only a few records of Indian burning on the coastal plain, yet this is one of the highest fire frequency regions in North America. The coastal landscape also happens to be one of the physiographic regions with the largest fire compartments, many over 1,000 square kilometers without a natural firebreak. In Florida, lightning fires were a daily occurrence. Over two lightning seasons, 1962 and 1963, there were 1,146 and 1,048 lightning fires, respectively, in the 60% of the land area of Florida reporting (Komarek 1964).

On the other hand, there were hot spots of Native American burning in the vicinity of their settlements (Clark 1996). It should be possible to use physiography, climate, historical

records of vegetation, and Indian history to map relative importance of Indians to lightning in maintaining the presettlement fire frequencies found in different parts of the country. When we get around to comparing maps of historical Indian burning with maps of lightning ignition frequency, we will find that the interplay between lightning and Native American ignitions was complex, with "hot spots" resulting from each.

If we could distinguish the proportion of fire frequency due to Indians from that caused by lightning, it might raise the question of whether to manage lands for vegetation at only the lightning background frequency or to manage for the pre-European frequency, which was a combination of Native Americans and lightning. I suggested that we accept presettlement vegetation as the model for management of lands with natural vegetation since it had been around for some 6,000 years, in substantially stable composition despite oscillations in rainfall and local effects related to movement of Native American settlements. If we do so, then it makes sense to include effects of Indians in the model, since they had the entire 10,000 years of the Holocene using fire to shape the vegetation we inherited (Pyne 1982). In some areas, such as the prairie region, it is impossible to separate lightning and anthropogenic effects, since Native American immigration and use of fire actually preceded development of the Holocene grasslands (Bragg 1995).

Ultimately, within the stated objectives of this paper, it is not at all necessary to separate the relative effects of Indians and lightning. The first objective was to develop a first approximation map of presettlement fire frequency regimes. This represents a window ranging from around 1565 to around 1890. The map is derived from findings of fire history studies, fire frequency indicator species and historical records. As such it represents the actual role of fire in the presettlement landscape, regardless of the ignition source.

CONCLUSION

From Figure 5.1 it becomes evident that more half the country contained large areas in which fire occurred at intervals between 1 and 12 years, while fire played some role in most of the rest. Thus the pre-European United States should be considered a fire landscape. Frequent light fires would have maintained bilayered stands with canopy and often dense, species-rich

herb layers. Light, understory-thinning fires may have been the norm for millions of hectares of eastern hardwood forest, some Douglas-fir, and other western types. In modern fire-suppressed forests, however, herbs may be nearly eliminated by the dense litter buildup (Frost 1998). Many rare fire-dependent and shade-intolerant species are the first to go. The continent-wide loss or depauperization of the pyrophytic herb layer following 20th century fire suppression is one of the ecological catastrophes of landscape history.

In restoring fire, it is obvious that in the East, with its smaller islands of natural vegetation, we will have to be the future ignition source, with lightning a very minor partner. In the West, however, lightning will play a role, but will require human participation if we are to restore a more natural fire regime in place of the fire-suppression/fuel buildup/catastrophic wildfire cycle that has become pandemic. Important lines of research will include construction of detailed presettlement vegetation maps at the soil series level, and maps showing local presettlement fire regimes, so that appropriate land management decisions may be made.

Until recently, most fire history work using fire scars has been done in the West where virgin stands of species like ponderosa pine have conspicuously fire-scarred bases. It has been long assumed that trees in the East rotted out too quickly to permit such methods. Recent fire scar analyses (Sutherland et al. 1995, Sutherland et al. 1997, Caljouw et al. *this volume*), which cover the early settlement period in Ohio and the southern Appalachians, challenge this assumption.

The Western Hemisphere is so recently settled that the record of presettlement vegetation and fire frequency is still available in historical records, in herbarium records of fire frequency indicator species, in vegetation remnants, and within the rings of trees still standing. It is still possible to map or construct a reasonable approximation of presettlement fire history and vegetation of the entire United States at the soil series level. There remains only to do the work.

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CHAPTER 5

ARE THERE FIRE DEPENDENT SPECIES?: EVIDENCE FROM VENUS FLYTRAP AND ROUGH-LEAVED LOOSESTRIFE

ABSTRACT

In the southeastern United States the majority of rare plants appear to be fire-dependent species. Fire dependency may be of two types; dependency on direct effects of fire, such as scarification of seeds by the passing heat pulse, or dependency on indirect effects, such as removal of litter and competing species, especially small woody stems. Whether effects are direct or indirect, the dependency is real: without fire the species will go extinct. This may happen within a few years, as appears to be the case with the most fire-frequent species, or might be a matter of slow decline, with a species eliminated from its best habitat but clinging to a marginal habitat refuge for decades before extinction. This seems to be the case with many rare plant species. In 16 years of monitoring survival of Venus flytrap and other species, it became apparent that two factors must be considered when studying the effects of fire interval on survival. First is the time since last fire, since some species will be lost if a single interval is too long. Second is recent fire history, since it was found that there is a cumulative effect of the spacing and intensity of recent fires on plant vigor and survival. For frequent-fire communities, the 10 year mean fire-return interval may be the most significant basis for management decisions. With its requirement for 1-3 year fire, Venus flytrap appears to be the most fire-dependent species thus far documented. Beginning with rare species, we need to study response to fire of every species in our flora, and accumulate that knowledge for managing habitats. If the responses of the individual species to fire are known, and the presettlement fire frequency for the site can be reconstructed, it should be possible to predict the presettlement community composition of specific sites. This will be essential for restoring and managing natural areas and their species diversity. Such management will be required in perpetuity for fire-dependent species.

KEY WORDS: Fire ecology, Fire-dependent species, Fire frequency, Fire return interval, Venus flytrap, *Dionaea, Lysimachia asperulifolia, Aristida stricta*, Rare species, Endangered species.

INTRODUCTION

Why do we need to answer the question "Are there fire-dependent species?" Those of us involved in the conservation of rare plant species increasingly tend to talk about the need to manage fire-dependent species, and to use this argument as justification in proposals for acquiring and protecting natural areas. From fire-history studies we know that there were frequent-fire regions in the presettlement landscape (Frost 1998, Chapter 4). There also is mounting evidence that many of the rarest native plant species in the southeastern U.S. occurred in the most frequent-fire regions. These were also the most species-rich portions of the landscape (Walker and Peet 1983, Walker 1985). Yet, while there is abundant evidence of the effects of fire on vegetation (Agee 1981, 1993, Bond and van Wilgen 1996, Frost 1998, Lemon 1949, Wright and Bailey 1982), there has been little concrete evidence to demonstrate that particular species actually require fire for their survival. There is even less in the literature to document that survival of any species might be dependent upon nearly annual fire. This paper presents the case for the existence of truly fire-dependent species in the southeastern U.S., including a suite of species that appear to require for their survival a fire-return interval of only 1-3 years.

Fire Dependence

Fire dependent plants may be defined as species that would have gone extinct had fire been removed from the presettlement landscape. For managed landscapes (most future landscapes) we might define fire dependent plants as species that, with reduction in fire frequency, will become extinct, or will be reduced to the status of rare plants occupying the most marginal parts of their habitat. Clinging to existence under adverse conditions, such species will be in constant danger and extinction probability will be increased. Extinction may just be a matter of time until some environmental change or anthropogenic event eliminates them from their refugial niche.

Kinds of fire dependence. Two types of fire dependence may be distinguished, direct or indirect dependence. Plants directly dependent on fire require fire to affect the plants themselves or their propagules. The first case includes plants that require something specific like the heat pulse of a

passing fire to scarify the seed. Peter's Mountain mallow (*Iliamna corei*), a federal endangered species endemic to a single site in the mountains of Virginia, has been shown to need such scarification (Baskin and Baskin 1997). Table mountain pine (*Pinus pungens*) and several other pine species require fire to open the serotinous cones and release seeds (Barden 1977). At present, little is known as to what extent direct effects may be significant for germination in the hundreds of herbaceous species of savannas, piedmont woodlands and mountain fire communities of the southeastern U.S.

Other plants may be indirectly dependent upon fire to create and maintain their habitat. What we have learned so far indicates that the most pervasive kind of dependence is that which relies on indirect effects of fire on habitat. Habitat is structured by fire and species depend on habitat. Fires create canopy openings, and frequent fires prevent development of multistoried woody layers, which otherwise would shade out the herb layer. Of equal importance, fires periodically remove litter buildup to expose a fresh seedbed and prevent smothering of herbaceous species beneath a blanket of leaves and pine needles.

Fire Effects: Ecological Fire Effects, Event Dependent Effects and Interval Dependent Effects

There are several ways to look at fire effects. In Chapter 4, I classified ecological fire effects into ten categories ranging from litter removal to stand replacement and substrate destruction. Bond and van Wilgen (1996) distinguish event dependent effects versus interval dependent effects of fire. Some species like Atlantic white cedar (*Chamaecyparis thyoides*), jack pine (*Pinus banksiana*) and sand pine (*Pinus clausa*) require, at long intervals, a fire hot enough to kill everything to the ground, permitting a new stand to arise from the seed bank. If the event is lacking in windspeed and sufficiently low humidity and low fuel moisture, crown fire will not occur. All these are environmental factors that come together to create a particular event. Other event dependent effects are fires hot enough to open pine cones, or fires at times when litter moisture is low enough to have it burn away, exposing mineral soil.

Interval dependent effects are related to fire frequency and the pattern of intervals between fires. Some species need the right fire interval to match their life cycle. In chaparral of the western U.S. and shrub communities of Australia, species composition of plant communities changes if fire interval is too short to allow the shrubs to mature and set seed (Cary and Morrison 1995). In contrast, fire is so frequent in the southeastern U.S. that the dominant threat is that species may

disappear if fire frequency declines below a critical level. This paper concerns several kinds of interval dependent effects.

Fire Frequency Requirements of Venus Flytrap

In the Green Swamp of North Carolina, plots for monitoring rare plant species were established in 1983 in Shoestring Savanna (Frantz et al. 1983). The Green Swamp is a 5,570 hectare (13,850 acre) Nature Conservancy preserve consisting of numerous moist, sandy savannas interspersed in a vast pocosin wetland. Dominant vegetation of the savannas is an open canopy of longleaf pine with a very species rich herb layer, having up to 42 species/0.25 m^2 and 84 species/625 m^2 (Walker and Peet 1983). Kologiski (1977) described the natural vegetation and environmental parameters of the Green Swamp. Mean annual rainfall at Wilmington is 1271 mm, at Southport a few kilometers to the east it is 1318, and at a U.S. Forest Service station 25 km north it is 1600 mm. The landscape is a flat coastal plain terrace—a Pleistocene sea floor dating from a time when sea level was higher than at present. The land surface lies about 15-18 meters (50-60 ft) above sea level. It consists of broad, poorly drained interstream divides with a slightly convex peat buildup to a depth of 2 meters in places. With the swamp being the highest point in the landscape, there is radial drainage and all the small streams, as well as the head of the Waccamaw River, originate in or around the periphery of the peatlands. The Green Swamp preserve is one of five remaining strongholds for Venus flytrap.

Flytrap is an insectivorous plant of wet, frequently burned sites, primarily savanna/pocosin ecotones. There doesn't seem to be any limit to how long Venus flytraps may live under a circumannual fire regime. Flytrap bulbs appear to be small, laterally spreading clones. Many of the plants mapped in 1983 were still in place in 1999. It is a rare species, endemic to a small area, and it is known to remain at only 110 sites. Its presettlement range included 18 counties in southeastern North Carolina and three adjacent counties in South Carolina. It has been extirpated from much of its former range and now occurs, in some cases in only two or three small patches, in 10 counties in North Carolina and in Horry County, South Carolina (Boyer 1995).

Habitat of Venus flytrap. Sites in all eleven counties in which Venus flytrap still can be found were investigated in the field (Boyer 1995). Of 60 sites examined, flytraps were found on 11 soil series, as indicated on soil maps. Of these, however, the Kureb and Baymeade soils are clearly too dry to support Venus flytraps, and on these soils as well as the areas mapped Foreston, Tomahawk and Mandarin the flytraps probably occurred in wetter soil inclusions in the mapped type, or on its wetland margin. The site on Muckalee, a fluvial soil, probably occurred on an inclusion of one of the

soils below. The five remaining soils, Leon, Lynchburg, Murville, Torhunta and Woodington, are wet, sandy soils with varying amounts of organic matter. These comprise the definitive soils for Venus flytrap. The number of mapped occurrences on each soil series, along with seasonal high water table and soil taxonomy are listed in Table 5.1 below.

	SOIL SERIES	W.T. DEPTH (FEET)	SOIL TAXONOMY
1	Kureb	6.0	Spodic Quartzipsamments, thermic, uncoated
1	Baymeade	4.0 -4.5	Arenic Hapludults, loamy, siliceous, thermic
1	Tomahawk	1.5 -2.25	Arenic Hapludults, loamy, siliceous, thermic
4	Mandarin	1.5 -2.5	Typic Haplohumods, sandy, siliceous, thermic
11	Foreston	0.5-3.5	Aquic Paleudults, coarse-loamy, siliceous, thermic
8	Lynchburg	0.5 -1.5	Aeric Paleaquults, fine-loamy, siliceous, thermic
2	Woodington	0.5-1.0	Typic Paleaquults, coarse-loamy, siliceous, thermic
3	Torhunta	0.5 -1.0	Typic Humaquepts, coarse-loamy, siliceous, acid, thermic
1	Muckalee	0.5 -1.0	Typic Fluvaquents, coarse-loamy, siliceous, nonacid, thermic
25	Leon	0.0 -0.5	Aeric Haplaquods, sandy, siliceous, thermic
3	Murville	+1.0 - 0.0	Typic Haplaquods, sandy, siliceous, thermic

Table 5.1. Soils as mapped at sites where Venus flytrap was found. Ranked from driest (Kureb) to wettest (Murville) on the basis of soil taxonomy and depth to seasonal high water table. Water table figures are depth from the surface for the seasonal high water table, mostly from December to April.

Fire compartment size and fire frequency in the range of Venus flytrap. The Green Swamp is part of a 900 square mile fire compartment. A fire compartment is a landscape component without major firebreaks, such that, under wildfire conditions in the presettlement landscape, when an ignition occurred, the whole compartment was likely to burn unless extinguished prematurely by rain or a rise in humidity or fuel moisture (Frost 1998). Fire frequency is directly proportional to fire compartment size so that the larger the fire compartment the higher the fire frequency (See Chapters 6 and 7). In the Southeast the largest fire compartments are on the undissected lower coastal plain terraces and in the Sandhills, and these are the physiographic provinces that appeared to support nearly annual fires historically (Frost 1998). With the largest compartments approaching 2,600 km^2 (1,000 mi^2), the Green Swamp region should have had one of the highest fire frequencies in the southeast. The apparent requirement of Venus flytrap for fire every 1-3 years, discussed below, provides supporting evidence for the historic fire regime. Similar fire compartment size is evident historically in the rest of the range of Venus flytrap; around 2000 km^2 (800 mi^2) in the Holly Shelter fire compartment, and around 770 km^2 (300 mi^2) in the Croatan fire compartment. These have now been largely broken up into much smaller fire compartments by roads, ditches and canals.

Fire frequency in the Green Swamp. Prior to acquisition of the preserve by The Nature Conservancy in 1979, Shoestring Savanna had been burned almost annually for most of the 20th century, originally by wildfires and later by the timber company that owned the site (Clemmens 1983, pers. comm.). The latter were late winter-early spring burns. The site was not burned in 1980 or 1981 but burned in a wildfire in 1982. Thereafter it was burned in 1983, 1985, 1986, 1987 and 1988. Fire frequency then decreased from annual to biennial and the savanna was burned in 1990 and 1992. Then it was three years until the next burn in 1995 and four years to the summer of 1999 (Table 5.2 below). All were winter burns, mostly around February, except for the summer 1982 wildfire and a prescribed burn in June 1995 (Bucher 1999). As seen by comparing 1983 and 1999 photographs, the increase in length of fire-return intervals resulted in conspicuous vegetation changes since 1988, the date of the last annual burn. Especially obvious was the increase in shrub cover and the buildup of a dense thatch of live and dead wiregrass (*Aristida stricta*) and dropseed (*Sporobolus teretifolius*) intermixed with pine needle litter from longleaf pine, the only tree present. These conditions seemed to be adversely affecting a number of rare herbaceous plants, including Venus flytrap.

If even the interior longleaf pine habitats such as Shoestring Savanna burned at intervals of 1-3 years, the surrounding wetlands would have been maintained as pyrophytic low pocosin instead of high pocosin as found under fire suppression today. There should have been a progressive reduction in fire frequency through the 20th century as fires were suppressed in the surrounding lands and the land was partitioned into increasingly smaller fire compartments by construction of highways and the grid of logging roads. Federal Paperboard Company, however, maintained the original fire frequency, by winter burning of the savannas on a nearly annual basis for decades (Clemmens, pers. comm.).

METHODS

Plot Methods.

In 1983 a series of m^2 permanent plots were established in Shoestring Savanna for monitoring several rare plant species (Frantz et al. 1983). The plots were distributed across the moisture gradient with the wettest lying near the pocosin fringe and the driest toward the central part of the savanna. Flytraps were present in 25 of the plots toward the wetter portion of the gradient and absent from 10 plots toward the drier end. The 1983 plots were located and resurveyed in 1991, 1994, 1995 and 1999. In the 1983 setup, rough-leaved loosestrife (*Lysimachia asperulifolia*), a

federal endangered species, occurred in 10 of the 25 plots with Venus flytrap. Survival of this species in the same plots was followed for several years (Frantz et al. 1983, Palmer 1984, Moloney 1985). Individual flytrap plants were relocated and the total number of flytraps per plot was tabulated. In some years, number of flowering stems per m^2 was recorded and in 1983 and 1999 percent cover of tall shrubs was recorded. For each of 25 one m^2 plots, shrub cover was mapped on a 100 cm x 100 cm grid in 1983. In 1999 plots were resurveyed and cover estimates were again obtained. Mapping was accomplished by stretching a 5 meter tape between two pipes, anchoring the ends with strong clamps. Repeated measurements gave a measurement error <2%. That was sufficient to repeatedly locate a point within 2 cm, easily enough to relocate a plant. Clusters of plots were photographed each year and in 1991 all plants were photographed for future comparison of cover area.

Three Ways of Examining Fire Return Interval: Time Since Last Fire, Cumulative Fire Frequency, and 10 Year Mean Fire Return Interval.

Three measures which give an indication of the effects of fire frequency are time since last fire, the cumulative fire return interval over a set period of time, and the 10 year mean fire return interval. Time since last fire is just the number of years between the sampling date and the last fire. Cumulative fire frequency is the long term average fire return interval. The 10 year Mean Fire return Interval presented below, is a sliding mean. As seen below, for frequent fire species, human interruption of a regular, very frequent fire regime can lead to permanent loss of species. In the southeastern U.S., calculating the 10 year mean fire return interval may allow estimation of whether a particular species will survive or be extirpated through competition with shrubs..

Calculating 10 year Mean Fire Return Interval (MFRI). MFRI is a sliding mean of the intervals between fires, based on the fire intervals that fall within a 10 year window immediately preceding each sampling date. The MFRI cannot be calculated just by dividing the 10 years by the number of fires, however. There are two anomalies to account for. For any sampling date, at the recent end of the 10 year span, the last interval is just the time since last fire (which is not the same as time between fires). Then, at the early end of the 10 year window, the actual interval preceding the first fire is included. So, for example, consider a case where the time window is 1985-1995 and the first fire in that span occurred in 1987. If the preceding fire occurred in 1979, the first fire interval to be included in the MFRI would be 8 years, even though 1979 lies outside the 10 year span being considered. This is necessary to account for the actual effects of fire frequency on plants. An 8 year interval would likely have lasting effects on species and if we considered only the 2 year portion of

this interval that lies within the 1985-1995 window, we would not be measuring the real fire frequency. As noted below, flytraps were extirpated from some plots when intervals increased to 7 years, while they thrived on 2 year fire return intervals.

The 10 year MFRI is calculated as follows (see Table 5.2 below): 1. Determine the actual length of time since the previous fire for the first fire in the 10 year window. 2. Determine the length of each interval between other fires that occurred within the 10 years, and include the time since last fire as an interval. 3. Sum the intervals and divide by the total number of years. Note that the number of years will always be more than 10 because the interval preceding the first fire is always included. The sliding 10 year window just provides a frame of reference. 4. Repeat for each sampling year.

Year	Fire	Time Since Last Fire (Interval)	Year	Fire	Time Since Last Fire (Interval)
1973	Y	1	1987	Y	1
1974	Y	1	1988	Y	1
1975	Y	1	1989	N	-
1976	Y	1	1990	Y	2
1977	Y	1	*1991*	N	-
1978	Y	1	1992	Y	2
1979	Y	1	1993	N	-
1980	N	-	*1994*	N	-
1981	N	-	*1995*	Y	3
1982	Y	3	1996	N	-
1983	Y	1	1997	N	-
1984	N	-	1998	N	-
1985	Y	2	*1999*	Y	4
1986	Y	1			

Table 5.2. Recent Fire History of Shoestring Savanna, with fire intervals used for calculating 10 year Mean Fire Return Interval (MFRI). Most fires were prescribed burns and sampling was done before any fire for the sample year. The five sampling years are indicated by italics.

RESULTS AND DISCUSSION

Fire Frequency and Survival of Venus flytrap.

There was much variation in numbers of Venus flytrap between sample periods. While many of the original plants survived throughout the study, others died and were replaced through recruitment of new seedlings (Table 5.3). The total number of plants fluctuated greatly from year to year in

relation to number of seedlings germinated, but vigor of the mature plants declined steadily as indicated by declining size and number of plants flowering. Even including the seedlings, total flytrap number declined from 293 to 134, a 54% decrease between 1983 and 1999. Decrease in vigor of plants was even more striking. Flowering declined from 51 of 293 plants in 1983 to none in 1999 ($p = .01$). In 1983 most plants were large, vigorous, and had functional flytraps. In 1999 many plants produced no traps at all, while the others had traps which were vestigial or remained closed and nonfunctional (Figure 5.1.b). No plants had functional traps in any of the plots in 1999.

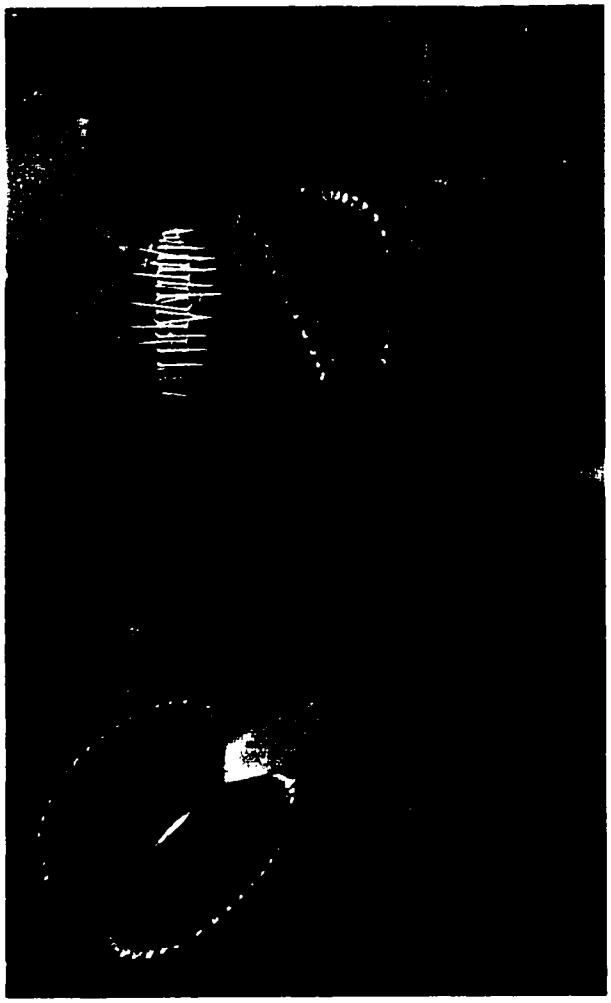
Other measures of plant vigor besides the decline in plant numbers and the general deterioration seen in Figure 1, were leaf size and number of plants flowering. In the 1991 sampling, the number plants having at least one leaf over 3 cm long was tabulated. Since leaves smaller than 3 cm rarely had functional flytraps, leaf length was considered a good indicator of plant vigor. In 1991, there were only 23 plants of 145 having the potential for functional flytraps (leaves > 3cm), and only 7 plants had flowers.

VENUS FLYTRAP SURVEYS IN SHOESTRING SAVANNA, 1983-1999

	SURVEY DATES															SUMMARY	
	1983			1991			1994			1995			1999			1999-1983	
PLOT	No	F	T	No	F	T	No	F	T	No	F	T	No	F	T	Dif	%
MSS1-1	50	.	1	44	0	1	16	.	2	39	0	3	24	0	4	-26	- 52
MSS1-2	44	.	1	36	0	1	37	.	2	56	9	3	28	0	4	-16	- 36
MSS1-3	13	.	1	18	0	1	10	.	2	12	0	3	11	0	4	- 2	- 15
MSS1-4	1	.	1	0	0	1	0	.	2	0	0	3	0	0	4	- 1	-100
MSS1-5	0	.	1	0	0	1	0	.	2	0	0	3	0	0	4	NA	NA
SubT	108	0	1	98	0	1	63	.	2	107	9	3	63	0	4	-45	- 42
LSS2-1	6	.	1	1	0	4	1	.	2	2	0	3	0	0	7	- 6	-100
LSS2-2	12	.	1	6	0	4	4	.	2	8	2	3	0	0	7	-12	-100
LSS2-3	22	.	1	4	0	4	5	.	2	9	5	3	0	0	7	-22	-100
LSS2-4	34	.	1	0	0	4	2	.	2	7	1	3	0	0	7	-34	-100
LSS2-5	19	.	1	0	0	4	2	.	2	3	0	3	0	0	7	-19	-100
SubT	93	15	1	11	0	4	14	.	2	29	8	3	0	0	7	-93	-100
LSS1-1	18	.	1	0	0	4	11	.	2	15	2	3	0	0	4	-18	-100
LSS1-2	1	.	1	0	0	4	0	.	2	0	0	3	0	0	4	- 1	-100
LSS1-3	5	.	1	0	0	4	1	.	2	5	0	3	0	0	4	- 5	-100
LSS1-4	1	.	1	0	0	4	0	.	2	1	0	3	0	0	4	- 1	-100
LSS1-5	0	.	1	0	0	4	0	.	2	0	0	3	0	0	4	NA	NA
SubT	25	6	1	0	0	4	12	.	2	21	2	3	0	0	4	-25	-100
DSS4-1	11	.	1	12	0	1	8	.	2	11	2	3	11	0	4	0	0
DSS4-2	26	.	1	18	0	1	15	.	2	10	0	3	16	0	4	-10	- 38
DSS4-3	19	.	1	18	1	1	25	.	2	15	1	3	18	0	4	- 1	- 0.5
DSS4-4	1	.	1	1	1	1	2	.	2	3	0	3	5	0	4	+ 4	+300
DSS4-5	0	.	1	0	0	1	0	.	2	0	0	3	0	0	4	NA	NA
SubT	57	21	1	49	2	1	50	.	2	39	3	3	50	0	4	-7	-13
LSS3-1	1	.	1	6	0	1	7	.	2	6	2	3	2	0	4	+ 1	+100
LSS3-2	6	.	1	8	1	1	10	.	2	8	4	3	5	0	4	- 1	- 17
LSS3-3	2	.	1	3	1	1	6	.	2	4	4	3	2	0	4	0	-100
LSS3-4	1	.	1	13	3	1	12	.	2	13	2	3	10	0	4	+ 9	+900
LSS3-5	0	.	1	2	0	1	1	.	2	2	1	3	2	0	4	+ 2	+200
SubT	10	9		32	5	1	36	.	2	33	13	3	21	0	4	+11	+110
TOTAL	293	51	1	190	7	1	175	.	2	229	35	3	134	0	4	-163	-54%

TABLE 5.3. No.- number of flytrap plants, F - number of plants flowering, T – time since plot last fire, Dif – change in munber of flytraps from 1983 to 1999.

Figure 5.1 (a). Venus flytrap (Dionaea muscipula), a rare plant endemic to the coastal plain of North and South Carolina, may require the highest fire frequency of any species yet documented. Traps here are 1.3 x life size, about 2.5 cm long in nature, at a site burned every 1-2 years (Camp Lejeune, Onslow County, NC). (b). Originally thriving under a mean fire return interval (MFRI) of 1.22 yrs prior to 1983, the flytrap in this photo, taken in 1991, 4 years post fire in a fire exclusion plot, was drastically reduced in vigor. None of the plants flowered and no functional traps were produced. Nonfunctional traps often rotted, like the one on the tip of leaf at top center. Live traps like that on bottom leaf remained closed. The traps were often shed, leaving only heart-shaped leaf tissue like that at left, leaving the plants scarcely recognizable as flytraps. The single live trap is life size, 7 mm long. (c). The last gasp: just to left of the dime is a tiny flytrap with a single leaf and a vestigial trap only 3.5 mm long.




LIBERTY

Effects of increasing shrub cover. Venus flytrap inhabited a zone of mesic and wet-mesic mineral soil where peat feathered out onto a low lens of sandy soil with longleaf pine (*Pinus palustris*) and wiregrass (*Aristida stricta*). Flytraps occurred in 17 of 20 1-m^2 plots in the wet zone, and 4 of 5 plots in the slightly drier intermediate zone. They were absent from 20 plots 18 meters away toward the slightly drier center of the savanna. Table 5.4 summarizes the distribution of shrub cover across the moisture gradient. The five plots at top of the table were too dry for flytraps and also had no cover from tall shrubs in either 1983 or 1999. Those in the intermediate area saw 131 % increase in shrub cover during the study, and the remaining plots, on moist soils of approximately equal wetness, all had over 250% increase, reaching a maximum of 97% shrub cover in one plot. Most cover was provided by gallberry (*Ilex glabra*), with only a few percent each from *Gaylussacia frondosa, Ilex coriacea, Lyonia lucida, Magnolia virginiana, Myrica heterophylla, Sorbus (Aronia) arbutifolia* and *Vaccinium atrococcum*. In wet and intermediate areas, the drastic changes observed with only a slight reduction in fire frequency illustrate the great susceptibility of the habitat of Venus flytrap to being overgrown with shrubs.

Walker and Peet (1983) found that species richness, up to 42 species/0.25 m^2, occurred in the middle part of the moisture gradient. Christensen (1988) observed that rates of succession varied with moisture status, with drier sites having little or no hardwood-shrub succession when deprived of fire for several years, while significant invasion of mesic to wet savannas was seen in just a few years after a burn. In the present study it was found that this process was accelerated on the wet pocosin fringes, with a great increase in competition from shrubs when mean fire frequency dropped from circumannual to just 3 or 4 years.

Table 5.5 summarizes changes in shrub cover from 1983 to 1999 in relation to the mean fire return interval (MFRI). In comparing the increase in shrub cover in plots having higher MFRI over those with MFRI of 1.22 years, shrub cover increased over 200% between 1983 and 1999 ($p = .01$).

CHANGES IN SHRUB COVER WITH REDUCED FIRE FREQUENCY IN SHOESTRING SAVANNA

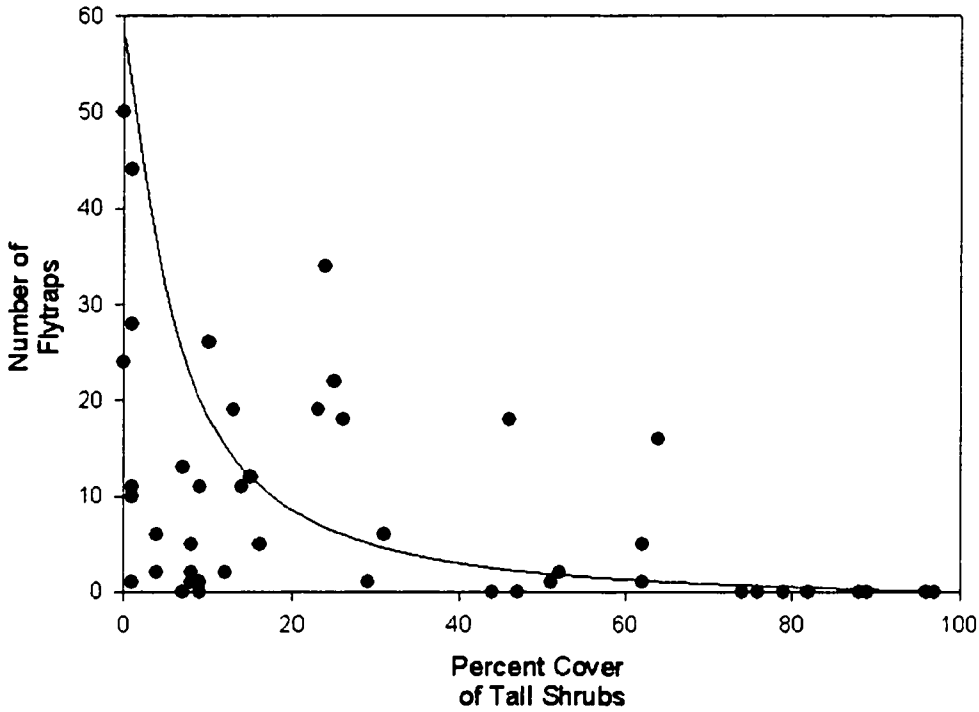
		1983	1999	
	PLOT	% COVER	% COVER	% CHANGE
DRY	MSS2-1	0	0	0
	MSS2-2	0	0	0
	MSS2-3	0	0	0
	MSS2-4	0	0	0
	MSS2-5	0	0	0
	Mean	0	0	0
INTER-MEDI-ATE	MSS1-1	0	0	0
	MSS1-2	1	1	0
	MSS2-3	7	1	- 6
	MSS1-4	29	89	+ 60
	MSS1-5	44	96	+ 52
	Mean	16	37	+ 21 (+131%)
MOIST	LSS2-1	31	76	+ 45
	LSS2-2	15	82	+ 67
	LSS2-3	25	79	+ 54
	LSS2-4	24	88	+ 64
	LSS2-5	23	97	+ 74
	Mean	24	84	+ 60 (+250%)
MOIST	DSS4-1	14	9	- 5
	DSS4-2	10	64	+ 54
	DSS4-3	13	46	+ 33
	DSS4-4	9	8	- 1
	DSS4-5	7	74	+ 67
	Mean	11	40	+ 29 (+264%)
MOIST	LSS3-1	8	52	+ 44
	LSS3-2	4	16	+ 12
	LSS3-3	4	8	+ 4
	LSS3-4	1	1	0
	LSS3-5	9	12	+ 3
	Mean	5	18	+ 13 (+260%)
	MEAN	14	45	+ 31 (+221%

Table 5.4. Shrub invasion with reduction in fire frequency varied dramatically along the moisture gradient. There was no change in dry savanna, 131% increase in intermediate savanna, and an average 258% increase in moist savanna, the primary habitat for Venus flytrap and other rare species.

INCREASE IN TALL SHRUB COVER IN RESPONSE TO LONGER FIRE-RETURN INTERVAL IN VENUS FLYTRAP HABITAT				
YEAR	No. OF M^2 PLOTS	MEAN FIRE-RETURN INTERVAL	PERCENT SHRUB COVER	NUMBER OF FLYTRAPS
1983	20	1.22	14	268
1999	15	2.75	32	134
	5	6.00	84	0

Table 5.5. Percent shrub cover increased dramatically with reduction in fire frequency in Shoestring Savanna.

Figure 5.2. Decline in number of Venus flytraps with increasing shrub cover following reduction in fire frequency. Points represent the number of plants in individual m^2 plots. On the left, the high numbers correspond with almost annually burned sites with no shrub cover, while, to the right, flytraps died out of the wet-mesic plots that experienced the heaviest shrub increase.


60
50
40
30
20
10
0
Number of Flytraps
0
20
40
60
80
100
Percent Cover of Tall Shrubs

Effects of time since last fire versus recent fire history. Table 5.2 above showed the time since last fire for the 25 plots sampled repeatedly from 1983 to 1999. The number of flytraps often declined during longer fire-return intervals but correlation between numbers of Venus flytraps and time since last fire seemed only fair[1]. Time since last burn was 4 years in some of the plots from 1991 and 1995, but response of flytraps varied widely.

Table 5.6 shows cumulative fire return interval for the 26 years for which data are available. While cumulative fire return interval results in a slow decrease in fire frequency that corresponds with decline in Venus flytrap, it is not at all responsive to the large short-term fluctuations seen in flytrap populations. The cumulative fire return interval increased while flytrap populations decreased, but the recent decline in flytraps seen in Table 5.2 seemed highly out of proportion to the very gradual rise in cumulative fire return interval. Since length of fire interval 20 years earlier might not be expected to have much lingering effect on a frequent fire species, it seemed more reasonable to use a sliding mean to follow recent fire history.

Sample Date	Fires	Cumulative F.R.I.
1983	8 of 10 yrs	1.25
1991	14 of 18 yrs	1.29
1994	15 of 21 yrs	1.40
1995	15 of 22 yrs	1.47
1999	10 of 26 yrs	1.67

Table 5.6. Cumulative fire return interval.

Effects of mean fire return interval. For Table 5.7, plots with the same fire histories were grouped for each sample year and the 10 year mean fire return interval (MFRI) was calculated for each group based on records showing which years each m^2 plot burned (Bucher 1999). The prescribed burns in 1988 and 1991 were patchy, and some plots were missed by fire. These plots were grouped to provide some of the longer intervals in Table 5.7. The low intensity of these mostly February burns, coupled with reduced fire frequency probably contributed to excessive shrub growth and the resulting decline of the Venus flytrap population. The actual number of burns experienced

[1] Numbers of flytraps in the later years of this study are slightly inflated by inclusion of small seedlings that were not recognized in the 1983 survey, so that the decline is even more pronounced than indicated.

by plots in the various groups in Table 5.7 during any 10 year period ranged from 1 to 8 (see Table 5.2).

MFRI subsumes recent fire history over the past several burns. Of various window lengths tried, the 10 year window seemed to optimize sensitivity to detecting changes in species numbers resulting from changing fire frequency. Calculating sliding means for shorter sampling periods (8, 6, 4 years) just began to approximate the decline in plant numbers related to time since last fire. Longer windows of time just approximated the cumulative fire return interval, with a corresponding loss of sensitivity in correlating fire frequency with decline in numbers of flytraps. The usefulness of the MFRI is illustrated more clearly in Figure 5.3 below, where number of flytrap per m^2 is plotted against MFRI. When the 125 one m^2 sample points are clustered into groups under the 9 different fire return intervals available in the study, the 10 year MFRI clearly demonstrates the remarkable dependence of Venus flytrap on frequent fire, with extirpation occurring when MFRI reaches 3 to 4 years.

Table 5.8 looks at the effect of MFRI on flowering. In 1995, 35 plants were flowering 3 years after fire, but flowering of flytraps ceased when MFRI exceeded about 2.5 years. What this suggests is that there is a cumulative effect of decreased fire frequency, which is picked up more reliably using the MFRI than simply time since last fire.

Venus Flytrap Decline with Increasing Mean Fire-Return Interval in Shoestring Savanna 1983-1999							
Sampling Date	Number of Plots	Sampling Interval (years)	No. of burns in Interval	10 yr MFRI	Time since last burn	No. of flytraps in plots	Total surviving flytraps
1983	25	10 (1983-1973)	8	1.22	1	293	293
1991	15	8 (1991-1983)	6	1.50	1	179	190
	10		4	2.00	4	11	
1994	15	3 (1994-1991)	1	1.57	2	149	175
	10		1	2.20	2	26	
1995	15	1(1995-1994)	1	1.71	1	179	229
	10		1	2.20	3	50	
1999	15	4 (1999-1995)	1	2.75	4	134	134
	5		1	4.00	4	0	
	5		0	6.00	7	0	

Table 5.7. Shows the decline in Venus flytraps as the Mean Fire-Return Interval increases[1]. With fire frequencies of 1-3 years, Venus flytrap may be able to maintain its numbers with new seedling recruitment after fires. In this study, when MFRI fell below 3 years flytrap was extirpated.

[1] MFRI (Mean Fire Return Interval) is a 10 year sliding mean of the intervals between fires, for the 10 years before each sampling date. It includes the complete interval for the first fire in the 10 year period even if the burn happened before the start of the 10 years, and also includes the time since last fire as an interval (note that MFRI is not the sum of the years in the interval divided by the number of fires).

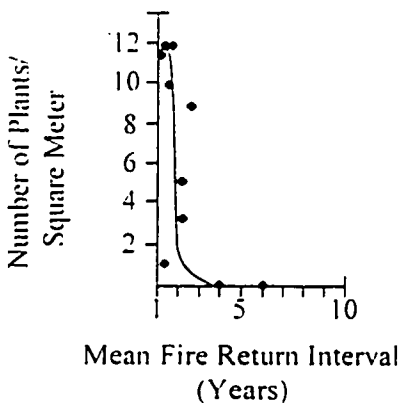
EFFECT OF FIRE-RETURN INTERVAL ON **FLOWERING OF VENUS FLYTRAP**				
YEAR	No. OF M^2 PLOTS	MEAN FIRE-RETURN INTERVAL	FLYTRAPS FLOWERING	%
1983	25	1.22	51 of 293	17.4
1991	15	1.50	7 of 179	3.9
	10	2.00	0 of 11	0
1995	15	1.71	25 of 161	15.5
	10	2.20	10 of 68	14.7
1999	15	2.75	0 of 134	0
	5	4.00	0	0
	5	6.00	0	0

Table 5.8 Flowering was greatest with mean fire-return intervals of One to around two years. No flowering was seen after MFRI approached or exceeded three years.

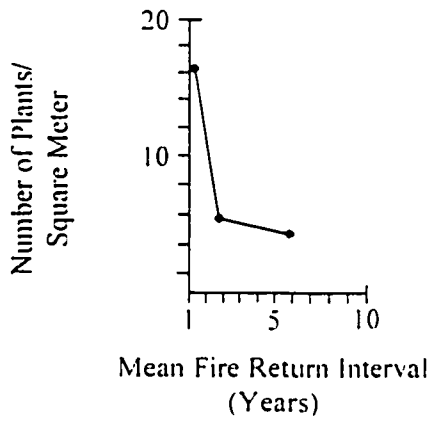
Figure 5.3. Decline of Venus flytrap in relation to mean fire return interval (MFRI). Each dot represents the mean number of flytraps in 5 to 25 plots of 1 m^2 that experienced the 10 year MFRI shown on the horizontal axis. No flytraps remained when MFRI dropped to 4 years.

The curve for *Lysimachia asperulifolia* suggests that the species is a little less drastically affected by reduction in fire frequency.

Venus Flytrap



Lysimachia Asperulifolia



Fire Frequency Requirements of Rough-leaved Loosestrife (*Lysimachia asperulifolia*)

Relative fire dependence between species that coexist on a site can be determined by following survival of each after reduction in fire frequency. In Shoestring Savanna, *Lysimachia asperulifolia*, a federal endangered species, shares habitat with Venus flytrap on the same wet mineral soil around the savanna-pocosin ecotone (Figure 5.4). When the two species co-occurred in the same plot, Venus flytrap was extirpated with either a single fire-free period of seven years, or when 10 year mean fire-return interval exceeded 3 years, but in these two situations, 30% and 27% of loosestrife stems persisted (Table 5.9).

The plants are mobile, by means of long, running rhizomes, and have the ability to put up few or many stems in relation to recentness of fire. In the frequently burned danger areas of Fort Bragg, Cumberland and Hoke Counties, North Carolina, *Lysimachia* thrives under a long-standing regime of wildfire and prescribed fire with MFRI of about every two years (Hoffman 1994). In sites I examined there and at Shoestring Savanna, stems were robust and flowering profusely the year after a fire. In the Bones Creek drainage of Fort Bragg I found plants blooming vigorously in June, only three months after a March fire. In comparison, the stems at Shoestring were reduced in number, small and spindly after 4-7 years without fire.

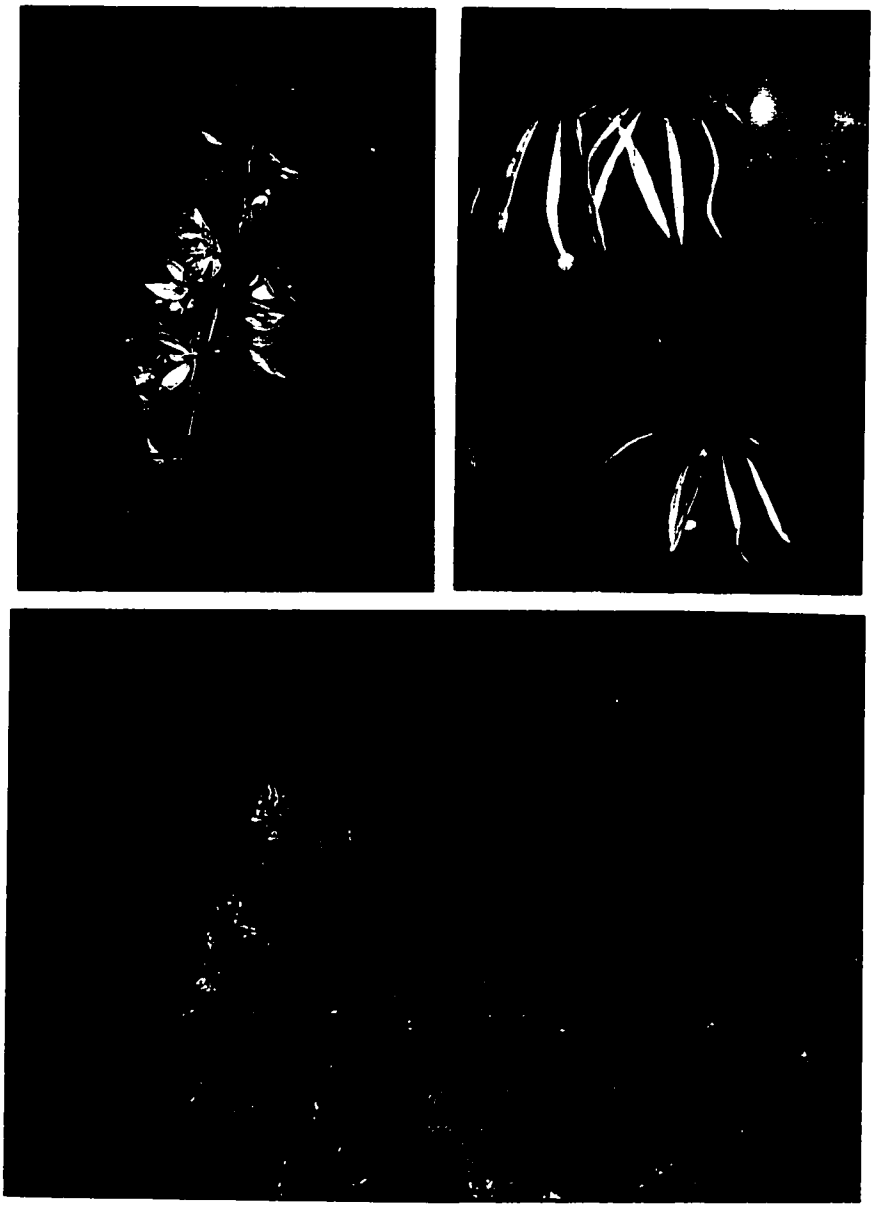
While flytrap, rarely more than 10 cm tall, may be densely shaded by overarching wiregrass leaves and dead foliage, the tall spears of *Lysimachia* (about 50 cm) had some capacity to penetrate and rise above the grass thatch. Although numbers and vigor were reduced as fire frequency exceeded three years, a small percent of loosestrife stems still produced flowers. There were not enough plots for statistical comparison, but it appeared that *Lysimachia* would tolerate at least one or two years longer fire free interval than Venus flytrap in this habitat. Its critical minimum mean fire-return interval is still being determined.

FIRE AND LYSIMACHIA ASPERULIFOLIA
IN SHOESTRING SAVANNA

	1983	1984	1999	1983-1999
PLOT	Stems	Stems	Stems	Decrease
LSS2-1	14	10	2	
LSS2-2	17	15	0	
LSS2-3	23	20	6	
LSS2-4	21	26	12	
LSS2-5	20	13	2	
Subtotal	95	84	22	-73 (-77%)
LSS3-1	17	16	0	
LSS3-2	39	9	7	
LSS3-3	20	9	3	
LSS3-4	10	5	6	
LSS3-5	13	4	13	
Subtotal	99	43	29	-70 (-71%)
TOTAL	194	127	51	-143 (-74%)

Table 5.9. Whorled loosestrife (*Lysimachia asperulifolia*), an endangered species, thrives under a 1-2 year fire regime, as does Venus flytrap, but seems able to persist a little longer in the absence of fire. In 1983 the 10 year mean fire return interval was 1.22 years. By 1999 it had dropped to 6.0 years for the upper set of 5 plots and time since last fire was 7 years. For the lower set MFRI was 2.75 years and time since last fire was 4 years. Under these conditions 30% and 27% of loosestrife stems persisted while Venus flytrap in the same plots died out.

Figure 5.4 (a) Whorled loosestrife (Lysimachia asperulifolia, federal endangered) shared habitat with Venus flytrap but required slightly less frequent fire for survival. Some stems of this species were able to penetrate the thick thatch of living and dead wiregrass leaves to reach sunlight. Although stem numbers were reduced as fire frequency exceeded three years, some still flowered. (b). Smooth coneflower (Echinacea laevigata, federal endangered) is a frequent-fire species of the piedmont and sandhills of the Carolinas. This species occurs in landscapes that once experienced fire about every 4-6 years. (c). Habitat for the fire-dependent species mountain golden-heather (Hudsonia montana) and Heller's blazing star (Liatris helleri, both federal threatened) in Linville Gorge Wilderness, North Carolina. Original fire-return interval averaged about 5-7 years. Before this burn in flammable pitch pine/ericad vegetation, about 95% of habitat formerly occupied by the two rare species had been overgrown by shrubs, relegating the herbaceous species to shallow soils near the ledges (photo by Gary Kaufmann, U.S. Forest Service).



Numerous other rare plant species share the same habitat with Venus flytrap and rough-leaved loosestrife, or are found in nearby habitats with the same, nearly annual fire frequency. Among them are *Parnassia caroliniana*, and the federally endangered *Astragalus michauxii, Oxypolis canbyi, Rhus michauxii, Schwalbea americana* and *Thalictrum cooleyi.*

CONCLUSION

Fire frequency indicator species. It seems apparent that there are fire-dependent species in all major provinces in the southeastern U.S. Most of the rarest species seem to be rare specifically because of human interference in the fire regimes that once supported them. Throughout its range from Virginia to Texas, at last 187 rare plant species, mostly herbs, are associated with the fire dependent longleaf pine ecosystem (Walker 1993). Some, such as Venus flytrap, die out when fire-return intervals become longer than 3 or 4 years. A great many more may need fire at least every 4-6 years.

If we can define the range of fire frequency required to maintain each species, we should be able to use those with the narrowest ranges of tolerance as fire frequency indicator species. This means that we could then use data such as herbarium records to put dots on maps where those species once occurred and assign a fire frequency range for that point. With a scattering of points we can construct and refine maps of presettlement fire frequency. This is a critical step in reconstructing presettlement vegetation for a site. Reconstructing fire frequency is an integral part of reconstructing original vegetation, and such maps are needed for projects involving restoration of natural areas (see Chapters 6, 7, and Case Study 4). Reed (1997) concluded that it is possible to predict responses of the prairie insect community to a controlled burn or series of burns, if the fire history of the site, the fire tolerance, the colonizing ability, and the basic biology of the individual species present were known. In the case of native plants, it will be vital to accumulate knowledge of response to fire of each species in our flora. It should be possible to predict the presettlement community composition of a site if the presettlement fire frequency for the site can be reconstructed and if the responses of the individual species to fire are known.

The individualistic responses of species to fire regime needs to be documented if we are to successfully manage fire communities for the perpetuation of species. We need to know both the time to extinction after elimination of fire, and the critical range of fire-return interval that each species requires for survival. In view of the increasing dichotomization of the eastern landscape into

developed land and managed natural areas, we need this information in the next two or three decades.

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CHAPTER 6

COMPONENTS OF LANDSCAPE FIRE ECOLOGY IN THE SOUTHEASTERN U.S.

ABSTRACT

This chapter proposes and begins to explore a new field called Landscape Fire Ecology. Several concepts of the field are presented for the first time. Fire compartments, fire filters, fire shadows, fire frequency indicator species, fire frequency indicator communities, fire-exposed versus fire-sheltered areas, fire-tension zones, and landscape scale fire frequency gradients are a few of the concepts that go into reconstructing original fire regimes and fire-dependent vegetation. These concepts appear to be essential for understanding the natural role of fire as it was played out before fragmentation of the modern landscape. Fire behavior and the effects of fire on vegetation at the landscape scale have been almost entirely ignored in the U.S. Yet it will be essential to understanding the role of fire in the original landscape if we are to maintain all the plant communities and species that were dependent upon fire.

KEY WORDS: Fire frequency, presettlement fire regime, fire compartment, fire filters, fire shadow, fire-frequency indicator species, fire-frequency indicator communities, fire-exposed versus fire-sheltered areas, fire-tension zones, fire frequency maps.

INTRODUCTION

Definition: Landscape fire ecology is the study of physical and biological factors that control the frequency of fire, the movement of fire in a landscape, and the effects of fire on vegetation. It is a fundamental element of landscape ecology, like physiography or topography. Given a climatic regime in which ignitions occur, either by lightning or by indigenous peoples, it is possible to

construct fire frequency maps for the original landscape. It is necessary to do this simultaneously with reconstruction of presettlement vegetation and presettlement fire compartment size, since partitioning of the modern landscape into smaller and smaller fire compartments makes present ignition rates and burn sizes largely irrelevant. Following is a summary of some principles and components of landscape fire ecology. These elements comprise the assumptions underlying the mapping of presettlement vegetation and fire regimes discussed in Chapter 7 and the four case studies which follow it (see also Appendix A, glossary of terms and concepts of landscape fire ecology).

Assumptions and assertions: The following principles are based on work elsewhere (Frost 1993, 1995, and 1998 [Chapters 2, 3, 4], the four case studies, and Chapter 5).

1. Under presettlement fire regimes, fire played a role in structuring all natural vegetation of the coastal plain, piedmont and mountains, except those vegetation types that are restricted to natural fire refugia like steep fire-sheltered slopes, islands and peninsulas.
2. Elimination of fire from a pyrophytic landscape initiates succession and replacement of pyrophytic species by non-pyrophytic species and communities.
3. Elimination of fire from a pyrophytic landscape initiates transformation of vegetation structure from one or two layers to multi-storied woody vegetation.
4. Lightning associated with growing-season convection storms drove the fire regime for the Coastal Plain. Native American influence predominated in areas where lightning ignitions were low (Pyne 1982), in portions of the landscape such as floodplain islands that are naturally isolated from fires on uplands (Harper 1911), or in more dissected topographic regions where lightning ignitions were high but fire compartments were small.
5. Landscape factors, such as fire compartment size, control fire frequency.
6. Landscape factors, such as landscape position, slope, aspect and soils, control fire intensity through effects on both vegetation and fire behavior.
7. Frequent fire vegetation and nonpyrophytic vegetation do not abut each other without some interaction. In the natural landscape there are fire-tension zones ranging in width from a few meters to several miles. Many rare species and important vegetation types, like some kinds of pyrophytic woodland, were found only in such zones.

TABLE 6.1. Physical and Biological Components of Landscape Fire Ecology.
Characteristics that affect fire frequency, fire intensity and fire effects on vegetation.

PHYSICAL

___Fire compartment size.
___Corridors and windows for fire flow between fire compartments.
___Fire shadows.
___Distance from nearest firebreaks.
___Fire filters—landscape and vegetation features that temporarily reduce fire intensity or rate of spread.
___Soil texture. In flat landscapes, soil texture controls fire frequency and fire effects through its influence on vegetation. There can be found 'islands' of mesophytic communities on moist clay soils in a sea of pyrophytic vegetation (Case Study 1).
___Depth to water table (especially outer Coastal Plain and upland flats of the middle and inner Coastal Plain and Piedmont).
___Slope & aspect.
___The soil series. While delimited by humans, and subject to frequent errors in mapping, soil series represent real noda of complex environmental variables in the multidimensional soilscape. The soil series, being much more enduring than vegetation, is the most useful mapping unit for putting boundaries on presettlement vegetation.
___Ignition source, lightning versus Indians.
___Land surface form (Hammond 1964, see Chapter 4).

BIOTIC (Vegetation)

___Pyrogenicity, the physical and chemical influence of vegetation on fire behavior, mediated by ignitability and fire-carrying capacity of living and dead vegetation, and also by litter decomposition rates.
___Fuel structure of live fuels, standing dead fuels, and litter.

LARGE-SCALE LANDSCAPE FACTORS AFFECTING FIRE FREQUENCY AND FIRE SPREAD

Fire compartments. The central concept of landscape fire ecology, defined in Chapter 4, is the fire compartment. This is a unit of the landscape having continuous fuel and no natural firebreaks, such that an ignition in one part would be likely to burn the whole unless there were a change in weather or fuel moisture. Figure 6.1 illustrates the underlying model. **The significance of fire compartments is that under a given fire regime, fire frequency increases**

as fire compartment size increases. This is a basic assumption with an underlying mathematical basis.

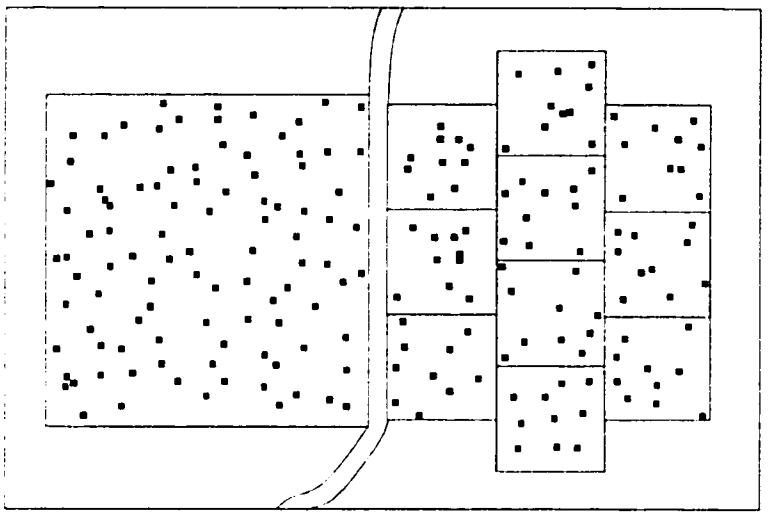
Consider the simplest model for lightning ignitions (Figure 6.1 (a)). In the example with square fire compartments at top of Figure 6.1, assume for sake of the model that the fire barriers that define the compartment are absolute and that the whole fire compartment usually burns. In a flat landscape, thunderstorms move across the landscape and over 100 years we would expect that the pattern of lightning ignitions would be randomly distributed. In this flat landscape there is a 2500 km^2 (1000 mi^2) fire compartment on one side of the river (54km or 33.3 miles on a side: compartments of this size do exist on the coastal plain. On the other side there is a cluster of 10 fire compartments, each 260 km^2 (100 mi^2), so the total is also 2500 km^2 1,000 mi^2. Each side of the river receives 100 lightning ignitions over 100 years, randomly distributed, so on the side with10 compartments, each will average 10 ignitions. This gives a long-term mean fire return interval (MFRI) of 10 years. On the other side of the river in the large fire compartment, there could be 100 ignitions in 100 years (MFRI = 1 year). This means that species in the larger fire compartment could experience a fire return interval ten times higher than on the other side of the river. The only difference is fire compartment size. This single factor seems likely to be the missing piece to account for the distribution of many rare fire-dependent species in the Southeast.

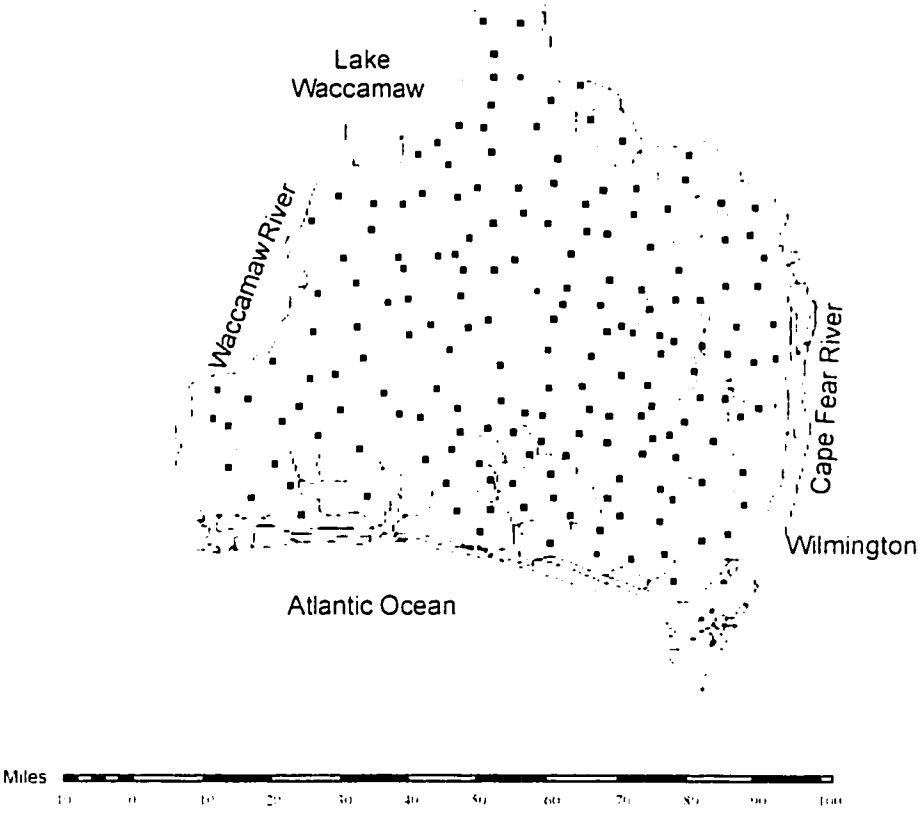
In practice, the situation is more complicated than that illustrated. With rare exceptions, there could be only one fire per year in any compartment, because the year's crop of fuel would be consumed. If 100 random ignitions occurred in 100 years, the Poisson distribution suggests that by chance about 37% of years will have no fire (this still gives a circumannual MFRI of 1.6 years, enough to support the most fire-dependent species known). On the other hand, if the lightning strike density were high enough, say two or three dry lightning strikes per year, to produce the annual fire frequency shown in the large compartment, the smaller compartments would not have as low an ignition rate as suggested in the illustrations.

If we doubled the rate of dry lightning strikes (those that strike in dry, ignitable fuel outside the rain pattern) to 200 per century, the large block could then be expected to experience nearly annual fire, and fire frequency in the smaller model compartments could nearly double, producing a cumulative fire-return interval of five years. As suggested in Chapter 5, this is still

Figure 6.1 (a). Model of the effect of fire compartment size on fire frequency. The 2500 km^2 (1000 $mile^2$) compartment on the left supports circumannual fire frequency, while the in the ten 260 km^2 (100 mi^2) compartments, mean fire return interval is only 10 years even though the total acreage is the same as on the other side of the river. Dots represent randomly distributed lightning ignitions, 100 on each side of the river.

Figure 6.1 (b). Ignition rate in the Green Swamp Region, Brunswick County, NC, as suggested by the model in Figure 6.1.a.





• Fire Ignition Point

too low to support the most fire-dependent species such as Venus flytrap[1]. Furthermore, it is once again unlikely that the fires would be distributed evenly over the 100 years, or that all fires would burn the whole compartment. As suggested by the data on Venus flytrap, there would likely be occasional single long intervals that would eliminate the most fire dependent species. The net result would be extirpation or prevention of colonization of those compartments by the most frequent-fire species.

In examining the actual distribution of Venus flytrap in the landscape, it appears that nearly all extant and historic populations are in the largest fire compartments. Since flytrap was extirpated from plots when 10 year MFRI dropped below 3 years (Chapter 5), this provides circumstantial evidence that the actual historical fire frequency in the largest fire compartments was 1-2 years.

In the bottom half of Figure 6.1 (b), 200 random ignitions were scattered over a real landscape in the Green Swamp vicinity, Brunswick County, North Carolina. Fire compartments were delimited by using streams and swamps wide enough to act as fire barriers under average wildfire conditions. This assumes a midflame windspeed of 6 mph, the average speed for the four months of the principal fire season, March, April, May and June, which should produce relatively mild burning conditions.

In this example there is one very large fire compartment of about 1600 km^2 (630 mi^2) and 19 small compartments, mostly distributed on a lower terrace near the coast and along the Cape Fear River. Of the 200 random ignitions, 148 fell within the largest compartment. Evidence from Shoestring Savanna suggests a presettlement fire frequency on 1.22 years for the Green Swamp (see Chapter 5, Tables 5.6 and 5.7), which is near the center of the largest compartment. Based on the simplest model, we can propose that 148 ignitions over 100 years were sufficient to produce the indicated fire frequency of 1.22 years in the large compartment. In the 19 small compartments, the number of ignitions ranged from 0 to 9, giving a comparable mean fire return interval ranging from 11 to 100 years. This is 16 to 148 times lower fire frequency than in the big compartment. This suggests that only the largest compartment had a fire regime sufficient to

[1] The model has not been further validated. For the Green Swamp region, Monte Carlo testing, using the mean of repeated sampling of the distribution of 100 or 200 random ignitions would give a better distribution of fire frequency by compartment size).

support frequent-fire species such as Venus flytrap. The distribution of known historic and extant populations of Venus flytrap in the region supports this hypothesis.

The rate of lightning ignitions in natural vegetation in the area is unknown but likely to be in the range modeled here with 148 ignitions over 100 years in a large compartment. Records of ignitions from lightning, being accumulated for the past 10 years at the Savannah River Site in South Carolina, are beginning to suggest that annual fire was the norm in the Sandhills. Some years may have seen no ignitions in the large compartment, while in other years there may have been several. We might expect a saturation point to be reached, however, beyond which it would make no difference whether there were 200, 300, 500 or 1,000 ignitions in 100 years. At most there could be two fires per year, one in spring and again in fall after accumulation and curing of the present year's growth. Prairie fuels have been shown to be capable of supporting two, albeit patchy, burns in a year (Bragg (1982). Since one or two fires would usually consume all the fuel for a year, any additional ignitions would die out quickly for lack of fuel, so that the net result of any number of excess ignitions would still result in circumannual fire. The largest fire compartments may have typically received ignitions in excess of that needed to maintain circumannual fire. Another consideration is that under moderate or severe burning conditions, most of the fire barriers that define fire compartments would cease to function as wind-driven fires spotted across them. This, and the fact that fire compartments are rarely completely closed, would have served to boost the actual fire frequency by increasing the effective fire compartment size, especially in years with severe fire behavior. As a result, the disparity in MFRI between the small and large fire compartments would not be as great as 148:1 or 16:1, but the model still holds: the large compartment should be the only part of the landscape that could support plants requiring circumannual fire.

Figure 6.2 shows the distribution of fire compartments from the coast in the vicinity of Wilmington, inland to the Piedmont. The interstream region is bounded by major firebreaks; the Atlantic Ocean, the Cape Fear and Haw River drainage, the Pee Dee and Catawba drainage, and Interstate 85 near Greensboro, a relatively new fire barrier. I expected a somewhat continuously graded set of fire compartments with the largest on the coast, decreasing steadily inland. Instead there are three huge compartments, each several hundred square miles in the Green Swamp vicinity, then a number of small compartments along the Little Pee Dee River, and then huge compartments again in the Sandhills surrounding Fort Bragg. The large compartments extend into the eastern fringe of the Uwharrie National Forest where there are still a few stands of

longleaf pine. Then there is an abrupt change to the smaller compartments of the Piedmont. Fire compartment size is accompanied by a corresponding landscape scale fire frequency gradient across the Uwharries, ranging from frequent fire, probably every 2 or three years in the original landscape, to infrequent in the hilliest regions on the west where longleaf pine drops out except on some dry ridges and south slopes. The abundance of rare species at Fort Bragg may reflect not only that the Army has maintained the original fire regime on Fort Bragg, but also the historical effect on fire frequency of the two huge fire compartments that make up its lands. Figure 6.3 is a plot of rare species in the Fort Bragg vicinity.

Fire barriers and fire filters. Fire barriers or firebreaks are natural landscape features, such as rivers, other bodies of water, steep slopes and non-pyrophytic vegetation, which prevent or resist the spread of fire. These comprise the boundaries between fire compartments that stop the flow of fire under average burning conditions. Other barriers are steep-sided, wet ravines and unvegetated sand and rock. Fire barriers are rarely absolute, and under severe burning conditions fires have been known to spot across bodies of water over a mile wide (Anon 1983). By definition, a fire barrier stops most fires that occur under average wildfire conditions. Any fire barrier that stops even a few fires automatically reduces the local fire frequency, so the more fire barriers in the landscape, the smaller the fire compartment size and the lower the fire frequency. Fire filters are topographic or vegetation features that temporarily reduce fire intensity or rate of spread. Examples are steep north slopes, areas with complex or rugged topography, moist ravines, bottomlands with oligopyrophytic vegetation or vegetation with poor fuel connectivity. Fire filters reduce fire frequency in two ways. First, a certain percentage of fires may be detained long enough for rainfall or cool, moist nocturnal conditions to extinguish the fire. Second, even fires that pass through the filter will have been delayed. A certain number will not spread as far as they would have before being extinguished by rain or other events, so the more fire filters in the landscape, the lower the expected fire frequency.

Figure 6.2. Fire compartments between the Atlantic Ocean and Interstate 85 near Greensboro, North Carolina, bounded by the Cape Fear/Haw River drainage on the east and the Pee Dee/Yadkin River drainage on the west. Dotted lines are bottlenecks connecting fire compartments.

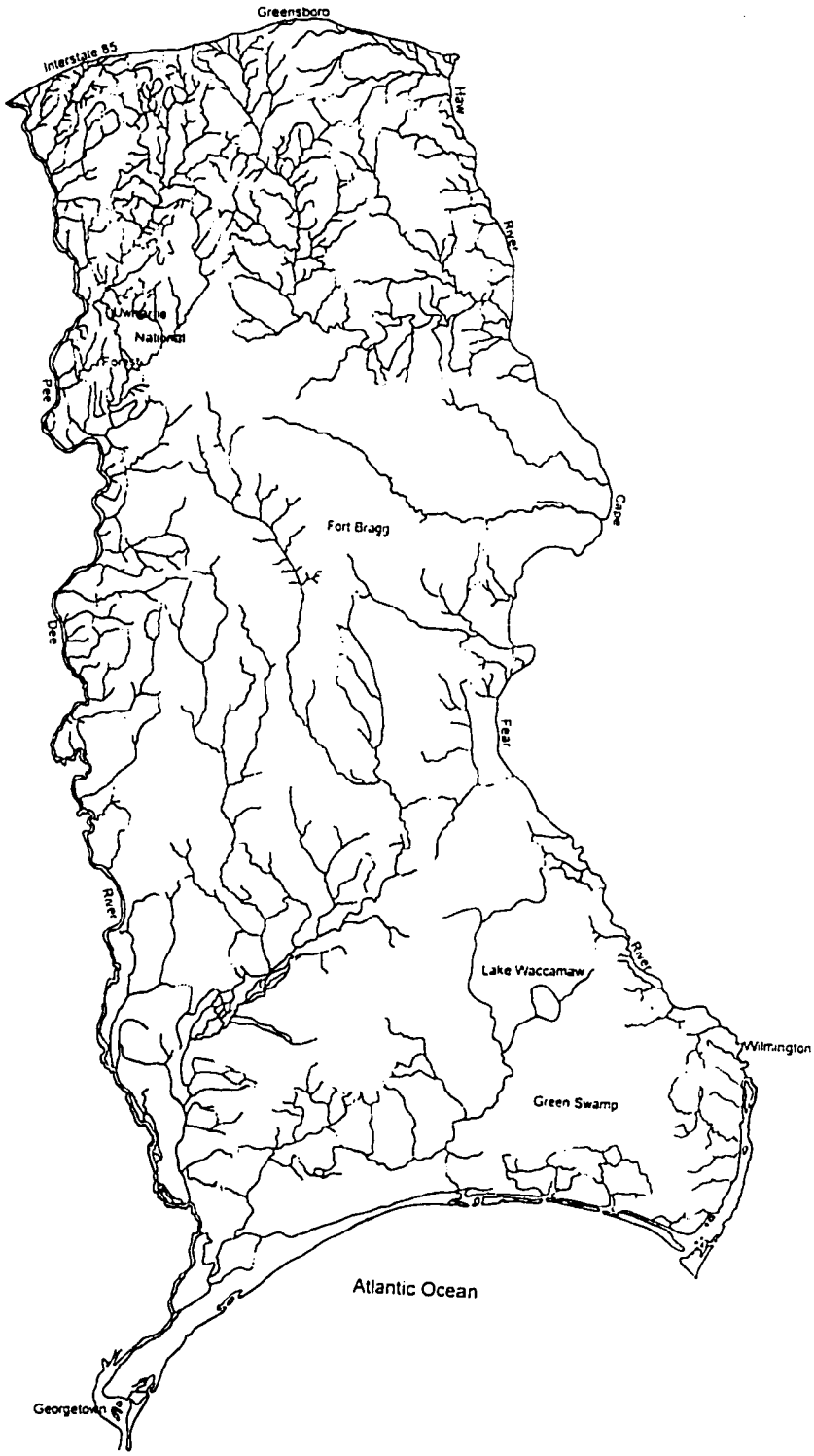
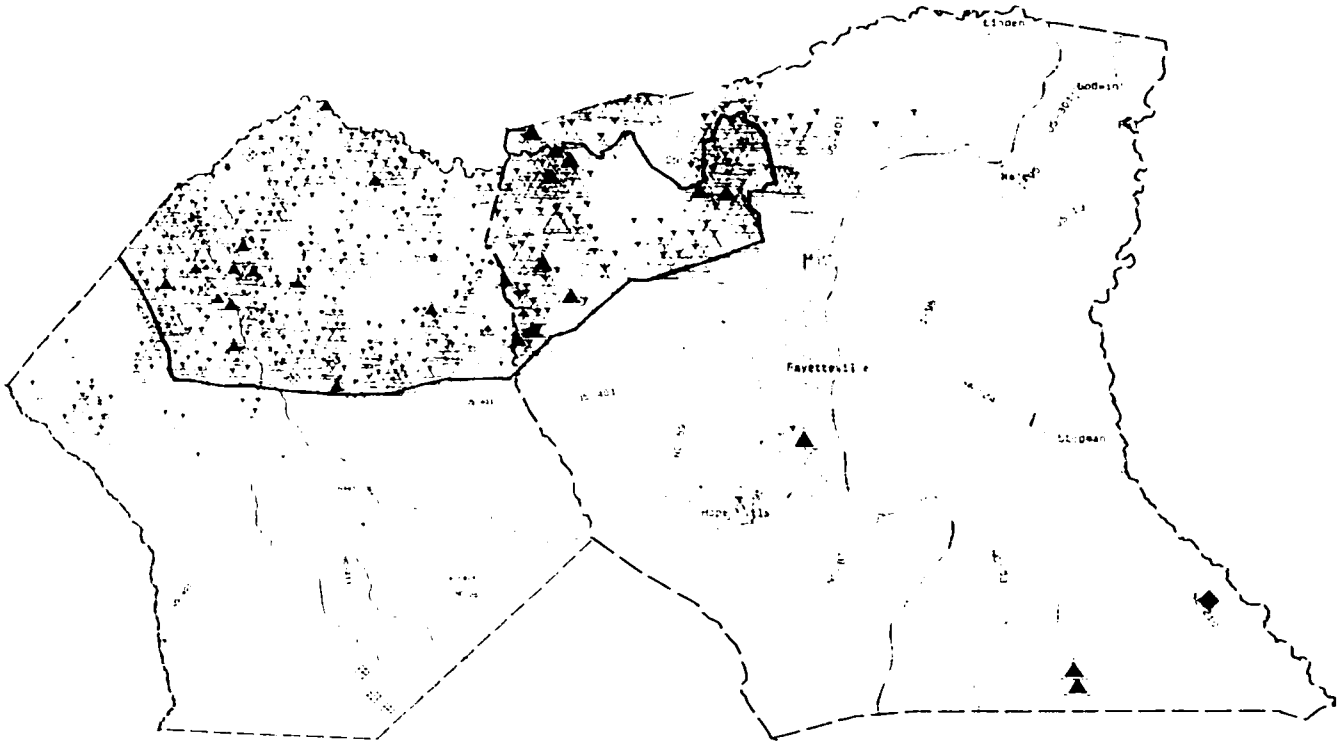

Greensboro
Interstate 85
Haw
River
Uwharrie
National
Forest
Pee
Dee
River
Cape
Fear
River
Fort Bragg
Lake Waccamaw
Green Swamp
Wilmington
Atlantic Ocean
Georgetown

Figure 6.3. A striking example of the relationship of endangered species to fire in the landscape, Ft. Bragg military reservation contains three impact areas enclosing a total of nearly 780 km^2 (300 square miles). These lands, in Hoke (left side) and Cumberland counties, North Carolina, are used as buffers around small central artillery targets. The remaining lands have been burned by wildfires during the growing season an average of every two years (Eric Hoffman, base biologist, pers. comm.), almost perfectly simulating the presettlement fire regime. Of the 444 federally listed endangered and threatened species occurrences mapped in the two counties, 370 or 83% are found within the boundaries of Fort Bragg. These lands, which contain a multiplicity of upland and wetland plant communities maintained by fire on a landscape scale, contain some of the most pristine examples of the presettlement Sandhills landscape. In the original landscape, these species were likely distributed over the entire region. Today, the exemplary fire communities and rich species diversity stop abruptly at the base boundaries. Fire-dependent species persist only in a few places in surrounding lands, where, like the rest of the fire-suppressed Sandhills landscape, fires have been effectively controlled for nearly 50 years. (Endangered species locations plotted by U.S. Fish and Wildlife Service, Raleigh Field Office.)



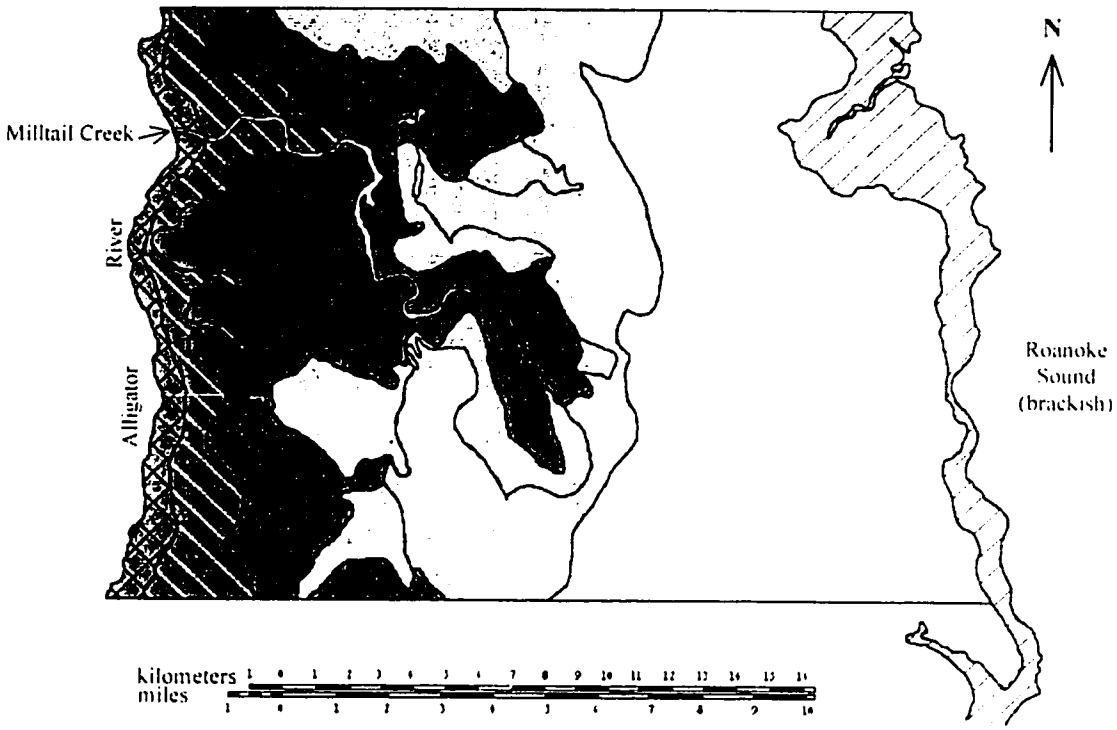
- American Chaffseed
- Michaux's Sumac
- Pondberry
- Rough-leaved Loosestrife
- Red-cockaded Woodpecker

Fire-tension zones. A fire-tension zone is an area transitional between frequent fire and nonpyrophytic vegetation. In the case of abrupt slopes, this zone may only be 10-20 meters wide. In large coastal plain wetlands it may range up to one or more kilometers in width, becoming a landscape-scale fire frequency gradient (see below), with vegetation changing gradually as fire frequency and impact decreases. Some species, such as shortleaf pine on the coastal plain, seem to find their primary habitat in fire-tension zones. At a site in compartment 33 at the Savannah River Site (Case Study 4), shortleaf pines up to 21 inches dbh were about 75 years old when cored in 1994. This would date them approximately to World War I, a time before fire suppression, when wildfires still maintained features like fire-tension zones. The distribution of several pine species changed across this zone. Pure longleaf pine occupied upland flats, while on the upper arm of the slope shoulder, longleaf and shortleaf formed a mixed pine savanna. Just below the slope shoulder, the community graded into pyrophytic woodland with longleaf, shortleaf, post oak, white oak, and occasional loblolly. The slope below graded into nonpyrophytic hardwoods, with scattered loblolly pines. Remnants of this natural distribution can also be seen in other old-growth fire communities such as those at Hitchcock Woods, small portions of which contain remnants of virgin longleaf pine forest (Aiken County, SC). The oldest canopy trees follow the distribution above; albeit with a long fire-suppressed brushy understory from which the herb layer has essentially vanished. See Figure 6.14 below for an example of a narrow fire-tension zone on the west side of the Great Dismal Swamp.

Landscape-scale fire frequency gradients. In general, flat landscapes can be expected to have large fire compartments and a correspondingly high fire frequency. On the Coastal Plain, however, I found several situations where, within a single fire compartment, vegetation changed along a fire frequency gradient. In some cases this gradient was long attenuated, extending from a frequent-fire area, to an area with lower frequency, to an area with 100 year fire-return interval or no fire at all. In Dare County, North Carolina, a fire frequency gradient extends across the entire mainland from Roanoke Sound to the Alligator River.

Within the mainland fire compartment vegetation is conspicuously zoned from frequent-fire types like marsh and canebrake on the east, to long fire-return interval types like Atlantic white cedar on the west. Oddly enough, the pronounced east-west fire frequency gradient seems to have been set up entirely by the difference in salinity between the east and west sides of the peninsula. The brackish water along the eastern margin maintains Juncus roemerianus marshes

Figure 6.4. This cross section of mainland Dare County illustrates a landscape-scale fire frequency gradient, apparently created by the difference in salinity between the east and west sides of the peninsula. The brackish water of Roanoke Sound on the east produces flammable salt marsh, which carries fire inland, supporting canebrake. The fresh water of the Alligator River produces nonpyrophytic cypress-gum swamp on the west side. Between these two fire extremes, is a zone of pocosin, then fire-maintained forest pyromosaic, and patches of Atlantic white cedar. Based on mapping from color infrared aerial photography taken around 1982.



Fire Return Interval

- 1-3 years
- 4-6 years
- 7-12 years
- 13-25 years
- 25-100 years
- 100-300 years
- Never burned

which form a continuous, wide shoreline band stretching some 80 km (50 miles), all the way from the Albemarle Sound, down the length of mainland Dare, south to the Pamlico Sound where the marsh borders all of Hyde County. This 50 mile fire corridor was augmented by equally flammable canebrake in the next vegetation band immediately to the west. The patches of maritime pine marsh and pocosin between the Juncus marshes and canebrakes appear to have been maintained by a combination of brackish storm overwash and fire, and the beginning of salt-intolerant canebrake may mark the western limit of storm overwash (see Case Study 2 and folded map 2).

On the west side, in contrast, non-pyrophytic cypress-gum swamp fringes the fresh waters of the Alligator River in a narrow band only about 100 meters wide. Between the frequent-fire communities of the eastern side and this wet margin on the west, lies a broad, landscape-scale fire frequency gradient. Pyrophytic pond cypress stands, Atlantic white cedar, *Nyssa biflora*, pond pine and tall pocosin comprise elements of the landscape-scale fire mosaic described in Chapter 3 (see Table 5.3). This mosaic is transitional between the frequent fire communities on the east side of the peninsula and the nonpyrophytic swamp forest on the west side along the Alligator River.

WITHIN-COMPARTMENT LANDSCAPE FACTORS AFFECTING FIRE FREQUENCY

Effect of position within the fire compartment. It should be possible to predict likely fire frequency for any point in a fire compartment, using environmental variables and spatial effects. Within-compartment factors and effects include the position of the point within the fire compartment, distance to firebreaks and fire filters, amount of local relief, proximity to fire shadows, and within-compartment variation in soil texture. Figure 6.5 illustrates a Piedmont fire compartment at Mineral Springs Barrens, a Nature Conservancy preserve in Union County, North Carolina. The preserve sits on the highest ridge in a southwest to northeast-trending fire compartment 24 km (15 miles) long and about 7 km (4.3 miles) wide. Elevation within the compartment ranges from 140 m (460 feet) at the Catawba River, up to 220 meters (720 feet). Soil textures range from clayey silt loam to gravelly loam.

At Mineral Springs, unusual soils, particularly the Zion, an Ultic Hapludalf, contribute to the persistence of a rare example of Piedmont prairie flora, with rare species like *Helianthus*

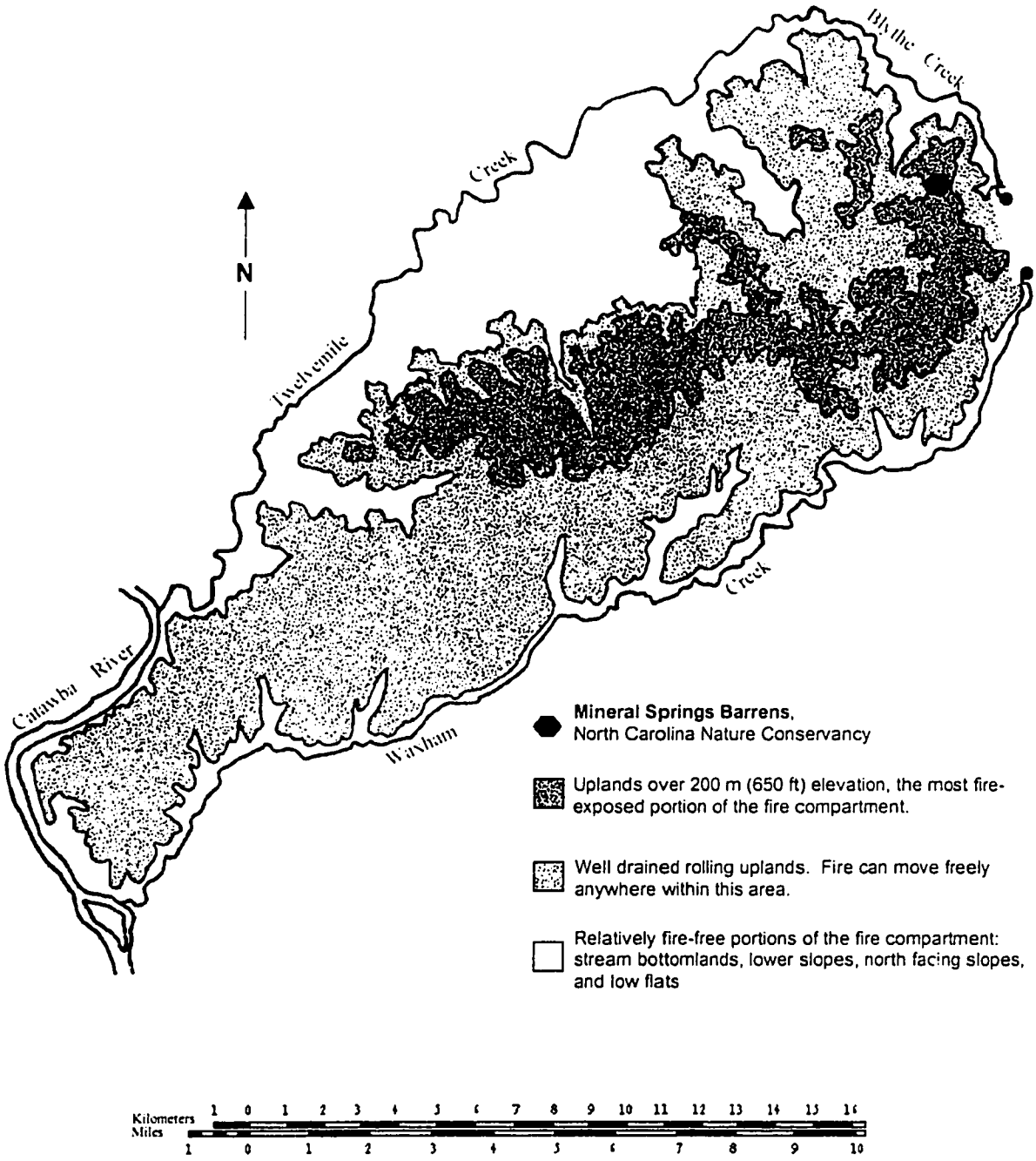
schweinitzii (Schweinitz's sunflower) and *Aster georgianus* (Georgia aster). A number of other unusual prairie and barrens species are also present. When the site was discovered, there had been considerable shrub and hardwood encroachment into the barrens, with resulting exclusion of some sun-dependent prairie species to an open area along railroad tracks.

The unique concentration of rare species and the persistence of piedmont prairie flora appear to be the product of a combination of four unusual factors. First is the soil, with mafic components (Zion) and soils with more clay than typical piedmont soils (Badin and Tatum). Severely clayey soils may be a factor in that they retard succession to multi-storied woody vegetation. Second is the topographic position, with the natural area being located on the highest and driest ridge in the fire compartment. Third, the site is toward the downwind end of a 24 km-long fire compartment. This means that, in the original landscape, ignitions anywhere along this length could move upslope and downwind and likely end up at Mineral Springs, which sits, like a target, at the downwind end of the compartment. In contrast, fires originating in the vicinity of Mineral Springs would have to back for days against the prevailing wind before burning the whole compartment, exposing such fires to a greater chance of being extinguished by rain. Fourth, the rare plant site is in near proximity to a portal to the next fire compartment, a source of augmented fire frequency from the east and southeast. The result is that, on average, the Mineral Springs Barrens could be expected to experience more frequent fires than anywhere else in the fire compartment. Both the topographic position and relative position on the downwind end of a long fire compartment conspire to make the site the most fire frequent in the vicinity.

This compartment illustrated in Figure 6.5 supports a number of rare, fire dependent species. It would seem that it is no accident that this is the site of *Helianthus schweinitzii*, *Aster georgianus* and other fire-dependent piedmont species.

Within-compartment effects of soil texture. There seem to be factors, endogenous within flat-lying sites, that can create nearly fireproof vegetation. In Pamlico County, between the fire frequency extremes of longleaf pine/wiregrass on the Minnesott Ridge, a segment of the Suffolk Scarp, and nonpyrophytic oak forest there was a fire-frequency gradient with a corresponding gradient of vegetation types (Figure 6.6). From west to east these followed this

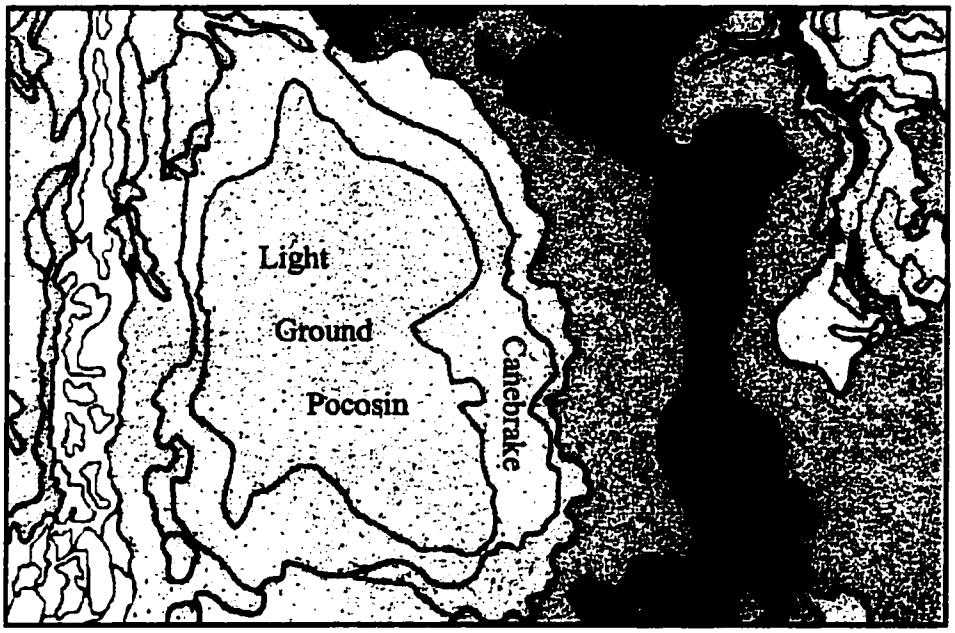
Figure 6.5. Topography and V-shaped stream valleys make for more within-compartment variability in the Piedmont and mountains than in flatter landscapes. All shaded areas are part of a single fire compartment. The darker shade indicates areas on upland flats and ridges. Since fire moves upslope these are the most fire exposed parts of the compartment. Mineral Springs Barrens, indicated by the black symbol to the right, is fully exposed to fires driven by the prevailing winds from the south and southwest. The open boundary just east of the preserve indicates a connector to the next fire compartment, an additional source of fire from the south and southeast. The combination of circumstances makes the immediate vicinity of the barrens the most fire-exposed situation in the surrounding 100-200 square miles. This is also the location for two fire-dependent endangered species: *Helianthus schweinitzii* and *Aster georgianus*.


Blythe Creek
Creek
N
Twelvemile
Creek
Catawba River
Wanham
Mineral Springs Barrens,
North Carolina Nature Conservancy
Uplands over 200 m (650 ft) elevation, the most fire-exposed portion of the fire compartment.
Well drained rolling uplands. Fire can move freely anywhere within this area.
Relatively fire-free portions of the fire compartment: stream bottomlands, lower slopes, north facing slopes, and low flats
Kilometers
Miles

sequence: longleaf pine/wiregrass, pyrophytic low pocosin, pond pine/canebrake, loblolly pine/canebrake and sweetgum/canebrake, sweetgum-tulip poplar forest and *Quercus laurifolia-Quercus michauxii* forest. The low pocosin was probably kept low by frequent fire rather than low nutrient status. On the east, between the pocosin and forest was a broad band of canebrake, the last remnants of which only died out in the 1970s. Old black and white aerial photographs showed vegetation with a whitish, fine textured signature suggestive of canebrake, and I found extensive areas where the ground was matted with decomposing cane stems when I explored the area in the 1980s. This is counterintuitive to the expected distribution of community types according to fire frequency as indicated in Table 2 in Chapter 3. More typically we would expect vegetation to be distributed along this fire frequency gradient as follows: longleaf pine wiregrass, 1-3 years -> canebrake 4-6 years -> pocosin 7-12 years. In Light Ground Pocosin, however, the pocosin lies at the wet toe of the longleaf pine/wiregrass scarp, where fire might be expected to be less frequent. The canebrake, which would seem to be out of place on the other side of the pocosin, may be supported by the increased fertility supplied by the underlying Alfisol, which raises pH. As mentioned in connection with the vegetation tables in Chapter 3, the distribution of cane versus pocosin in the complex presettlement peatland landscape seems to be explained by the variation in fertility. On soils with the same organic matter depth and fire frequency, pocosin dominates the most sterile sites while canebrake appears whenever there is some condition to ameliorate soil pH.

The clayey Alfisol also appeared to be responsible for the presence of islands of nonpyrophytic oak flats in a sea of fire vegetation. Along the western border of Light Ground Pocosin the former canebrakes were fringed with a narrow belt of loblolly pine, red maple, and *Gordonia* forest. These stands, which may be in part killed to the ground in major fires, were transitional to a wide zone of sweet gum, black gum and tulip poplar on wet brown alfisols with a clayey circumneutral basement. These in turn were transitional to fire-free oak flats on light-colored moist clay soils (Argent and Wahee series). These communities appear to have acted as fire suppressors in an otherwise frequent-fire landscape. They have never been much influenced

Figure 6.6 depicts soils of the Suffolk Scarp, Light Ground Pocosin, and the darkly shaded oak flats in the central part of the county. In the original forests, soil texture and moisture created mesophytic, fire-free islands of oak flats, entirely surrounded by frequent fire vegetation.



Fire Return Interval 1-3 Years. Suffolk Scarp longleaf pine savanna.

Fire Return Interval 4-6 Years. Pocosin, canebrake, and mixed pine savanna.

Fire Return Interval 7-12 Years. Pond pine forest, sweetgum, and loblolly pine.

Fire Free Oak Flats on Argent loam, an Alfisol. Quercus michauxii, Q. laurifolia, and beech.

Trent Creek, a brackish tributary of the Bay River.

by fire, other than by litter fires around the margins. In each of my 1/10 ha study plots I took 20 random litter depth measurements. Litter depth serves as one indicator of the pyrogenicity of the vegetation type present. In the Pamlico County oak flats, mean litter depths were the thinnest I found on any upland soil types. In the late spring fire season, the mean of 20 litter depth measurements in each of three 1/10 ha plots was only 1.7 cm, 3.0 cm, 3.5 cm, a trivial amount of litter. Since there was little in the way of shrubs, this essentially precluded fire, other than an occasional litter fire that might penetrate a short way into the stand. There seem to be at least three factors contributing to the resistance to fire by this community. First, the dense, white clay soils seem to be impervious to invasion by rhizomatous shrubs, which contribute to the flammability of nearby communities on sandy soils. Second, the tree species here, *Quercus michauxii, Quercus laurifolia, Quercus pagoda*, tulip poplar and beech, seem to produce thin leaf litter that decomposes more rapidly than that of upland oaks. Third, the flat, clay soil holds moisture that appears to facilitate matting down of the litter into a layer only one or two cm thick. By spring, this layer appeared to be partly decomposed and was so compact that its ability to carry fire seemed negligible. In this flat landscape, it appeared that soil texture, through its effects on vegetation type and litter decomposition, was responsible for producing the fire-free islands of mesophytic oak forest in a landscape otherwise dominated by fire.

USING FIRE-FREQUENCY INDICATOR SPECIES TO ESTIMATE ORIGINAL LANDSCAPE FIRE FREQUENCY

After determining landscape-scale and local factors affecting fire frequency, the next step in mapping presettlement fire regime is plotting locations of fire frequency indicator species and community types. Most of the frequent fire species of the southeastern U.S are inhabitants of three broadly defined fire ecosystems that once dominated the vegetation of the eastern U.S., east and south of the Appalachian Mountains. First was the longleaf pine ecosystem, which once extended from near the Maryland line in Virginia, south to east Texas and the vicinity of Houston. Second was the shortleaf pine-pyrophytic oak ecosystem that ranged from southeastern New York and New Jersey to the Piney Woods and Oak Savanna regions of East Texas (Correll and Johnston 1979). Third was the pitch pine/ericad shrub ecosystem that extended from eastern New York south into the mountains of the Carolinas and Georgia. The highest original fire frequency in these three systems ranged from nearly annual in the most fire-exposed parts of the longleaf pine ecosystem to around 4-6 years in the shortleaf pine-oak, to 5-12 years in pitch pine/ericad types Chapter 4). Many species were dependent upon fire in each ecosystem.

Fire Return Interval as Part of Species Life History

There are two kinds of interval-dependent fire frequency to consider in the life history of a species, landscape fire frequency and obligate fire frequency. **Landscape fire frequency** is the frequency that the species experienced under the presettlement fire regime. This is irrespective of any actual need for fire, since many species, such as longleaf pine, may thrive under a 1-3 year fire regime but do not require that frequency for the species to persist except on the most moist or fertile sites. **Obligate fire frequency** is the fire-return interval that the species must have for its long-term survival. As seen in Chapter 5, Venus flytrap seems to require a 1-3 year fire regime for its very survival as a species. The obligate frequency is somewhat site-specific since it will vary depending on the rate of succession to competing species on different soils. In trying to determine obligate fire frequency for a species we need to consider several variables; the soil characteristics at the site, the range of frequencies the species will tolerate, and the recent fire history, expressed as the mean fire return interval for the past 3 or 4 fires.

Soil Characteristics and Obligate Fire Frequency

The obligate fire frequency for a species to persist depends to some extent upon soil characteristics such as texture, soil moisture, and fertility. In Chapter 5, Venus flytrap was found to thrive under a nearly annual fire regime on wet mineral soil at the edge of a pocosin. With reduction in fire frequency it disappeared from wetter sites, which had the greatest susceptibility to being overgrown with shrubs, and declined in sites further upslope. Its last refuge was near the limits of its moisture tolerance in the slightly drier fringes of longleaf pine/wiregrass savanna, on a different soil series.

The range of fire frequencies that each species will tolerate becomes a critical research need as all species become increasingly dependent upon human control of fire regimes. Obligate frequent-fire species tolerate only a very narrow range of fire frequency. At the other extreme, Atlantic white cedar may require a fire-free interval of at least 25 years to reach the size and age for seed production, or it will be extirpated from peatlands. From there on, it can be found at fire return intervals up to 300 years (Chapter 3). As seen with Venus flytrap, there may be frequencies that a species will tolerate for an occasional episode, but probably not on a repeated basis. This may be the case when frequency is reduced by fire suppression or with too infrequent or too mild prescription burns. A species will still be trending toward extinction if a reduced fire regime does not provide the ecological conditions for its reproduction. Appendix B lists

examples of southeastern species and three kinds of relations to fire interval: the fire frequency they actually experienced in their habitat, their range of fire tolerance, and the maximum time they may endure without fire.

Marginal Habitats

An additional consideration is that many species appear to have certain minor or extreme habitats in which they may persist longer than in their primary habitats. One could hypothesize that such were the original habitats and most of these species were always rare. The extraordinary displays of robust, flowering communities packed with rare species that we see on military bases burned every 2 years such as Ft. Bragg and Camp Lejeune, could be considered artifacts of the unnaturally high fire regime. Field studies tend to support the opposite view, however, especially where the extent of former habitat is known to have been much larger under the historical fire regime. This seems to be the case for most of the rare species that we associate with fire. Mountain golden-heather (*Hudsonia montana*), for example, may be crowded out of its habitat of moderate soil depth (15-30 cm) onto ledges having very thin soils, by shrub overgrowth resulting from fire exclusion (Frost 1990). When this occurs, a few plants, perhaps finding a moist crevice in subsurface bedrock, can persist in very shallow soils on the ledges. So a few plants survive episodes of long fire exclusion in microhabitats that are too xeric and have soils too shallow for competing shrubs. While this may have served as an emergency refugium during an occasionally prolonged fire drought, field observations of the slow dieoff and lack of reproduction in these sites make it seem unlikely that the species as a whole could survive under such conditions for more than a few decades. We also know that the historical fire regime was much higher than at present, and the species was locally much more extensive. I have actually watched its exclusion from deeper soils by shrub growth over the last 14 years, only the most recent phase of decline in a period of 50 years of fire exclusion (Frost 1990).

Fire Interval Dependence Types

At least eight patterns of species relations to fire interval are apparent in southeastern vegetation. (Figure 6.7). First are the obligate frequent-fire species, those that require fire at intervals from 1 to 12 years. The 12 year cutoff seems reasonable because under conditions of high humidity and rainfall in the southeast (mostly 45-60 inches/year), fire interval less than 12 years seems to shift the advantage dramatically to woody species, and the herb layer is substantially obliterated by litter. Obligate frequent-fire species can be divided into three groups. First are the **circumannual fire obligates**, with species such as Venus flytrap, that require fire at intervals of

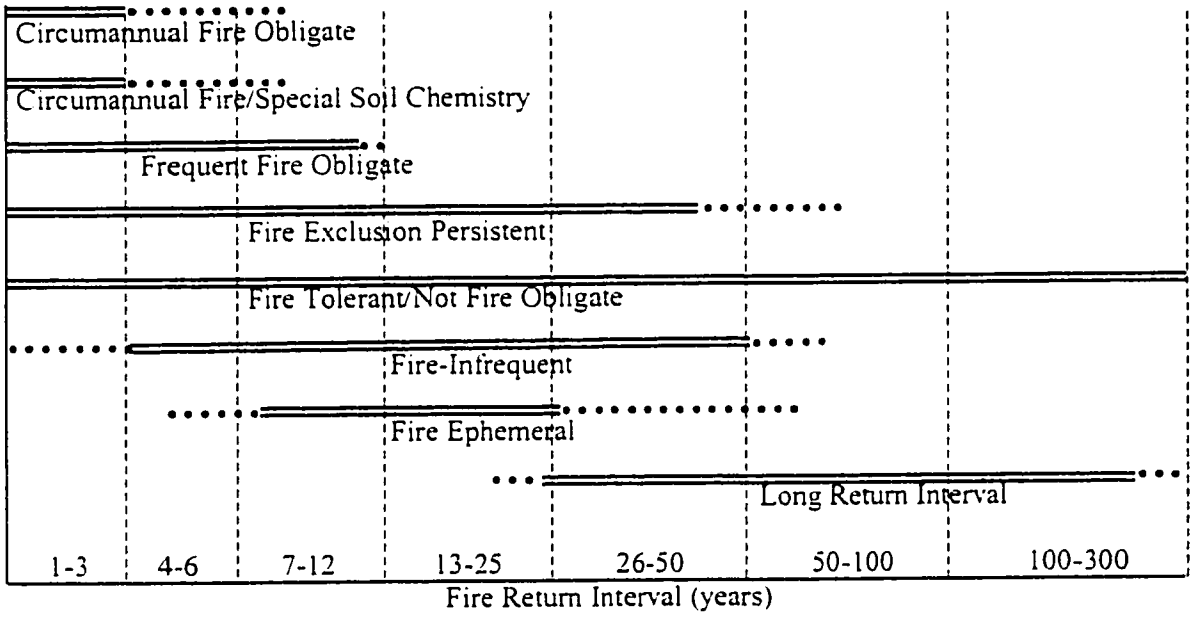
1-3 years on most sites but may hang on in marginal habitat for a few years longer. Second are a group of circumannual **fire obligates that are also restricted to situations of specific geology or soil chemistry.** This most often means circumneutral soils, a rarity in the acidic regions of the Atlantic slope. Such sites appear on the coastal plain only in situations such as lime sinks and other places where marl occurs near the surface, exceedingly rare north of Florida. Not surprisingly, these are the locations for communities of some of the rarest species, such as *Thalictrum cooleyi* and *Oxypolis canbyi*, both federal endangered.

Third are the **frequent fire obligate species that are found most often under a 4-6 year fire-return interval.** These are frequent fire species that occur in partially to mostly wooded landscapes, in woodland or savanna openings, where fire compartment sizes are too small to permit circumannual fires. These occur most extensively on the piedmont, but also on parts of the coastal plain and locally in the mountains

Fourth are fire-exclusion persistent species. Though not requiring frequent fire, these are pyrophytic species that serve as indicators that fire was once important on the site. These are good indicators of former savanna or pyrophytic woodland, and are commonly found on sites from which fire has been long excluded, and persisting after most of the rest of the herb layer has vanished. Typical species include *Tephrosia virginiana*, *Aster linarifolius*, *Liatris graminifolia*, *Pityopsis graminifolia* and *Solidago odora*. Some of these may persist as solitary specimens for 25-75 years after the last fire.

Fire tolerant species include a large group that can thrive or tolerate a frequent fire regime but do not seem to require it in any way. This would include a large percentage of our southeastern flora. Common examples include gallberry (*Ilex glabra*), wax myrtle (*Myrica cerifera*), red bay (*Persea palustris*), and sweet bay (*Magnolia virginiana*) which endure as dwarf shrubs in annually burned savannas, thrive in fire-infrequent sites, and develop into large shrubs and subcanopy trees in old growth forests and swamps. They all can also be found in swamps and on islands with absolutely no history of fire.

Figure 6.7. Eight fire interval species types in the southeast. All are fire-dependent, except for the fire tolerant species, which do not require fire for their survival, but tolerate, and may even thrive under a frequent fire regime.


Circumannual Fire Obligate
Circumannual Fire/Special Soil Chemistry
Frequent Fire Obligate
Fire Exclusion Persistent
Fire Tolerant/Not Fire Obligate
Fire-Infrequent
Fire Ephemeral
Long Return Interval
1-3
4-6
7-12
13-25
26-50
50-100
100-300
Fire Return Interval (years)

Fire-infrequent species are fire obligates that require at least occasional intervals in the 13-25 year range to reach maturity and complete their life cycle. This seems to be a common ecological niche in arid land vegetation (Cary and Morrison 1995), but quite uncommon in southeastern vegetation. It may apply to some of the oaks, such as post oak (*Quercus stellata*) which is found on lower slopes and other poorly fire-sheltered topographic positions in the Sandhills. In such situations, along a local fire frequency gradient, fire keeps the understory open, but oak saplings may experience occasional lapses in fire long enough to grow and produce fire-resistant bark. *Gordonia lasianthus* may be a similar case in a wetland setting. While it persists as a low shrub, resprouting prolifically in frequently burned pocosins, it reaches the stature of a small tree, able to flower and fruit abundantly for a number of years before being reduced to the ground under a 20-25 year fire-return interval such as is found in bay forest on the margins of flammable peatlands.

Fire ephemerals are species that may be absent or represented by only a plant or two during long fire return intervals, but proliferate after fire. Some may form a conspicuous presence with a large amount of cover for year or two after fire, produce a new crop of seeds, and then decline to obscurity (Figure 6.8). Fireweed (*Erechtites hieracifolia*) was not on the species list for the Blackwater Ecological Preserve (Isle of Wight County, Virginia) until after a prescribed burn in 1986, the first fire in over 35 years. In the year after the burn, it formed a prominent stand around the wetland periphery of sand lenses having longleaf and pond pine savanna. A moss, also previously unnoticed, formed conspicuous mats in a zone about 1-2 meters wide in all the transition areas between savanna and overgrown former pocosins. Similarly, huge blooms of a fire ephemeral moss, *Funaria hygrometrica* covered large reaches of the 260 km^2 (100 $mi^{2)}$ Open Grounds low pocosin in Carteret County, North Carolina after fires in the 1930s (Anderson, pers. comm.). In the Southern Appalachians, I have seen another ephemeral, *Robinia hispida*, appear after prescribed burns, lightning fires, and around campfire sites on Shortoff Mountain (Linville Gorge, NC), and Singecat Ridge (near Blue Ridge Parkway). The *Robinia* often appeared in areas where no plants had been seen before fire.

PATTERNS OF FIRE EPHEMERAL SPECIES

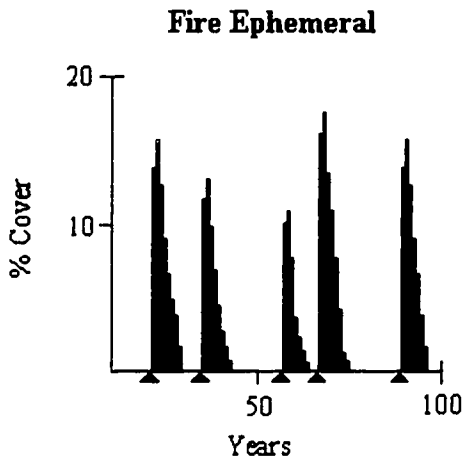


Figure 6.8. A hypothetical illustration of fire ephemeral species. This is an example of a species that may persist only as a seed bank, flourish briefly after fire, and produce a new crop of seeds to await the next burn, or a few inconspicuous individuals may continually contribute to the seed bank until fire returns. Triangles indicate fires.

Most ephemerals are annual or biennial. They represent a minor component of savanna flora, comprising only 6.5% of the 187 rare plant species native to the longleaf pine ecosystem (Walker 1993). The remaining 93.5% are perennials.

Long return interval obligates are species such as Atlantic white cedar (*Chamaecyparis thyoides*) in Virginia and the Carolinas, and sand pine (*Pinus clausa*) in Florida that are periodically regenerated from the seed bank or from seed shed during catastrophic, stand-destroying fire. While sand pine may persist in the absence of fire as a rare species on small

patches of xeric sand habitat, it seems likely that white cedar would become extinct without fire or human disturbance. It has been shown to behave as a pyrophytic patch mosaic species in Virginia and North Carolina peatlands (Chapter 3) and is often replaced with broad-leaved swamp forest trees after logging (Frost 1987). Despite its ability to live for more than 300 years, it is a highly shade-intolerant species and I know of no situation where it would reproduce itself in the permanent absence of fire.

Patterns of Species Response to Fire on Different Soils

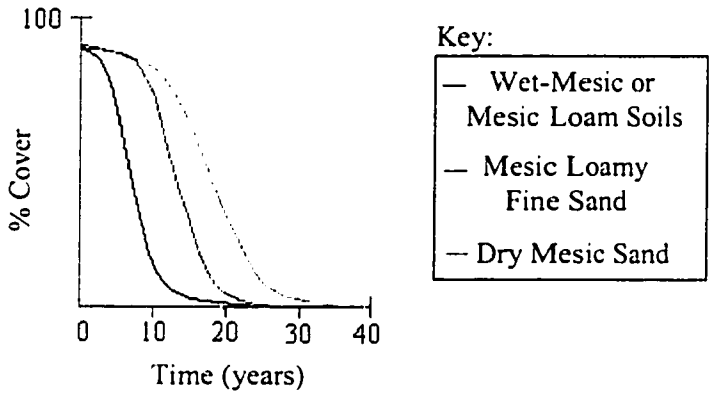
Aristida beyrichiana and *Aristida stricta* probably experienced 1-3 year fire over much of their ranges, but both species can persist much longer on drier soils (Figure 6.9). On the xeric Lakeland sand (Typic Quartzipsamments) at the Savannah River Site (Case Study 4) individual plants persisted on a small sandy peak for 36 years after the last fire (dated from fire scars, stem cross sections and post-fire sprouts on turkey oaks (*Quercus laevis*) at the site). On the other hand, on mesic loam soils, reduction of fire frequency to less than every 10 years is probably sufficient to extirpate the species. In one plot on Craven loam, a moist, fine-textured soil in the Croatan National Forest, burned every 5 years, wiregrass contributed 32% cover to the species rich herb layer (about 80 species per 1/10 ha). The site was designated a federal wilderness area in 1984, the year the study plot was established and one year after the last fire in 1983, when the Forest Service discontinued burning (prescribed fire was not allowed in wilderness at the time, although fire suppression was required!). When I revisited the plot in 1993, it had not been burned for 10 years and wiregrass cover had been reduced to less than 10% (see paired photos of succession on Craven loam in Case Study 3).

Lemon (1949) commented that there are probably as many different patterns of response to fire as there are species. Walker (1993) pointed out the acute lack of information about the ecology and life history attributes of individual species. It will be essential to accumulate information on the fire requirements of many individual species on a variety of soils in order to manage habitats for their survival.

Patterns of Decline of Fire Communities and their response to Reintroduction of Fire.

Foresters began experimenting with the results of fire exclusion just before the end of the 19th century. Sherrard (1903) produced a dense stand of slash pine saplings beneath old longleaf pine turpentine trees in South Carolina simply by excluding fire and fencing out hogs (see photo

Figure 6.9. Species persistence and time since last fire: a model of the effect of soil type on decline of wiregrass after fire exclusion. Displacement by shrubs and tree saplings is most rapid on soils that are wetter and finer textured. On the dry, sandy soil extreme of its tolerance, wiregrass may persist two or three times longer in the absence of fire.


100
% Cover
0
10
20
30
40
Time (years)
Key:
— Wet-Mesic or Mesic Loam Soils
— Mesic Loamy Fine Sand
— Dry Mesic Sand

reproduced in Chapter 2). In this case, the first stage of succession was replacement of longleaf pine with slash pine, a species with a lower fire frequency requirement.

Succession and Species Turnover with Reduction in Fire Frequency

Table 6.2 demonstrates the replacement of frequent fire species and communities by non-pyrophytic species as fire frequency and fire exposure decrease. Data from nine 1/10 hectare plots on Aquic Paleudult soils were pooled. The plots occurred on three very similar soil series that differed only in fine degrees of soil texture: Craven – clayey Aquic Hapludults, Exum – fine-silty Aquic Hapludults, and Goldsboro – fine-loamy Aquic Hapludults. The plots in Table 6.2 are ranked from the most frequently burned and most fire-exposed situations on the left, to the most fire-suppressed and most fire-sheltered situations on the right. The trends are summarized in Figure 6.10.

Shrubs and hardwoods once released from control by fire can dominate a moist site to the exclusion of most herb species within 5-10 years. Once established they maybe hard to eliminate. Twenty-two years of winter burns had little effect on woody understory on 73 permanent plots in the Everglades (Taylor and Herndon 1981). The first burn may be disheartening to land managers who find that the burn produces 2-20 new sprouts for every shrub or sapling stem that was there before. "The first burn just infuriates the shrubs" (Imm 1998). I have known instances in which such an experience has led managers to resort to goats, cattle grazing, herbicides and mowing on the first-experience conclusion that fire is not the answer. The answer, though, may be a series of closely spaced growing-season burns.

The most dramatic turnaround of this sort that I have observed occurred on the Goose Creek Game Land in Pamlico County, NC. In 1984 I installed a permanent 1/10 ha plot at Goose Creek in a stand that had the curious combination of mature longleaf pine over an understory comprised of a dense thicket of sweet gum. The site was a natural stand that had been burned at about three-year intervals. The sweet gum layer rebounded to 2 meters height the second year after each fire. The soil series was Tomotley (Typic Ochraquults) having a surface layer of moist, dark grayish brown

Figure 6.10 demonstrates replacement of fire dependent species with mesophytic, nonpyrophytic species as fire frequency is reduced. Nine plots (points across the bottom of figure) were located on three Aquic Hapludults, all relatively fertile, fine-textured, mesic soils on which succession from savanna to hardwoods might be expected to be much more rapid than on dry sandy soils. The first two plots were in the Croatan National Forest, with a recent history of fire about every 3-5 years. The other plots had experienced increasingly longer times without fire. Arranged according to fire history, the five plots demonstrate complete replacement of frequent fire species such as longleaf pine, ultimately with beech forest, probably the most fire intolerant tree species in the region. The declining curve shows the number of species in each plot remaining from the 70 fire-related species in the most fire-frequent plot on the left. The ascending curve represents the increasing number of non-pyrophytic species (the species in common with the most fire-suppressed site on the left). Only seven found at both ends of the fire frequency spectrum. These were ubiquitous species present as seedlings in many habitats, or species with a broad range of both fire and shade tolerance, or fire species that persist for a long time after cessation of fire: red maple, cane, sweetgum, cinnamon fern, *Polygala lutea, Smilax rotundifolia, Vaccinium tenellum.*

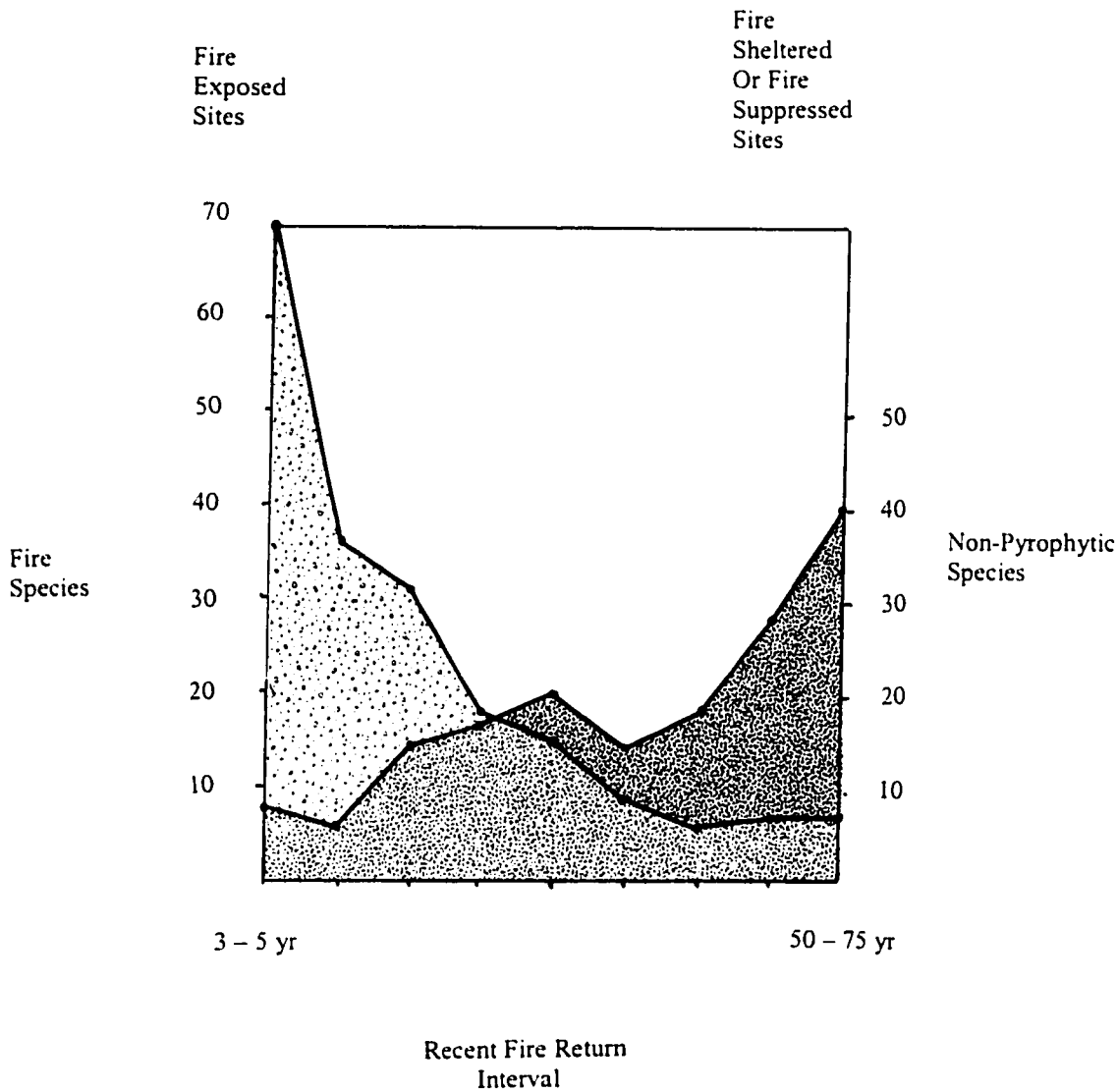

Fire
Exposed
Sites
Fire
Sheltered
Or Fire
Suppressed
Sites
70
60
50
40
30
20
10
Fire
Species
50
40
30
20
10
Non-Pyrophytic
Species
3 – 5 yr
50 – 75 yr
Recent Fire Return
Interval

TABLE 6.2. SPECIES TURNOVER WITH REDUCTION IN FIRE

	1/10 HECTARE PLOTS WITH IMPORTANCE VALUES								
Species:	**CR03**	**JO03**	**CR09**	**CR07**	**CR08**	**GA08**	**GA13**	**GA02**	**GA01**
Acer rubrum	.01	.01	6.99	1.29	.49	.63	.08	1.25	4.17
Agalinis purpurea	.	1.52	.	.01	.	.	.	.	.
Aletris farinosa	.	.12	.	.01	.	.	.	.	.
Amelanchier arborea	.	.	.13	.	.	.	.	.01	.
Anisostichus capreolata	.	.	.	.	.05	.	.	.	.
Andropogon glomeratus	.84	.52	.	.	.	.	.	.	.
Andropogon scoparius	5.32	9.04	.	.12	.	.	.	.	.
Andropogon glomeratus var. glaucopsis	.	.	.01	.	.	.	.	.	.
Arnica acaulis	.	.24	.	.	.	.	.	.	.
Arundinaria gigantea	.24	.	2.36	.01	.	.	.01	3.96	1.76
Aristida longispica var. longispica	.	.	.	.	.	.	.	.	.
Aristida stricta	44.04	32.0	.	.01	.	.	.	.	.
Aristolochia serpentaria	.	.	.	.04	.	.	.	.	
Aster dumosus	.	.	.	.	.	.	.	.	.
Aster linariifolius	.12	.84	.	.08	.	.	.	.	.
Aster patens	.01	.04	.	.	.	.	.	.	.
Aster paternus	.	.08	.	.	.	.	.	.	.
Aster solidagineus	.	.04	.	.	.	.	.	.	.
Aster squarrosus	.36	.96	.	.	.	.	.	.	.
Aster tortifolius	.01	.	.	.04	.	.	.	.	.
Asimina triloba	.	.	.	.01	.	.	.	.	.
Athyrium filix-femina ssp. Asplenioides	.	.	.	.	.01	.	.	.08	.01

Species:	CR03	JO03	CR09	CR07	CR08	GA08	GA13	GA02	GA01
Bartonia virginica	.01	.	.	.	.	.	.	.	.
Berchemia scandens	.	.	.	.01	.	.	.	.	.
Callicarpa americana	.	.	.	.	.	.	.	.01	.01
Carphephorus bellidifolius	.01	.	.	.	.	.	.	.	.
Carpinus caroliniana	.	.	.	.	.	.	.01	.	.01
Carex comosa	.	.	.	.	.	.	.	.48	.01
Carya glabra	.	.	.	.	.	.	.	.21	.02
Cassia nictitans	.	8.24	.	.01	.	.	.	.	.
Campsis radicans	.	.	.	.	.	.	.	.	.01
Carduus repandus	.04	.01	.	.	.	.	.	.	.
Carduus spinosissimus	.01	.	.	.	.	.	.	.	.
Carya tomentosa	.	.	.	3.29	.52	.04	.01	.26	.09
Chasmanthium laxum	.	.	1.88	.48	.40	.84	.01	.	.
Chimaphila maculata	.	.	.	.	.	.	.	.01	.
Chondrophora nudata	.01	.24	.	.	.	.	.	.	.
Chaptalia tomentosa	.	.01	.	.01	.	.	.	.	.
Clethra alnifolia	.08	.	8.33	.25	1.04	.57	.	.	.
Cornus florida	.	.	.01	5.26	1.18	.01	.01	.21	.65
Crataegus flabellata	.	.	.	.	.	.	.	.	.01
Crotalaria purshii	.	.28	.	.	.	.	.	.	.
Desmodium cileare	.	.	.	.01	.	.	.	.	.
Desmodium nudiflorum	.	.	.	.01	.32	.	.	.	.
Desmodium paniculatum	.	.12	.	.	.	.	.	.	.
Desmodium tenuifolium	.01	.44	.	.	.	.	.	.	.
Dichanthelium aciculare	.44	3.36	.	.52	.	.	.	.	.
Dichanthelium commutatum	.	.	.	.04	.08	.	.	.	.
Dichanthelium dichotomum var. dichotomum	.	.	.	2.0	.	.	.	.	.
Dichanthelium dichotomum var. tenue	.36	.	.	.32	.01	.	.	.	.
Dichanthelium laxiflorum	.	.	.	.	.04	.	.	.	.
Diospyros virginiana	.	.	.48	.	.	.	.	.	.
Elephantopus nudatus	.16	.	.	.	.	.	.	.	

Species:	CR03	JO03	CR09	CR07	CR08	GA08	GA13	GA02	GA01
Elephantopus tomentosus	.	.	.	.07	.	.	.	.	.
Epifagus virginiana	.	.	.	.	.	.	.01	.	.32
Erianthus giganteus	.	.48	.	.	.	.	.	.	.
Euonymus americanus	.	.	.	.	.05	.	.01	.01	.28
Eupatorium mohrii	.28	.	.	.	.	.	.	.	.
Eupatorium pilosum	.72	.56	.	.	.	.	.	.	.
Eupatorium rotundifolium	.20	.08	.	.01	.	.	.	.	.
Fagus grandifolia	.	.	.	.	.	.81	.17	.63	8.45
Galium circaezans	.	.	.	.	.	.	.	.	.01
Gaylussacia dumosa	.56	3.68	.	.08	.	.	.	.	.
Gaylussacia frondosa	17.29	9.44	7.92	30.73	.80	11.77	.	.	.
Galactia regularis		.	1.32	.	.	.	.	.	.
Gelsemium sempervirens	.48	.	1.17	.24	.17	.	.	.	.
Goodyera pubescens	.	.	.	.	.	.	.	.	.01
Habenaria cristata	.	.01	.	.	.	.	.	.	.
Helianthus atrorubens	.01	.64	.	.	.	.	.	.	.
Heterotheca nervosa	.48	2.28	.	.12	.	.	.	.	.
Hieracium gronovii	.04	.12	.	.	.	.	.	.	.
Hypericum hypericoides	.01	.08	.01	.04	.01	.	.	.	.
Ilex glabra	21.45	8.36	22.69	20.29	2.89	.	.	.	.
Ilex opaca	.	.	.72	.16	.05	.17	.01	.21	.05
Iris verna	.92	.28	.	.	.	.	.	.	.
Juniperus virginiana	.	.	.	.	.	.	.01	.09	.08
Lespedeza angustifolia	.	.40	.	.	.	.	.	.	.
Leucothoe axillaris	.	.	6.88	.	32.33	.	.	.	.
Lespedeza capitata	.04	.	.	.	.	.	.	.	.
Lespedeza hirta	.	.	.	.16	.	.	.	.	.
Lespedeza repens	.	.	.	.01	.	.	.	.	.
Lindera benzoin	.	.	.	.	.	.01	.	.	.
Linum floridanum	.	.04	.	.	.	.	.	.	.
Liatris graminifolia	.12	.04	.	.	.	.	.	.	.

Species:	CR03	JO03	CR09	CR07	CR08	GA08	GA13	GA02	GA01
Lilium michauxii	.	.	.	.01	.	.	.	.	.
Liquidambar styraciflua	.45	.33	10.29	7.09	5.37	.13	.01	.02	.02
Liriodendron tulipifera	.	.	.	.20	.	.	.03	.05	.09
Lonicera japonica	.	.	.	.	.	.	.	.	.01
Lobelia nuttallii	.12	.	.	.	.	.	.	.	.
Lyonia ligustrina	.01	.	.	.	.	.	.	.	.
Lyonia loomisii	.28	.	.	.	.	.	.	.	.
Lyonia lucida	.	.20	.	.	.	.	.	.	
Lysimachia terrestris	.	.12	.	.	.	.	.	.	.
Malaxis unifolia	.	.	.	.01	.	.	.	.	.
Magnolia virginiana	.05	.	.	.	.16	.01	.	.	.
Mitchella repens	.	.	.	.	1.48	.84	.01	1.16	2.28
Morus rubra	.	.	.	.01	.01	.	.	.	.
Myrica cerifera	.	.96	.57	3.33	.	.05	.	.	.
Myrica heterophylla	.	.36	.	.	.16	.	.	.	.
Myrica cerifera var. pumila	2.76	.	.	.	.	.	.	.	.
Nyssa biflora	.81	.01	.01	.01	.	.	.	.	.
Nyssa sylvatica	.	.	.04	.01	.	01	.	.05	.13
Osmunda cinnamomea	.01	.	.	.01	.04	.	.	.01	.01
Osmunda regalis	.	.	.	.01	.	.	.	.01	.
Oxydendrum arboreum	.	.	.05	.05	3.81	.01	.02	.01	.
Parthenossisus quinquefolia	.	.	.	.	.01	.	.	.01	.76
Panicum rhizomatum	.	.01	.	.12	.	.	.	.	.
Persea palustris	.01	.	1.45	2.33	.01	.	.	.	.
Pinus echinata	.	.	.	.	.02	.	.	.	.
Pinus palustris	.30	.33	.03	.19	.	.	.	.	.
Pinus serotina	.28	.05	.	.	.	.	.	.	.
Pinus taeda	.	.	1.80	1.77	.81	.05	.10	.04	.
Polygonatum biflorum	.	.	.	.	.	.	.	.16	.01
Polygala lutea	.01	.	.01	.	.	.	.	.	.01
Prunus serotina	.	.	.	.02	.01	.04	.	.	.05

Species:	CR03	JO03	CR09	CR07	CR08	GA08	GA13	GA02	GA01
Psoralia psoralioides	.84	.	.	.60	.	.	.	.	.
Pteridium aquilinum	2.16	2.08	.	.20	.	.	.	.	.
Pycnanthemum flexuosum	.	.01	.	.	.	.	.	.	.
Quercus alba	.	.	.31	4.37	.27	.50	.02	.29	.49
Quercus coccinea	.	.	.	.	.	.	.01	.	.
Quercus falcata	.16	.01	.	1.65	.15	.10	.01	.02	.
Quercus laurifolia	.	.	.	.25	.05	.	.	.	.
Quercus marilandica	.	5.57	.	3.74	.	.	.	.	.
Quercus michauxii	.	.	.	.12	.08	.	.01	.	.
Quercus nigra	.01	.	.65	.53	.32	.01	.01	.	.
Quercus pagoda	.	.	.	.	.	.	.01	.	.
Quercus phellos	.	.	.01	.	08	.04	.	.	.
Quercus rubra	.	.	.	.	.	.14	.04	.24	.
Quercus stellata	.	.	.05	.06	.11	.01	.01	.01	.
Quercus velutina	.	.	.	.	.	.01	.01	.01	.21
Rhexia alifanus	.20	.	.	.	.	.	.	.	.
Rhododendron atlanticum	.	.80	.40	2.60	.	.20	.01	.04	.24
Rhus copallina	.01	.96	.01	.33	.	.	.	.	.
Rhus radicans	.	.	.	.	.13	.	.	.36	.04
Rubus argutus	.	.	.	.	.	.	.	.04	.
Rubus sp.	.	.	.01	.41	.01	.	.	.	.04
Rubus hispidus	.	.12	.16	.	.	.	.	.	.
Sassafras albidum	.	.	.05	.57	.	.	.01	.	.
Sanicula smallii	.	.	.	.	.	.	.	.01	.01
Scirpus olneyi	.	.	.	.	.	.	.	.08	.
Scleria oligantha	.	.	.	.	.	.	.	.	.
Scleria triglomerata	.	.16	.08	.	.	.	.	.	.
Sisyrinchium albidum	.12	.	.	.	.	.	.	.	.
Silphium compositum	.01	.	.	.40	.	.	.	.	.
Smilax bona-nox	.	.08	.	.16	.08	.	.	.	.
Smilax glauca	1.04	.09	.77	.04	.29	.04	.01	.	.

Species:	CR03	JO03	CR09	CR07	CR08	GA08	GA13	GA02	GA01
Smilacina racemosa	.	.	.	.	.	.	.	.	.04
Smilax rotundifoia	.68	.	4.21	.02	.01	.	.	.04	.44
Smilax smallii	.	.	.	.01	.	.	.	.	.
Solidago arguta	.80	.	.	.	.	.	.	.	
Sorbus arbutifolia	.44	.40	.	.	.	.	.	.	.
Solidaga odora	.01	.36	.	.48	.	.	.	.	.
Solidago pinetorum	.	.72	.	.	.	.	.	.	.
Solidago pulchra	.01	.	.	.	.	.	.	.	.
Solidago stricta	.01	.	.	.	.	.	.	.	.
Stylosanthes biflora	.08	.52	.	.01	.	.	.	.	.
Symplocos tinctoria	.04	.	.01	.	.	.	.01	.	.
Tephrosia hispidula	.16	.16	.	.	.	.	.	.	.
Tephrosia spicata	.	.92	.	.	.	.	.	.	.
Thelypteris hexagonoptera	.	.	.	.	.	.	.	..01	.
Thelypteris noveboracensis	.	.	.	.	.	.	.04	.48	.01
Tipularia discolor	.	.	.	.	.01	.	.01	.	.01
Tillandsia usneoides	.	.	.	.01	.	.	.	.01	.
Trilisa paniculata	.32	1.04	.	.	.	.	.	.	.
Vaccinium atrococcum	.01	.04	1.01	.	.77	.	.	.	.
Vaccinium crassifolium	4.52	14.96	.	.	.	.	.	.	.
Vaccinium stamineum	.	.	.60	.	.08	.01	.	.48	.16
Vaccinium tenellum	16.72	16.44	1.20	8.24	1.48	.40	.	.04	.08
Vitis aestivalis	.	.	.	.02	.01	.	.	.	.
Viola pedata	.	.04	.	.	.	.	.	.	.
Viola primulifolia	.01	.	.	.	.	.	.	.	.
Vitis rotundifolia	.	.52	4.93	10.77	2.41	.25	.01	2.40	.96
Woodwardia areolata	.	.	.	.12	.01	.	.	.	.01
Xyris caroliniana	.36	.	.	.	.	.	.	.	.

loamy fine sand only a few centimeters above sea level. The only canopy trees were longeaf pine, 43 stems per 1/10 ha and pond pine, 15 stems per 1/10 ha. Two of the largest longleaf (up to 46 cm [18 inches] dbh) were 77 and 93 years, while the oldest pond pine was only 51 years, perhaps dating to onset of fire suppression in the region in the 1930s. There were 820 stems of sweet gum and 230 stems of red maple per 1/10 ha. In addition there were 680 shrub stems taller than 1 meter. There were no young longleaf pines and no reproduction was even remotely possible under existing conditions. There were only 21 herb species, suggesting a period of fire suppression in the past. Two small clumps of wiregrass, *Xyris caroliniana*, *Carphephorus bellidifolius* and other scattered single individuals of fire exclusion "persisters" gave the only clues to the previous existence of the species-rich moist savanna, probably with 80-100 species of herbs, that once occurred here.

When I returned 8 years later, in 1992, I was astonished at the change. The woody understory had completely vanished. The pine canopy was largely intact though a few small to mid-sized trees of both pine species had been killed by fire. There were literally no understory woody stems other than 5 or 6 blackened remains, and hardly any sprouts in the herb layer. According to the forester for the site, when fire had been reintroduced sometime in the 1960s or 1970s, the burning was done in the winter. Just after my visit in 1984, he had switched to growing-season burns, carried out about 1-3 years apart. The community had been transformed from a woody thicket to a two-layered longleaf pine/savanna herb community. This was accomplished with nothing more than a closely spaced series of three growing-season burns.

It has been known for some time that belowground carbohydrate reserves are lowest in early summer after the winter's supply has been spent on leafout. Repeated summer burns represent cumulative stress, which can lead to high mortality of woody species. Lotti (1956) was the first to report that a series of summer burns could actually eliminate persistent understory species like sweet gum and bayberry but this finding was overlooked for many years. In my study plot, all sapling and shrub-sized stems of red maple, *Amelanchier*, *Nyssa biflora*, red bay (Persea palustris), *Myrica heterophyla*, *Clethra alnifolia*, *Rhus copalina*, gallberry, and Gaylussacia frondosa were either killed or reduced to the status of sparse dwarf shrubs in the herb layer.

In conversation with land managers, it has been suggested that three summer burns may be the "magic number" for successful eradication of dense shrubs and hardwood saplings. Few organizations to date, however, seem to have had the resources to follow this prescription.

Effect of soil types on persistence of species with time since last fire. The time that each species will persist after fire is another attribute that we must know, in addition to MFRI. Even Venus flytrap, with an extremely narrow range of variation in tolerable fire frequency, showed a slight increase in persistence on slightly drier soils. Figure 6.9 above modeled the range of times that wiregrass may persist after fire on different soils. This was based on 35 plots with different fire regimes. On moist, fine-textured soils wiregrass might be characterized as a frequent fire obligate (see Figure 6.7 above), considering that it was in steep decline after 12 years. On dry sandy soils it behaved as a "persister", with a few telltale clumps found 30 or more years after fire, and serving to identify the site as former savanna. The curves were constructed from plots on 20 soil series that spanned the moisture and textural gradients from Kureb sand (Typic Quartipsamments) to Rains loam (Typic Paleaquults), and from annually burned to 36 years without fire. Percent cover of wiregrass ranged from 74% on frequently burned Mandarin sand (Millis Road Savanna, Croatan National Forest) to a microscopic 0.01% on Tomotley loam in the winter-burned plots infested with sweetgum at Goose Creek Game Land mentioned above. Such curves could be constructed for all fire-dependent species.

In many localities managed with fire, but having uncharacteristically low cover of wiregrass, it was obvious that the site had undergone a period of fire suppression in the past, followed by reintroduction of fire. The model in Figure 6.11 examines response of species richness to various periods of fire exclusion.

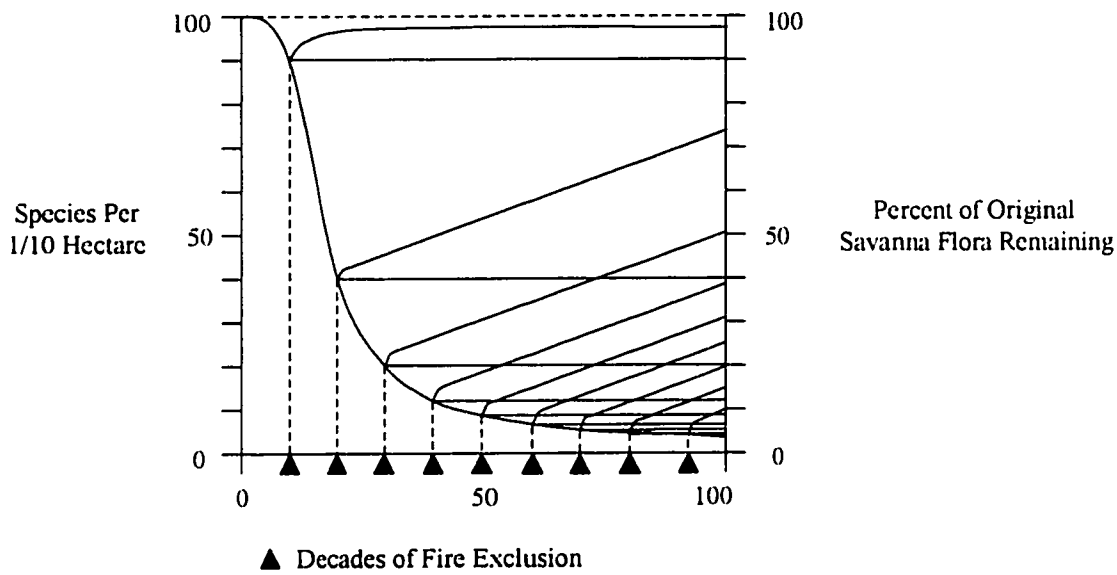
Species richness and reintroduction of fire. Over several years of searching for sites with natural, fire-maintained vegetation on all of the soil series of eastern North Carolina, I often set up study plots on sites in which fire had been reintroduced after a period of fire exclusion. I routinely determined time since last fire and in some cases the second and third fire in the past, by coring fire scars and coring the largest pines. I also determined the age of even-aged shrub classes dating to past fires, using stem cross-sections and bud scale scars, which were usually good for the preceding 10-12 years. On moist savanna sites, predictably, those that had been burned the most frequently in the past 10 years or so had the most species. On the other hand there were many sites currently being burned, often with species-rich comparable sites on the same soils elsewhere, that had severely depauperate herb layers. Some, like the site at Goose Creek, had dense understory or shrub layers despite burning, while others in drier or more sterile sites had excessive ground cover of sprawling vines, most commonly yellow jessamine (*Gelsemium sempervirens*), catbrier (*Smilax glauca* and *Smilax*

rotundifolia) and wild grape (*Vitis rotundifolia*). Simple reintroduction of fire seemed to have done little to restore either herb cover or species diversity. Even in the case of Goose Creek, where the bilayered community structure was dramatically restored with frequent, growing season fire, the site remained floristically depauperate, with the herb layer now dominated by ferns, first by bracken and later by cinnamon fern (*Osmunda cinnamomea*). Savanna remnants such as wiregrass were nearly as sparse as before. Questions were raised around the loss of species in relation to length of fire exclusion, and the likely time required to reestablish species diversity and density. The patterns in Figure 6.11 were suggested from study plots, some 115 1/10 ha intensive study plots and 352 species lists, each from a stand on a particular soil series. These plots spanned the spectrum of soil moisture, texture and fire frequency available in the Albemarle-Pamlico region in North Carolina, and were supplemented with species lists from plots in southeastern Virginia and the Sandhills of North and South Carolina.

Starting with a species rich, wet-mesic savanna, having around 100 species per 1/10 ha and maintained by frequent fire, Figure 6.11 illustrates two patterns of species richness in relation to fire exclusion and reintroduction. A hundred species per 1/10 hectare is in the upper range of diversity for longleaf pine savannas, but not uncommon for wet-mesic savannas that have been burned every 1-3 years, and up to 140 species per 1/10 ha have been found (Peet and Allard 1993). Table 5.4 in Chapter 5 demonstrated the relative resistance to shrub invasion by dry-mesic savanna at the same time that wet-mesic habitats for Venus flytrap a few meters away were overrun by shrubs when 10 year mean fire return interval was reduced from 1.22 to 4 years. Figure 6.11 is constructed around a species richness curve for such a site.

Figure 6.11 suggests that upon exclusion of fire, there is little change in species number for three or four years. Between 4 and 10 years, frequent-fire obligate species start to drop out. As litter accumulates and woody growth in the form of shrubs and tree saplings approaches 100% cover, diversity plunges. Herb diversity continues to decline with development of multistoried woody vegetation, until the remaining pyrophytic vegetation consists only of the persistent fraction of fire-dependent herbaceous vegetation (Figure 6.7) and long-lived frequent fire obligates such as longleaf pine. After about 50 years, the curve flattens and if the longleaf pine are removed by logging, the only species remaining are the non-fire dependent species, mostly shrubs and saplings that may have been present in the original flora but only as dwarf shrubs and sprouts that were confined to the herb layer by fire. These species comprise the new dominants of the site along with winged species such

Figure 6.11. Species richness curve for diverse, wet-mesic longleaf pine savannas with a natural regime of circumannual fire. With fire exclusion, species numbers decline with each passing decade. Reintroduction of the original fire regime should result in a gradual recovery, beginning at the point of reintroduction (slanting lines). Reintroduction of fire, but at a frequency lower than the original fire regime, could arrest species loss but not be sufficient to restore original diversity (horizontal lines). The second model appears to be the rule in most instances where fire has been reintroduced in the South.


100
50
0
Species Per
1/10 Hectare
100
50
0
Percent of Original
Savanna Flora Remaining
0
50
100
▲ Decades of Fire Exclusion

as sweet gum (*Liquidambar styraciflua*), tulip poplar (*Liriodendron tulipifera*), pond pine and loblolly pine, that may seed in if a nearby seed source is available.

The upward slanting lines represent expected response of species numbers to reintroduction of fire. In the first three years we might expect a slight rebound caused by germination of species that had been relegated to the seed bank. Further recovery should be a cumulative process as species slowly recolonize from short and long distance dispersal of seed or spread of rhizomes. This part of the model assumes that the lost species still exist in the surrounding landscape to provide a source of propagules. Otherwise the curve will be asymptotic, probably never recovering to the original diversity.

The lines extending horizontally to the right constitute the second pattern in the model. They represent the common case where fire is reintroduced but at a lower frequency than in the original fire regime. Reintroduction of fire at a lower frequency may result in prevention of further species loss but not be sufficient to put the site on the path to restoring original diversity. The actual slope of the lines will be positive or negative, in relation to the degree to which the reintroduced fire regime approximates the original.

Horizontal or down-trending lines would also result if no propagules were available in the surrounding lands. In the presettlement landscape, if fire were excluded for 10 years a stand might return to the previous richness through migration of propagules in two or three decades. In the modern landscape, most lands surrounding natural areas are managed for forest products or agriculture, or neglected until they produce a timber crop. Any spontaneous recolonization must come from long distance dispersal of seeds from other islands of species rich, frequently burned moist savanna, themselves also isolated in a sea of human-altered land uses. Island biogeography theory indicates that the likelihood of immigration of lost species from other distant vegetation islands will be offset by occasional extirpation of species within the natural area (MacArthur and Wilson 1967). The reality suggested in Figure 6.11 is that sites depauperized by fire exclusion will never regain their original species composition unless the frequent fire obligates are intentionally reintroduced.

USING FIRE-FREQUENCY INDICATOR COMMUNITIES TO ESTIMATE ORIGINAL LANDSCAPE FIRE FREQUENCY

Presence of particular plant communities, either as small remnants or as historical records, may be used for mapping presettlement fire regimes. In Chapter 3, fire relations of different wetland plant communities like canebrake, pocosin, bay forest and white cedar forest were determined (Tables 3.1-3.3). Where past locations of such communities can be determined, the approximate fire–return interval for that vegetation type can be determined from the vegetation tables, and the corresponding historical fire frequency can be mapped for that point. This was the primary method used in producing the map of presettlement fire regimes of the Dismal Swamp Region below. Figures 6.12 and 6.13) show rare canebrake communities dependent upon 2-5 year fire intervals. Frequently mentioned in the historical literature, and occupying a narrow range on the fire frequency gradient, these are good examples of fire frequency indicator communities.

USING LANDSCAPE FIRE ECOLOGY AND HISTORICAL VEGETATION NOTES TO RECONSTRUCT LANDSCAPE-SCALE FIRE FREQUENCY OF THE GREAT DISMAL SWAMP

A very compressed fire-tension zone can be seen on the western side of the Great Dismal Swamp where it is bounded by the Suffolk Scarp. This is a distinct zone where fire once approached circumannual frequency on the top of a longleaf pine ridge that forms the western boundary of the swamp. Within 100 meters in some places, fire frequency dropped to 100-300 years in the Atlantic white cedar that made up the majority of the vegetation in the Dismal (Akerman 1923).

The great peat bog lies at about an elevation of 8 meters (25 feet) at the toe of the Suffolk Scarp. This is an old beach ridge, left from a time when this was the Atlantic shoreline, around the end of the Sangamon Interglacial, some 60,000-80,000 years ago. The top of the scarp, which ranges up to about 16 meters (50 feet), is the driest and most fire-exposed portion of the local landscape. In 1728, this long, linear sand ridge, which stretches from the James River in Virginia, south to Edenton, North Carolina, was covered with longleaf pine (see Byrd quote, Chapter 7). Today, not a single longleaf can be found on the Virginia segment, although I found a handful of old trees at scattered sites in Suffolk, one of which, a mile west of the scarp, was

Figure 6.12. Frequently burned bottomland canebrake, a fire-frequency indicator community. Three months after an early growing season wildfire, the cane layer has recovered to about a meter tall, about half the height it will reach by fall. The best images of what presettlement vegetation communities looked like in the South can be found in buffer areas around impact zones on a few military bases. Accidental growing season fires ignited by flares and ordinance used in artillery practice simulate the presettlement lightning fire regime. At this location, burned an average of every two years (Eric Hoffman, Fort Bragg biologist, pers. comm.), the canopy is pure pond pine with a canebrake (*Arundinaria gigantea*) and cinnamon fern (*Osmunda cinnamomea*) understory. Several rare species occur at this site: whorled loosestrife (*Lysimachia asperulifolia*, federal endangered), pocosin lily (*Lilium* sp., possibly *Lilium gazarubrum* or a new species) state endangered, federal candidate), a recently described new sedge, *Carex lutea*, and St. Francis satyr, a rare butterfly. Despite the high fire frequency, occasional small understory stems of pond pine are available to fill canopy gaps. Longleaf pine dominates the upland scarp barely visible in the left background.

Bones Creek drainage, Ft. Bragg, North Carolina

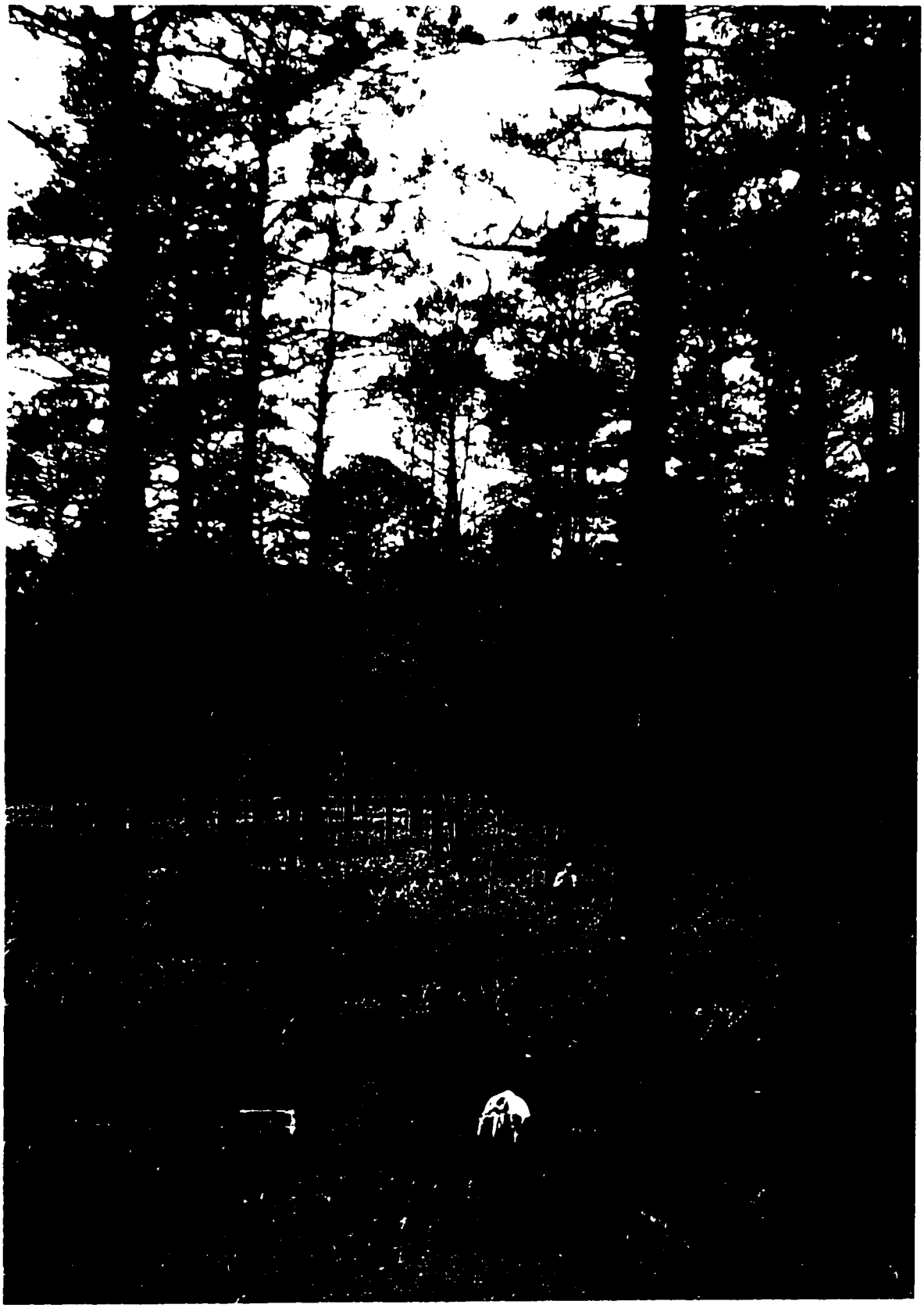


Figure 6.13. A rare community type, hardwood/canebrake, another fire-frequency indicator community, two months after an early growing season wildfire. Flammable canebrake and bottomland hardwoods coexist in dynamic balance related to fire effects. On the one hand, cane is dense enough to carry fire and to burn hot enough to maintain the understory largely free of shrubs and tree saplings. On the other hand, the hardwood canopy is shady enough to prevent cane from becoming so dense that it would burn hot enough to kill the canopy trees. Note the light and shadow effect on the cane layer caused by the partially open canopy. Established trees may enhance their own safety because shade increases closer to the trunk, leaving a patch free of cane fuel. Occasional hardwood saplings establish themselves in cane-free microsites. As with pyrophytic hardwood communities, successful new stem recruitment into the canopy is rare, but small stems are present, and the rare survivor that escapes into the canopy is all that is needed to maintain community structure. This site was habitat for several rare plants. True bottomland hardwood/canebrake is also historic habitat for the rare Swainson's *warbler (Limnothlypis swainsonii)* (Meanley 1972) and Bachman's warbler (*Vermivora bachmanii*) (Hamel 1986). Once widespread in the South, this habitat type is now quite rare, nearly all historical sites having long since succeeded to closed canopy forest.

Photo, Bones Creek drainage, Fort Bragg, NC.

Presettlement Fire Regimes in Vegetation of the Dismal Swamp Region

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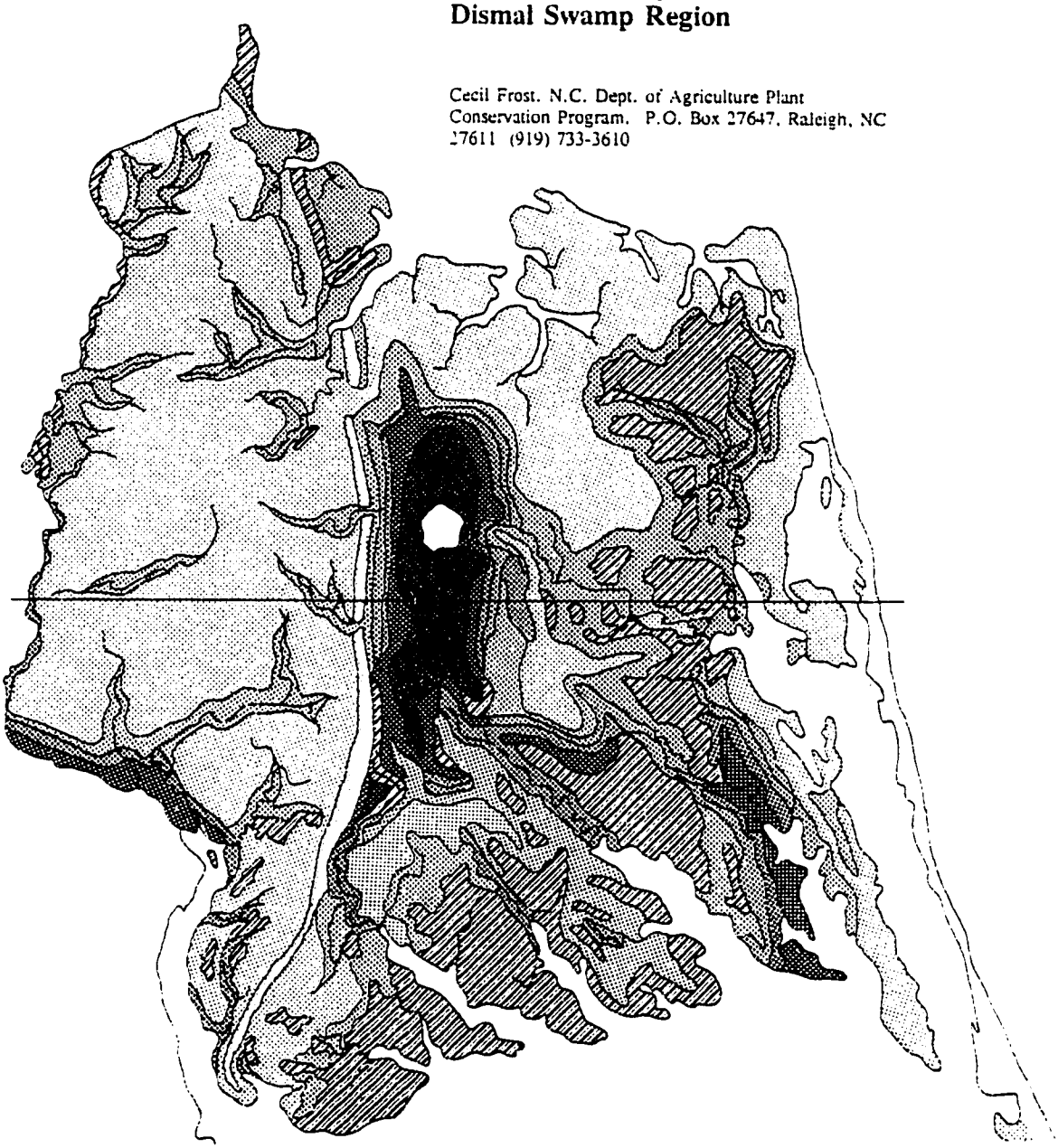

	1-3 yrs	Longleaf pine savannas along the Suffolk scarp, the dryest and most fire-exposed part of the landscape.
	4-6 yrs	Longleaf pine forest and pyrophytic woodlands on sandy plains of the Pamlico Terrace and Isle of Wight Plain; canebrakes on shallow histosols; marshes.
	7-12 yrs	Pyrophytic woodland and forest on slightly fire-protected landscape positions. Narrow zones of pocosin and bay forest along margins of peatlands and fluvial wetlands.
	13-25 yrs	Pocosins, bay forest and small white cedar patches in fire-tension zones (broad transition areas between frequently burned uplands, canebrakes or marshes), and infrequently-burned white cedar or nonpyrophytic freshwater swamps.
	26-50 yrs	White cedar forests, and patch mosaics of white cedar, pond pine, red maple, and bay forests in fire-tension zones between more frequently burned canebrake or pocosin, and water or infrequently-burned white cedar or nonpyrophytic freshwater swamps.
	50-100 yrs	White cedar forests in fire-tension zones between more frequently burned types above, and water, nonpyrophytic freshwater swamps, or very-infrequently-burned white cedar
	100-300 yrs	Pure stands of old-growth white cedar in the fire-infrequent interior of the Great Dismal Swamp. Fire was the result of rare climatic events such as prolonged drought in combination with hot, dry winds that carried crown fire into the interior.
	Non-pyrophytic	Oak flats and mixed mesic hardwoods in fire-sheltered landscape positions, or on clay soils which resist spread of flammable rhizomatous shrubs. Other than light litter fires which may have prevented establishment of beech on oak flats, fire played little role.

about 250 years old. At the toe of the scarp in the vicinity of Corapeake (Gates County, NC) George Washington found pines growing in standing water (Washington 1763). These were likely loblolly or pond pine savanna maintained by fire on the moist soils at the toe of the scarp, and intermittently flooded by water from the outfall of Corapeake Swamp into the Dismal. With many decades of fire exclusion, no example of this frequent fire community remains.

Using fire compartment size, soils, remnant natural vegetation and historical descriptions, particularly those of George Washington in 1753 and William Byrd in 1728, I reconstructed the original fire frequency regimes of the Dismal Swamp region (Figure 6.14). Lake Drummond can be seen in the center of the Dismal on the north side of the state line, which bisects the swamp. The most fire-frequent zone was the sandy Suffolk Scarp, the light strip running north south along the edge of the Dismal, where William Byrd described longleaf pine as the dominant tree in 1728. At the other extreme was the stand of some 120,000 acres of Atlantic white cedar in the Dismal Swamp itself (Akerman 1923). Less than 1% of the original acreage of white cedar remains. Longleaf pine flats and savannas once occupied the uplands to the west of the scarp and there is still a thin sprinkling of old longleaf trees, up to 300 years old, across this landscape. On the east side of the swamp, just south of the state line, is a light area indicating fire return interval of 4-6 years that was known as the Green Sea, a vast canebrake of about 50 square miles described by William Byrd, George Washington and later authors. A narrow finger of the canebrake can be seen extending north across the line. In 1728, Byrd's survey crew crossed this arm of canebrake, which was then bordered by pine flatwoods on the east and white cedar on the west. Cane was called reed in Colonial times, the term canebrake being unknown in the Mid-Atlantic area until the 19th century.

> "However small this distance may seem to such as are us'd to travel at their Ease, yet our Poor Men, who were oblig'd to work with an unwieldy Load at their Backs, has reason to think it a long way; especially in a Bogg where they had no firm Footing, but every Step made a deep Impression, which was instantly fill'd with Water. At the same time they were labouring with their Hands to cut down the Reeds, which were Ten-feet high, their Legs were hampered with the Bryars. Besides, the Weather happen'd to be very warm, and the tallness of the Reeds kept off every Friendly Breeze from coming to refresh them. And, indeed, it was a little provoking to hear the Wind

whistling among the Branches of the White Cedars, which grew here and there amongst the Reeds, and at the same time not have the Comfort to feel that least Breath of it."

I thoroughly explored this region, having lived three miles west of the Suffolk Scarp for six years. During this time, I carried out a survey of remnant pocosin wetlands in southeastern Virginia for the Virginia Natural Heritage Program, and conducted natural area inventories for the five North Carolina counties just south of the line. I lived there from 1976 to 1981 while employed as Ranger in Charge of Merchants Millpond State Park in Gates County, North Carolina. I also had some responsibilities for the 12,000 acre tract of state-owned land in the Dismal Swamp lying along the south side of the state line west of highway 17. By that time, the canebrake of the Green Sea had long since succeeded to pocosin under mid 20th century fire suppression. In 1988 I explored the narrow finger of canebrake that gave Byrd such discomfort and there was not a stem of cane to be seen, the entire zone having succeeded first to tall pocosin and then to dense red maple thicket. It was discrepancies such as this, between historical and modern vegetation, that tipped me off to the pervasive role of fire in wetlands, and to the realization that some areas had been completely transformed to another vegetation type with nothing more substantial than reduction or elimination of fire. In all, Byrd described vegetation at some 30 points along the state line from the Atlantic to central Gates County. This comprised an early transect of presettlement vegetation, and the fire frequencies indicated by the vegetation types he described in 1728 were used along with soil maps and field work to reconstruct the original fire frequencies mapped in Figure 6.14.

Bad Day at Stumpy Point

The world's highest reported fire frequency occurred at Stumpy Point, Hyde County, North Carolina, in pocosin vegetation. Pocosin fires are notoriously hard to fight because the dense, shrub vegetation can burn too hot for direct attack and requires special high-floatation equipment to traverse the wet peat soils. Stuck equipment has sometimes had to be abandoned and been destroyed by fire. This fire was especially difficult because it occurred near the margin of Pamlico Sound, where fires are affected by onshore breezes from the Sound and the Atlantic Ocean. Different rates of heating and cooling between land, which heats up quickly, and water, which changes slowly, lead to twice daily reversal of wind direction. This is compounded by effects from the Sound, which, being some 10 miles wide and extending 60 miles to the south

from that point, has its own effects on wind changes, perpendicular to those of the oceanic breezes. This creates unpredictable changes in fire behavior.

As related to me by an old forester, who worked on the Stumpy Point fire, the fire crossed the pocosin in the morning, and they thought it was about under control when a wind shift occurred. The fire reversed direction and, much to the surprise of fire crew, began to burn the pocosin a second time. Driven by wind in the morning, the fire had carried through the top of the shrub layer but had not burned all the fuel. The lower layer of leaves and low shrubs, however, had dried out enough with passage of the fire overhead that by afternoon the rest was ready to burn. The fire recrossed the pocosin and by late afternoon the weary crew thought they were done, but it was not yet over, "We thought we had it licked but then the wind changed and here it come again." This time it was a surface fire, carried by ferns, stick litter and fallen green leaves, crisped and dropped during passage of the preceding fires. The fire was finally contained that night. Fire three times a day would give a mean annual fire return internal of 1,095 fires a year, surely a record high fire frequency.

CONCLUSION

Landscape fire ecology is a new field. It has been slow to emerge because by the time widespread interest in vegetation ecology emerged in the mid-20th century, fire landscape processes had become largely obscured. In the eastern U.S. there were two factors at work. First, nearly all of the landscape had come under effective fire suppression by 1950. Second, the landscape had become fragmented into trivially small fire compartments by the grid of roads, ditches, fields and towns. In the western U.S., the emphasis was on fire suppression and fires were treated as a public problem of anthropogenic origin, not a natural process. Much research was conducted on fuel models, and rates of fire spread in different kinds of vegetation and different topographic situations. Other work quantified the influence of weather and fuel moisture on fire behavior (Anon. 1981). While all these projects were potential contributions to landscape fire ecology, focus was narrowed to calculating how far a particular fire would spread before it could be contained by suppression equipment. Interest in fire as a natural process was further obscured by the enormous size of western fire compartments. One western researcher was puzzled when I raised the question of the importance of fire compartment size on fire frequency. He had never considered it, since it seemed apparent that during fire season fires just kept going—nothing seemed to stop them in dry western vegetation. In contrast, in the East, hundreds

of obscure creeks carry more water than most western rivers. In addition, eastern creeks are often deeply incised into the surrounding land and are bordered by mesophytic vegetation on the sloping creek valley walls, increasing their effectiveness as firebreaks. The same principles apply in the West as in the East. The effects of fire compartment size are just more readily apparent in the smaller compartments of the East and Southeast.

From fire history studies, the presettlement U.S. can be seen to have been a fire landscape (Chapter 4). Only in the search for ways to reconstruct original fire frequency and presettlement vegetation did elements of landscape fire ecology begin to emerge. Plant communities can be classified according to their fire frequency relations (Chapter 3). Plant species can be assigned to fire frequency categories, and those that can tolerate only a limited range of fire frequency can be used a fire-frequency indicator species (Chapter 5). As demonstrated above in the Dismal Swamp region, and below in Case Study 4, the Savannah River Site, we can reconstruct presettlement fire regimes with some detail at the local level, using principles of landscape fire ecology. The key elements appear to be fire compartments, fire filters, fire shadows, fire frequency indicator species, fire frequency indicator communities, fire-exposed versus fire-sheltered areas, fire-tension zones and landscape scale fire frequency gradients.

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CHAPTER 7

USING LANDSCAPE FIRE ECOLOGY FOR MAPPING PRESETTLEMENT VEGETATION

Finding ways to map original vegetation has been my particular Holy Grail for the past 20 years. Starting with landscape fire ecology may seem an odd approach to mapping vegetation but it turns out to be essential. Fire is arguably the most important environmental parameter in explaining Southeastern vegetation. Variation due to rainfall seems almost trivial in comparison. Variation due to soils is important but within the space of a kilometer absolutely different vegetation, with no species overlap, can be found on the same soil series. The difference can be accounted for almost entirely, by whether the stand is in a fire-sheltered or fire-exposed part of the landscape. In the Albemarle-Pamlico region and in the Croatan National Forest, the Augusta and Craven soils both support the vegetation extremes of longleaf pine savanna and beech forest on the same soil series, with the differences in vegetation apparently the result only of different degrees of fire shelter or fire exposure in the landscape. It is necessary to map local fire compartments and construct a local map of fire regimes in order to predict which of the range of plant communities, from pyrophytic to fire-refugial, will be found on a site. It is further necessary to understand fire behavior in response to slope and aspect in the immediate vicinity of a specific stand to be able to predict vegetation at the level of the individual soil pedon at hand. Presented below is a review of presettlement vegetation methods. This is followed by an outline of steps in mapping vegetation under past fire regimes, using principles of landscape fire ecology discussed in Chapter 6.

PREVIOUS METHODS OF RECONSTRUCTING PRESETTLEMENT FORESTS

A variety of methods have been tried for reconstructing former vegetation. These are presented below in increasing order of precision. Since the first few approaches lack any means for mapping vegetation at a local scale, they are of limited value for land management.

Palynology. Fossil pollen studies like those of Whitehead (1972, 1981), Delcourt and Delcourt (1974, 1977), and Davis (1981) awakened interest in vegetation history and presettlement vegetation of eastern North America. Numerous other palynological studies of the eastern U.S. reviewed by Webb (1988) shed light on events between the end of the Wisconsin glaciation and development of the major plant formations found at the time of European settlement. Among the drawbacks of palynology are the imprecise time scale provided by radiocarbon dating, especially for recent dates, including the settlement period; the over-representation of pollen of wind-pollinated species, and the over-representation of wetland species, since the cores for pollen analysis are usually collected in peatlands or under bodies of water. Also, since it may take a year to analyze a single core, palynologists are forced to extrapolate broadly about regional vegetation from a very few points. These limitations prevent the use of palynology in determining presettlement vegetation at a scale useful for mapping or managing natural areas.

Historical descriptions. Bromley (1935) used historical records and general comments of early explorers, along with virgin forest remnants still in existence, to describe presettlement forest types of New England. This method, based on descriptions by contemporary observers, is necessarily a broad-brush approach and lacks a mapping base. Nevertheless, such descriptions represent windows in time and are sometimes our only connection to what was. Forman and Russell (1983) recommended several criteria for evaluation of historical statements about vegetation:

1. Was the observation first, second or third-hand? Many historical sources are vague as to whether statements were the author's own or others, and plagiarism was not uncommon. A notorious example, Brickell's Natural History of North Carolina, is almost entirely paraphrased from John Lawson's "A New Voyage to Carolina, published in 1709, and much of the rest is plagiarized from the writings of others (Brickell 1737, Lawson 1709).

2. Was there ulterior purpose or bias in the statement? Early descriptions of the land often exaggerated the virtues of the climate, the kinds of things that could be grown, and the friendliness and helpfulness of the Indians. The objective was frequently to recruit settlers whose expected production of exportable goods (primarily tar, pitch, turpentine, lumber, furs and tobacco) could be monopolized by the sponsoring corporation. Thomas Harriot's "Briefe and True Report of the New Found Land of Virginia", published in 1590, was one of the first to promote immigration and settlement: "...the nature of the climate, being answerable to the island of Japan,...the excellent temperature of the ayre there at all seasons...often in the time of winter, our lodging was in the open aire and upon the grounde...", and of the Indians "...there is good hope they may be brought through discreet dealing and government to the embracing of the trueth, and consequently to honour, obey, feare and love us" (Harriot 1590).

3. Did the author have the necessary knowledge to make the statement? We might also ask whether the author was a good observer. There were few trained botanists afield during the in the first century of settlement. It is not necessary, however, that the writer have any training at all if he or she only provides a good description. William Byrd of Virginia was not a botanist, and had never seen longleaf pine when he noted in 1728 that north of Edenton, North Carolina, "The pines in this Part of the country are of a different Species from those that grow in Virginia: their bearded Leaves are much longer and their Cones much larger. Each Cell contains a Seed of the Size and Figure of a black-ey'd Pea, which, Shedding in November, is a very good Mast for Hogs, and fattens them in a Short time" (Byrd 1728 [1967]). He goes on to describe the 9 inch cones and the use of the tree for producing tar and pitch, leaving no doubt that longleaf pine was the species in question. Most of the valuable ecological information available from first settlement to the end of the Colonial Era is provided by nonscientists.

Mapping "climatic climax" or "potential natural vegetation". Quarterman and Keever (1962) examined hardwood stands and succession on the Coastal Plain and concluded that "southern mixed hardwood forest" was the climax vegetation of the region. Shortly thereafter, Küchler (1964) published a map called "potential natural vegetation of the conterminous United States", in which nearly all of the southeastern Coastal Plain was classified as "Southern Mixed

Forest" (beech, sweetgum, magnolia, pine and oak). Most lands from South Carolina north were labeled "oak-hickory-pine forest." As a result, Küchler and Quarterman and Keever have been widely misinterpreted to mean that the original vegetation of the South was hardwood, something neither author apparently intended (Quarterman 1981).

Küchler's is not a map of presettlement vegetation, but rather a theoretical prediction of 'climax' vegetation that might exist someday in a landscape without fire or human disturbance. The paradigm appears to be accurate, in that removal of fire from fire communities initiates succession such as that from pine savanna to hardwood forest. Ware et al. (1993), however, pointed out that true "southern mixed hardwood forest" was found in less than 2% of the presettlement landscape. The issue has been confused further in the southern U.S. by the ubiquitous mesophytic succession to loblolly, sweetgum and other hardwoods that has resulted from displacement of the original longleaf pine ecosystem from 97% of its original range. The term climatic climax should not be taken as having anything to do with presettlement vegetation in the Southeast, other than the 2% of the landscape that was naturally protected from fire in fire-sheltered portions of the landscape such as steep slopes, islands and peninsulas. On the other hand, the ability to recognize the stages of succession resulting from fire exclusion is critical for reconstruction of presettlement vegetation.

Intensive site analysis. Nichols (1913) used data from a detailed study of a 120 ha (300 acre) remnant of virgin forest and observations of other remnants to sketch broadly the presettlement vegetation of Connecticut. He used extremely in-depth work on a very limited site to extrapolate widely to a large area. This approach has been neglected to a surprising degree. Perhaps the closest approximation can be found in the numerous fire scar chronologies that have been done in the West. Most natural sites contain a great deal of information about vegetation and fire history over the past 100-200 years. Reconstructing fire and human disturbance history through detailed site analysis is one approach of the landscape fire ecology method. Steps include identification of cut stumps (pine versus hardwood at least), coring fire scars, taking sections through fire scars, looking at age class distributions of canopy trees, noting subcanopy species that may have filled in with fire suppression, and presence of even-aged shrub layers that can be used to date past fires (the three most recent fires could sometimes be determined), looking for

single old-growth or virgin forest tree specimens, noting evidence of past grazing and logging, remnant fire frequency indicator species, specimens of savanna "persisters" (see Chapter 6), the fire relations of adjacent communities, and the like. I did not use all of these methods on every site, but employed those that yielded the minimum information needed to approximate the original vegetation. The possibility of soil methods using residual soil pollen and opal phytoliths make it seem possible to reconstruct presettlement vegetation (only 200-300 years ago in most of the South, after all) for a site even down to the herb layer, if the methods were refined and enough time spent.

Metes and bounds method. Colonial era surveyors usually listed boundary line trees by name, making it possible to map vegetation from the original plats. Beckerman (1983) found that it required about 80 hours of searching early land records to obtain about 1,000 tree points. Much previous work, however, had already been done by another in locating the original deeds and sketching the approximate locations of the original land grants, so this is a moderately time-intensive method. Precise placement of survey plats on soil maps is problematic and the ability to identify some of the trees to species may be difficult since trees often may be only identified by genus like 'pine' or 'oak' (Russell 1981, Saterson 1977). Saterson, however, was able to identify 24 tree species and to construct a vegetation map for the Williamstown, Massachusetts vicinity. Lindsey et al. (1965) identified 73 species in the whole state of Indiana. The metes and bounds method usually gives 2-3 times as many data points as the General Land Office surveys (below).

The serious drawback of working with boundary line trees is that, even with title searches, it is difficult to precisely plot the location of a tract in question. Most early plats were not drawn to scale or with accurate angles at corners, and the surveyor had no aerial photos, so that placement of creeks and other landmarks were only approximate. Consequently, both the plats and natural features were usually considerably skewed. In plotting survey maps for the Savannah River Site (Case Study four, below), a certain amount of "rubber sheeting" was required to stretch the survey boundaries to fit known landmarks. Despite difficulties, however, early survey plats are the best source of real data on historical vegetation in the Atlantic states. Such records were used to test the accuracy of vegetation mapped at the Savannah River Site in Case Study 4 below. In

practice, it was found that many could be placed reasonably accurately, using distinctive bends in creeks or known cultural features like bridges and roads.

The General Land Office Survey. Over much of the country, particularly in the states settled after the American Revolution, vegetation cover types can be reconstructed from records of the U.S. General Land Office (GLO). The system actually had its roots in North Carolina, where, in the 1650s, the Lords Proprietors established 640 acres as the standard size grant to any one individual. The GLO system later called the 640 acres a "section", with 36 sections to a township. The GLO system, however, did not come into use until 130 years later. By that time, all the land in most of the Atlantic states had been divided using metes and bounds, and only the unsettled portions of Florida and Maine were included in the GLO survey. The ordinance establishing the General Land Office was passed in 1785. Townships 6 miles on a side, comprised of 36 sections of 640 acres (260 ha), or 1 mile^2 each, were surveyed over a period from 1786 to 1910 (Stewart 1935). "Bearing trees" and "witness trees" were blazed and data were collected which now allow calculation of frequency, density and dominance of trees in the original stands (Cottam and Curtis 1956). The GLO survey system evolved, with changing practices occurring in 1805, 1813, 1834, 1834, 1845, 1851 and 1855, after which methods were standardized until the end of the system in 1910. Most commonly, four "bearing trees" were selected at township corners and at those section corners which occurred on township and range lines. Four trees were also sometimes used at interior section corners. Species and distance to a stake at the corner were recorded, and approximate diameter was estimated. Trees blazed at half-mile intervals along boundaries where called "witness trees" or "line trees". In some surveys, major changes of vegetation type like 'forest' or 'prairie' were also recorded along survey lines. In others, all trees occurring along the line were recorded, and a few individual surveyors kept notes on understory vegetation (Stewart 1935, Bourdo 1956, Siccama 1971, Stearnes 1974).

The data thus unwittingly collected provided the basis for future analytical studies. Cottam (1947), and Cottam and Curtis developed the "random pairs" methods based on deviation of observed spacing of trees at corners. This led to the "quarter-point" technique, by which relative frequency, relative density and relative dominance of each species could be calculated from bearing tree data (Cottam and Curtis 1956). Various authors have combined two or three of the

figures, as available, into importance values. The "Wisconsin importance value" is the mean of the three.

The GLO records have been used for numerous studies, mostly at the county or multi-county level (Musselman et al. 1971, Schafale and Harcombe 1983). Leitner and Jackson (1981) reconstructed the flora of a portion of southern Illinois, encompassing six entire counties and parts of nine others. GLO survey notes were used to determine forest canopy species of the area in the period 1805-1815. Density, basal area dominance and importance values were calculated for 16,016 trees, and four major forest types were recognized and mapped. The above study was carried out entirely with witness tree data. Recently, Schwartz (1994) used GLO records to map the presettlement vegetation of northern Florida, demonstrating a preponderance of pine savannas on uplands.

While useful for reconstructing vegetation at the state or county level, the GLO method is limited in precision by the grid size. At best, the GLO records give the name of a single tree every half mile or a group of 4 trees every mile. This permits reconstruction of original vegetation at something like the level of the vegetation Formation (a vegetation category which usually includes a number of community types). Leitner and Jackson only mapped 4 formations. Lindsey, using GLO records for the whole state of Indiana, used 5 formations. Information on understory and herb layers is usually lacking in GLO records, except for the unusual instance where an individual surveyor happened to make notes on the vegetation.

Old timber surveys. Kologiski (1977) used an 1870 timber survey of the Green Swamp to interpret past and present pocosin vegetation. The extent to which this type of data source may still exist in the South has not been investigated, but may be occasionally available on a local basis.

Historical photographs and maps are locally more informative than GLO records because a great deal can sometimes be determined visually about vegetation structure and fire frequency. Hastings and Turner in "The Changing Mile" (1956) gathered historic photos of the American Southwest, and took matching modern photos to document 100 year changes in vegetation. The

study demonstrated replacement of native oaks by mesquite, along with other changes associated with grazing, farming and fire suppression. In the west, photo sites could be relocated by finding people who could recognize the shapes of mountains in the distance. The problem with this method in the eastern U.S. is determining exactly where the photo was taken, since the trees usually hide any recognizable landmarks. I have used some of the Wright brothers' original pictures of the Outer Banks of North Carolina to take matching photos, and there are a few places in the Appalachian Mountains where this can be done (see Ayres and Ashe 1905).

In the South, historical photos can be used to estimate original fire frequency at the site of the photo. In Chapter 2, Figure 2.1 a fire return interval of 1-3 years can be estimated with some confidence. The figure shows a virgin longleaf pine canopy and a perfect lawn of herbs without a single shrub stem. On the moist coastal plain soils of this site, any less frequent fire regime would have left visible shrub stems, even if recently killed by fire. I visited this region in 1995 and most similar stands now have a noticeable shrub layer under a less frequent fire regime.

Interpreting vegetation changes from green vegetation overlays on old USGS topographic maps. Many USGS maps contain a variety of shading and texture patterns that were used to indicate forest, marsh and other wetlands, and treeless areas. Schafale and Harcombe (1983) used Public Land Survey records and changes in the amount of shading on old USGS maps to show a decline in prairie openings in east Texas. These are of course only useful as far back as USGS topographic maps exist.

Aerial photos are useful for showing 20th century vegetation change. Since aerial photos taken before 1930 are rare, their use in determining presettlement vegetation is limited to those areas that were still untransformed by that time. A series of aerial photos of the Outer Banks of North Carolina, in the vicinity of Kill Devil Hills, taken in 1928 still exists. Gemborys and Lund (1992) used aerial photos and plats to demonstrate 20th century change at a site on the Virginia Piedmont.

Pedological method. Veatch (1928, 1931) first demonstrated the use of soil surveys for mapping presettlement forests. A major drawback was that the early soil maps were not

produced on aerial photos, permitted only approximate correlation of vegetation boundaries with soil boundaries. Lindsey et al. (1965) used GLO records along with soil data to map presettlement vegetation of Indiana. Punched cards for 70,240 trees were used to calculate importance values for 73 species. Eighty-seven major soil types were selected from the 357 soil series in Indiana, and the relative influence of 11 soil factors was determined for each species, using multiple regression analyses for importance value, basal area per acre and mean individual basal area. Phytosociological tables for each soil type and all species were obtained and five major forest regions were mapped in presettlement Indiana, once again at a degree of resolution approximating the Formation level. Floras occurring on many soil types were lumped into these five categories, yielding a map giving an overview of original vegetation of the entire state, but still not providing a degree of resolution very useful for site management. The potential of the pedologic approach has never been fully explored. It plays a central role in the landscape fire ecology method described below, providing the boundaries for vegetation types at the community type level.

While there is no entirely satisfying way to reconstruct presettlement vegetation strictly from quantitative data, there exist several kinds of evidence that provide "hard" data for southeastern vegetation. First are witness trees mapped by surveyors around the perimeter of individual survey plats. Second are living trees old enough to date to virgin forests. Historical photos constitute a third kind of hard evidence when trees and other species can be identified, but photos that can be pinpointed on the heavily forested eastern landscape are vanishingly rare. Soils, upon which the original forests grew, are another form of hard evidence that can be associated with vegetation. Evidence for presettlement fire frequency includes fire compartment size, another variable that can be determined accurately for the original, undissected landscape (Chapter 6). Finally, the presence of herbarium specimens and historical records of fire frequency indicator species and fire frequency indicator communities provide hard evidence that may often be plotted with precision.

The method below presents an entirely new approach, based on principles of landscape fire ecology. It relies on finding at least a few remnant natural communities, especially fire communities that have still been burned, on each upland soil series, or past vegetation species

lists and descriptions, or historical photos of vegetation structure that can be localized to specific soil series. The landscape is then examined for the factors that controlled fire frequency and fire flow, to estimate the type of vegetation that would have been found on each soil pedon in the study area. Some of the elements of landscape fire ecology include reconstructing presettlement fire frequency using fire compartment size, and remnant fire frequency indicator species and communities. The next step is relating vegetation to fire regimes for each soil type and topographic situation. Finally, soil maps are used to put boundaries on vegetation types.

Elements of the past approaches described above are used to supplement landscape fire ecology, and to provide tests of the first approximation vegetation map. These include historical descriptions, successional patterns with and without fire, intensive site analysis of remnant natural vegetation (especially for fire history on the site), boundary line trees noted on historical survey plats, and any historical photos that might be available.

THE LANDSCAPE FIRE ECOLOGY APPROACH TO MAPPING PRESETTLEMENT VEGETATION

In this approach, presettlement vegetation and presettlement fire frequency are built up simultaneously through a series of two or three successive approximations. Since wildland fire has been eliminated over most of the eastern landscape, and since evidence is amassing to indicate that elimination of fire has produced dramatic changes in species composition, species dominants, and vegetation structure, it is essential to reconstruct the original pattern and frequency of fire on the land in order to reconstruct the vegetation pattern. Scattered bits of historical information, such as presence of fire-related species, provide clues about the original fire frequency, and in landscapes where something is known about fire frequency, it is possible to estimate the structure and species composition of original vegetation.

Concepts and Assumptions of the Method.

The landscape fire ecology method adds six new elements to the inquiry into presettlement vegetation. First, the approach assumes that the fire effects gradient was one of the master gradients underlying distribution of species and vegetation types in the landscape. It assumes

that within a given climatic and floristic region, the natural fire regime was one of the master gradients determining species composition and vegetation structure, as important as climate, topography, hydrology and soil. Second, the method assumes that land surface forms and soil series are the most stable elements influencing vegetation in the landscape, and can be used to predict natural vegetation even when the original vegetation is gone. Third, fire-frequency indicator species and fire-frequency indicator communities are used to reconstruct presettlement fire regimes. Fourth, soil series on an aerial photography base are used in conjunction with topographic maps, slope and aspect, to put boundaries on original vegetation types. Fifth, the method can be used to predict whole community species composition and structure, since species composition and cover of each species, in each vegetation stratum, on each soil series, can be studied and extrapolated to other identical sites within a local landscape. While all previous methods have dealt only with trees, this approach includes herb, shrub, and subcanopy species as well as trees. Sixth, the approach uses principles of landscape fire ecology to include fire behavior on a landscape scale as a predictor of original natural vegetation. The following chapter describes how to use landscape fire ecology to describe the fire frequency gradient that shaped original vegetation in a study area.

The method further assumes that other master gradients like depth to water table and soil texture are subsumed by soils, and uses soil pedons on soil series maps to put boundaries on vegetation. It also assumes that the presettlement fire regime can be determined concurrently with reconstruction of natural vegetation.

Collecting Evidence of Presettlement Vegetation and Fire Regime.

Table 7.1 lists various ways to gather data about past vegetation. The method requires obtaining maps with soils mapped to the series level on aerial photos, something only widely available within the last 20 years. Historical data points for individual plant species or community types, or sites with extant natural vegetation, must be located for each soil series. The historical information may be from any of the methods described above: GLO surveys, early survey plats, historical accounts by early travelers who describe the land and mention fire-indicator species like longleaf pine and wiregrass, aerial photos, old topographic maps, early timber surveys, early botanical collections and more recent specimens in herbaria. Then data points must be

TABLE 7.1. KINDS OF EVIDENCE FOR PRESETTLEMENT FIRE FREQUENCY AND PRESETTLEMENT VEGETATION

Asterisks indicate degree of usefulness, with four being most valuable.

LANDSCAPE AND ENVIRONMENTAL FACTORS:

**** Original fire compartment size.

*** Presence of fire barriers and fire filters: landscape factors, which resist flow of fire between compartments (steep slopes, water bodies, and certain vegetation and soil types).

*** Soil maps and observations of fire behavior on different soil types.

** Lightning ignition records.

* Records of size of area burned by wildfires.

HISTORICAL EVIDENCE:

**** Early survey plats with witness trees, verbal descriptions of vegetation, and vegetation sometimes sketched on survey plats.

*** Historical records mentioning fire frequency indicator species and indicator vegetation types.

** Historical references to fire or fire frequency.

** Historical references to use of fire by Indians.

** Vegetation on old photos and aerial photos.

* Palynology and varved lake sediments.

EVIDENCE FROM REMNANT NATURAL VEGETATION

**** Observations of vegetation structure, by layer, under known fire regimes.

**** Fire scar dating.

*** Studies of vegetation response to fire exclusion (on each soil series).

**** Vegetation response to reintroduction of fire (on each soil series).

*** Presence of remnant fire frequency indicator species.

*** Presence of remnant fire frequency indicator communities.

**** Presence of fire-refugial species with individuals old enough to predate fire suppression.

TABLE 7.2. FIELD METHODS. FOR EACH SOIL SERIES:	
1.	Verify soil taxonomy in the field and correlate soil with vegetation types.
2.	Assemble complete species list by vegetation layer (canopy, subcanopy, shrub layer, herb layer). Make cover estimates by layer to gauge degree of woody succession. Record existing community type and make preliminary estimate of presettlement community type.
3.	Examine vegetation change along local soil, moisture and fire frequency gradients.
4.	Determine recent fire history from fire char, fire scar cores, shrub stem age classes.
5.	Determine extent of human disturbance history, including any evidence of turpentining, logging, grazing and fire suppression.
6.	Determine fire compartment size.
7.	Assign first estimate of presettlement fire return interval.
8.	Determine number and effectiveness of natural firebreaks.
9.	Collect any local and regional records of original vegetation.
10.	Assemble any historic and recent vegetation records and studies from other parts of the southeastern landscape that may apply.
11.	Record any fire-frequency indicator species, either extant or in the historical record and map them onto the specific soil series on which they are or were found.
12.	Assign tentative estimates of recent fire frequency and revise original fire frequency estimate.
13.	Assign tentative estimates of presettlement vegetation type and species dominants.
14.	Determine variation, if any, by slope and aspect.
15.	Determine range of variation in vegetation between pedons of the same soil series within the study site.

associated with specific soil series. In some cases, where the specific location can be determined, points can be placed precisely on soil maps. In other cases subjective decisions must be made.

In addition to soil maps and historical data, the method also requires accumulating a list of fire frequency indicator species and fire frequency indicator communities. This part should become easier in the future as regional and local fire frequency maps are published and information is compiled on the fire relations of individual species. Table 7.2 lists some of the field methods in this study, and kinds of information collected for each soil series.

Plot Methods.

I used two types of plots to document natural vegetation. The first was a 1/10 hectare plot (Whittaker 1960), of which there were 116. Second was a quick method in which the plot was a specific soil pedon of a particular soil series. There were 352 of these plots, accumulated while doing county natural area inventories in Virginia and in ten counties of North Carolina. Following is an example of field methods and results from one of these plots. A complete list of all species present on that soil pedon was compiled; unknown specimens were pressed for herbarium identification. Cover values were obtained for each stratum. The following ten cover classes, defined by the North Carolina Vegetation Survey (Peet et al. 1998), were used:

COVER SCALE			
10	95-100 %	5	5-10
9	75-95	4	2-5
8	50-75	3	1-2
7	25-50	2	0-1
6	10-25	1	Trace (as with one seedling, no appreciable cover)

Cover area for each species, by layer, was estimated for an area of about 100 meters square and then adjusted while wandering through the plot. The species lists and cover values are roughly equivalent to those that would be obtained from 1/10 hectare plots. See Table 7.3 below, for a typical plot.

TABLE 7.3. Species and cover values for a fire-suppressed longleaf pine-scrub oak stand on Lakeland sand. Botanical nomenclature follows Kartesz 1994.

C=canopy, U=subcanopy, S=shrub layer, V=vine, H=herb layer, **=Rare species.

	C	U	S	V	H
Pinus palustris	8	1	4		2
Pinus taeda	6	6	4		
Prunus serotina	3		4		
Quercus laevis	7	8			
Quercus margarettiae	6	4	5		
Quercus marylandica		4	6		
Carya tomentosa			4		
Cornus florida		4			
Nyssa sylvatica		4	4		
Gaylussacia dumosa			2		
Vaccinium stamineum			2		
Vaccinium arboreum			6		
Robinia pseudo-acacia			2		
Crataegus flava			2		
Diospyros virginiana			3		
Rhus copalina			3		
Sassafras albidum			2		
Rubus sp.			2		
Gelsemium sempervirens				6	
Vitis rotundifolia				3	
Smilax glauca				3	
Toxicodendron toxicodendron				2	
Aristida beyrichiana					5
Nolina georgiana (**)					1
Cnidoscolus stimulosus					1
Carphephorus bellidifolius					3
Tradescantia rosea var. rosea					2
Shrankia microphylla					2
Heterotheca gossypina					2
Pityopsis graminifolia					2
Stipulicida setacea					2
Galactia regularis					2
Baptisia lanceolata (**)					2
Baptisia bracteata					2
Polypremum procumbens					2
Aureolaria pectinata					2
Tephrosia virginiana					3
Lespedeza hirta					2
Rhynchosia reniformis					2
Opuntia compressa					2

	C	U	S	V	H
Euphorbia ipecacuanhae					2
Euphorbia corollata					2
Stylisma patens					2
Commelina sp.					2
Andropogon virginicus					3
Danthonia sericea					3
Grass sp.					3
Dichanthelium sp. 1					2
Dichanthelium sp. 2					2
Carex tenax (**)					2
Liatris sp.					2
Liatris regimontis					2
Liatris graminifolia					2
Solidago odora					2
Aster paternus					2
Aster tortifolius					2
Tragia urens					2
Eriogonum tomentosum					2
Tillandsia usneoides					2
Cladina					1

For the plot in Table 7.3, time since last fire was 36 years (determined from cores of fire-scarred loblolly pine and turkey oak). The existing vegetation type, defined from the cover data, was: *Pinus palustris-Pinus taeda*-mixed hardwoods/*Quercus laevis*-mixed scrub oaks and dry-mesophytic hardwoods/mixed dry-mesophytic tree saplings and shrubs/diverse but scattered dry-mesophytic savanna herbs. There was a sparsely populated patch of southern wiregrass (*Aristida beyrichiana*) on top of the ridge. This species, now largely extirpated from this fire-suppressed region, was considered an indicator of a high fire frequency in the past. The heavy cover of hardwoods in shrub and subcanopy, along with conspicuous smothering of the herb layer by heavy leaf and needle litter also indicated extensive succession in the long absence of fire. This was a situation that would never have occurred in nature for this site. The plot was on a fully fire-exposed ridgetop surrounded by longleaf pine lands in a large fire compartment with no significant firebreaks nearby. There were 3 rare pineland species present, all barely surviving, and a number of fire-frequency indicator species. Wiregrass, for example, is most typically found in communities that experience fire at 1-3 year intervals. At this site it was persisting

marginally in one sunny gap, on the driest peak. Single depauperate plants, scattered over a wide area and largely buried in litter, suggested much more open habitat maintained by fire in the past. There were 60 plant species present and it seemed likely that others had been lost to site shading and litter buildup. The first estimate of presettlement community type proposed for this site was *Pinus palustris/Aristida beyrichiana*-diverse dry-mesic savanna graminoids and forbs. These first-step results were obtained for a ridgetop site on Lakeland sand. Equally involved reasoning was involved in making estimates of presettlement vegetation on each of the other soil series, by slope and aspect, in the region.

SYNTHESIS AND MAPPING

After obtaining soil photomaps and assembling the historical data, the method consists of the following major steps. Plant taxonomy generally follows Kartesz (1994). Following are some guidelines for this stage of mapping.

1. Approximating presettlement community types.

a). Sample remnant natural vegetation on each soil series in the area under study, according to the scheme in Table 7.2. This should include burned examples if fire is believed to have played a role in presettlement vegetation. If some series have no natural remnants, then sample remnants on the same soils in any nearby counties for which they are available.

b). Watch for fire frequency indicator species (such as *Astragalus michauxii*, smooth coneflower (*Echinacea laevigata*) and wiregrass (*Aristida beyrichiana*), and fire-frequency indicator communities (like canebrake, pocosin, white cedar or beech forest), both in the field, in herbarium records, and in the historical record. Each site for these indicators can be assigned a fire frequency, based on the known range of fire frequency tolerance for each species (for examples see Appendix B, Fire regimes of selected rare and common fire dependent species of the southeastern U.S.). Adjust these figures slightly upward or downward depending upon soil type and topographic situation and degree of fire shelter or fire exposure for each specific occurrence.

c). Build species lists and make cover estimates by layer (canopy, subcanopy, shrubs, herbs, vines) for all communities on each soil series, under natural fire regimes, and under fire suppression. Learn to recognize the degree of fire suppression for each.

d). Record evidence of successional changes resulting from fire exclusion, reduction in fire frequency or change in season of burn.

2. First approximation vegetation map. Decide upon appropriate mapping units like beech forest, pine savanna, or canebrake, and assign vegetation types to each slope class of each soil series. Group related soils with similar vegetation and assign a color to each group on GIS.

3. First approximation presettlement fire frequency map. Using a copy of the soil series base map, plot all known existing or historical fire indicator species and communities. This should begin to yield a picture of the regional pattern of fire regimes. Where data are scarce, it is useful to reconstruct fire frequency over the larger region that includes the study area. Since there will then be many more examples found, the information can be extrapolated to portions of the study area where information is lacking. Threading contours along lines of equal fire frequency will produce something like a topographic map, only the isopleths will represent different fire-return intervals, or different levels of fire effects, rather than elevation. Alternatively, fire frequency can be mapped by fire compartment (see case Study 4, the Savannah River Site).

4. Second approximation vegetation map. Compare the first map of vegetation with the first fire frequency map. At this point some adjustments can be made and areas needing more field work will become obvious. Return to the field to resolve any apparent discrepancies, such as frequent-fire vegetation types and non-pyrophytic vegetation that occur in immediate proximity (this may not be an error--there may just be a locally steep fire-frequency gradient). Pyrophytic wetlands usually require further work because they may have more than one vegetation type on the same soil series. The effects of local natural firebreaks may need to be investigated.

5. Readjust the vegetation map, using the new field data.

6. Refine the fire frequency map, using any new fire frequency data and the adjusted vegetation map.

7. **Return to the historical record** for discussions or information that may be better interpreted now, after the questions are better known.

8. **Refine both the presettlement vegetation and fire frequency maps**, using any new insights from the historical record. At this point there will probably be more field questions to answer. There may be more iterations of steps 5, 6, 7 and 8 before a final map is arrived at (see Case Study 4 map).

9. **Apply an external test to determine accuracy of map results.** Mapping results may be tested in more than one way. The most rigorous test that can be applied is to reserve any information on boundary line trees from historical survey plats until the map is completed using only landscape fire ecology and all the other types of information discussed above. In this test, historical survey plats are mapped onto the vegetation map. Then the historical boundary trees are compared with those predicted by the vegetation map. In Case Study 1 below, historical sources were used to test map accuracy at 200 random points. Within the somewhat broad categories of vegetation available in historical records map accuracy was 83%. The map was further refined to include the historical information which had been reserved up to that time as a way to test the map built up strictly with existing remnant vegetation and landscape fire ecology. In Case Study 4, at the Savannah River Site, two different types of tests using historical information were applied. See this case study for a full application of the methods developed.

DISCUSSION

If we are to perpetuate examples of all our original native plant communities, we must know what communities and species were present at time of European settlement. We must also be able to determine how they were distributed over the land and what processes maintained them. The goal of research on presettlement vegetation[1] in the western hemisphere is to map original natural plant communities as closely as possible to that which existed at time of European

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Presettlement versus pre-Columbian: The somewhat ungainly term "pre-settlement" or presettlement is preferred because it is more precise than pre-Columbian, which just means before 1492. First exposure of the land to European influences came much later in most of the South: presettlement in east Florida, for instance, means around 1565, in southeastern Virginia it means 1607, in the southern Appalachians it means around 1800, and in central Alabama it means 1821.

discovery. The goal of land management, in those portions of sites in which natural values are the primary concern, should be to protect existing remnants of presettlement vegetation, or to restore communities to their condition at time of first settlement. This necessitates creating a reasonably detailed map of original vegetation.

There is some question about what is meant by original vegetation, and, given that vegetation is always in a state of change in response to disturbance or change on some climatic scale, there may be some question whether "original" means anything at all. On a human time scale, there is considerable evidence that "original" vegetation is a valid concept. We live in a warm interglacial period, and for as long as genus Homo has been evolving there have been glacial cycles. With each cycle there have been major geographic displacements of species, perhaps to form somewhat different community groupings in their new latitudes (Webb 1988). Some species with heavy seeds, like walnuts and hickories, may take longer to migrate than those with light, wind-borne seeds, and some species, in response to minor climatic fluctuations, may be in somewhat continual adjustment at the fringes of their range. One possible conclusion, then, is that since vegetation is constantly in flux, presettlement vegetation is meaningless, as is any effort to preserve or restore examples. This is a close relative of the reasoning that concern over the extinction of species is misplaced because it is the natural course of species to arise, flourish, and then die off. This is the geological view taken to the extreme. We are likely to reach different conclusions on the time scale of human history.

Southeastern plant communities began their postglacial sorting out at around the same time as the beginning of recorded human history. The Wisconsin glacial epoch ended some 10,000 years ago, and a climate with warm winters similar to those we now experience stabilized around 8,000 years ago. Most modern plant assemblages finished responding to these changes and have been in place for the past 6,000 years (Webb 1988). Minor Holocene climatic fluctuations like the "little ice age", a slightly cooler period from AD 1450 to 1850, produced no substantial shifts in the major plant formations. The natural communities found by the first explorers, then, had been in place for thousands of years. The species of which these communities were composed, themselves probably the products of hundreds of thousands of years of evolution, were the survivors of a number of glacial migrations, whereas literate human civilization has yet to

experience its first ice age. Given that these natural communities existed for all of recorded human history, it seems reasonable that these are the communities that we would want to perpetuate on natural areas. Some interglacial periods have lasted a hundred thousand years, and we are only 10,000 years into the current cycle, so the idea of abandonment of presettlement natural community types may be premature by up to 90,000 years.

Neither is it appropriate to despair knowing what presettlement vegetation existed on a particular site. The goal of presettlement vegetation methods should be to get to some resolution useful at the site level. The method presented above uses the interrelationship between landscape fire ecology, vegetation, and soils to map presettlement vegetation with precision at the soil series level, and accuracy testable by historical survey maps.

The pyrographic method is a synthesis of all available data. The actual process is of successive approximations, each of which takes some of the previous results as assumptions. The use of the fire frequency map to predict the vegetation map, which is then used to modify the fire frequency map and so on, may look suspiciously like circular reasoning. In an attempt to explain, I once referred to the process half-jokingly as spiral reasoning. Hoffman (1988) pointed out the value of what he called Nearly Circular Reasoning, and argued that most new discoveries in science occur by this process. The pyrographic method is an example of nearly circular reasoning in which repeated iterations are used to refine a model.

All previous methods only yield information about trees, and none provide a map base useful at the site management level. The pyrographic method deals with all species that occur on each soil series, and provides vegetation mapping at the soil series level. The results can be applied in the field for management at the level of the soil pedon. The evidence is fading over much of the landscape, and the maps created by the pyrographic method may be the best approximation we will ever have.

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CHAPTER 8

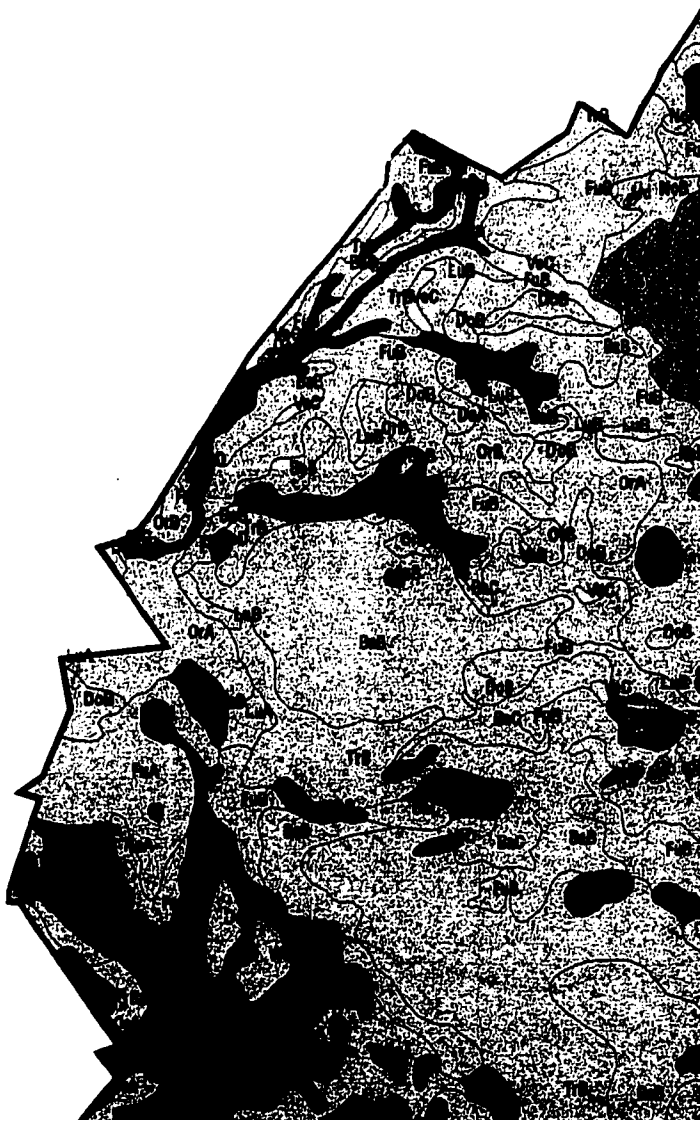
CONCLUSION

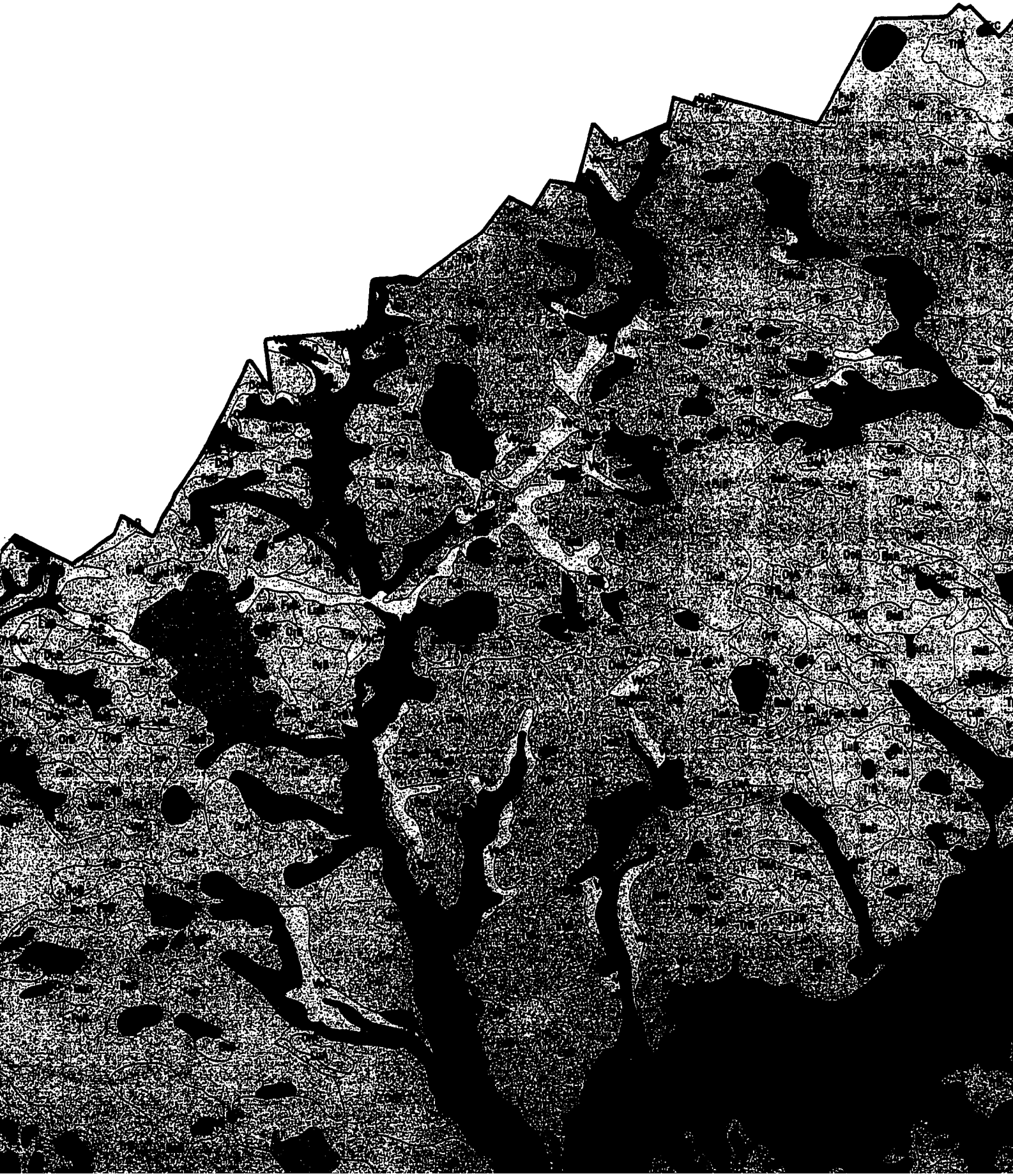
This dissertation proposes and begins to explore a new field called Landscape Fire Ecology. Several concepts of the field are presented for the first time. Fire compartments, fire filters, fire shadows, fire frequency indicator species, fire frequency indicator communities, fire-exposed versus fire-sheltered areas, fire-tension zones and landscape scale fire frequency gradients are a few of the new concepts introduced here. These are points of view that are required for reconstructing original fire regimes and mapping fire-dependent vegetation. These concepts appear to be essential for understanding the natural role of fire as it was played out before modern fragmentation of the landscape.

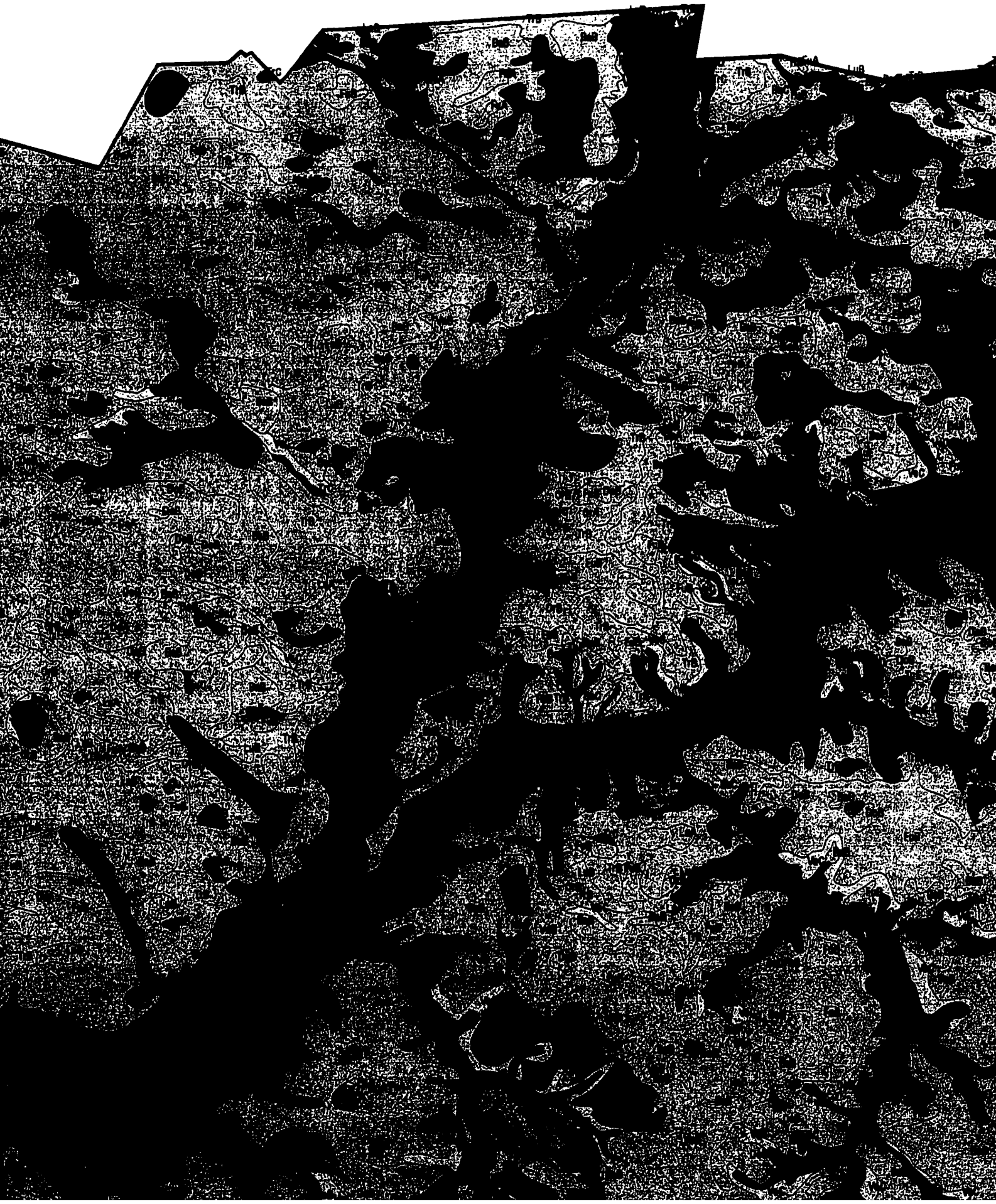
If, in the South, all the developable land will have been converted in a few decades, this will mark the conclusion of something equivalent in magnitude to the end of a geological era. For the first time in evolution, survival of all native plant communities and species will depend on human management. This transition in how we relate to the land is rapidly approaching its climax in the eastern U.S. In less than 100 years all the land of the planet will be managed, either in a domesticated sense or as managed wild land. In domesticated landscapes, with only a few percent of the natural land surface to work with, we must simulate the habitats and processes that once supported 100% of the original species diversity. For this we will have to know, down to a workable level on each individual site, the original vegetation and original fire regime. After 20 years of chasing this goal and having mapped presettlement vegetation for four county-sized areas, I am confident that this can be done anywhere at a practical level of resolution. I also have come to believe that, using historical plats and other checks, such mapping will provide an approximation of presettlement vegetation and fire frequency, adequate for preservation of species.

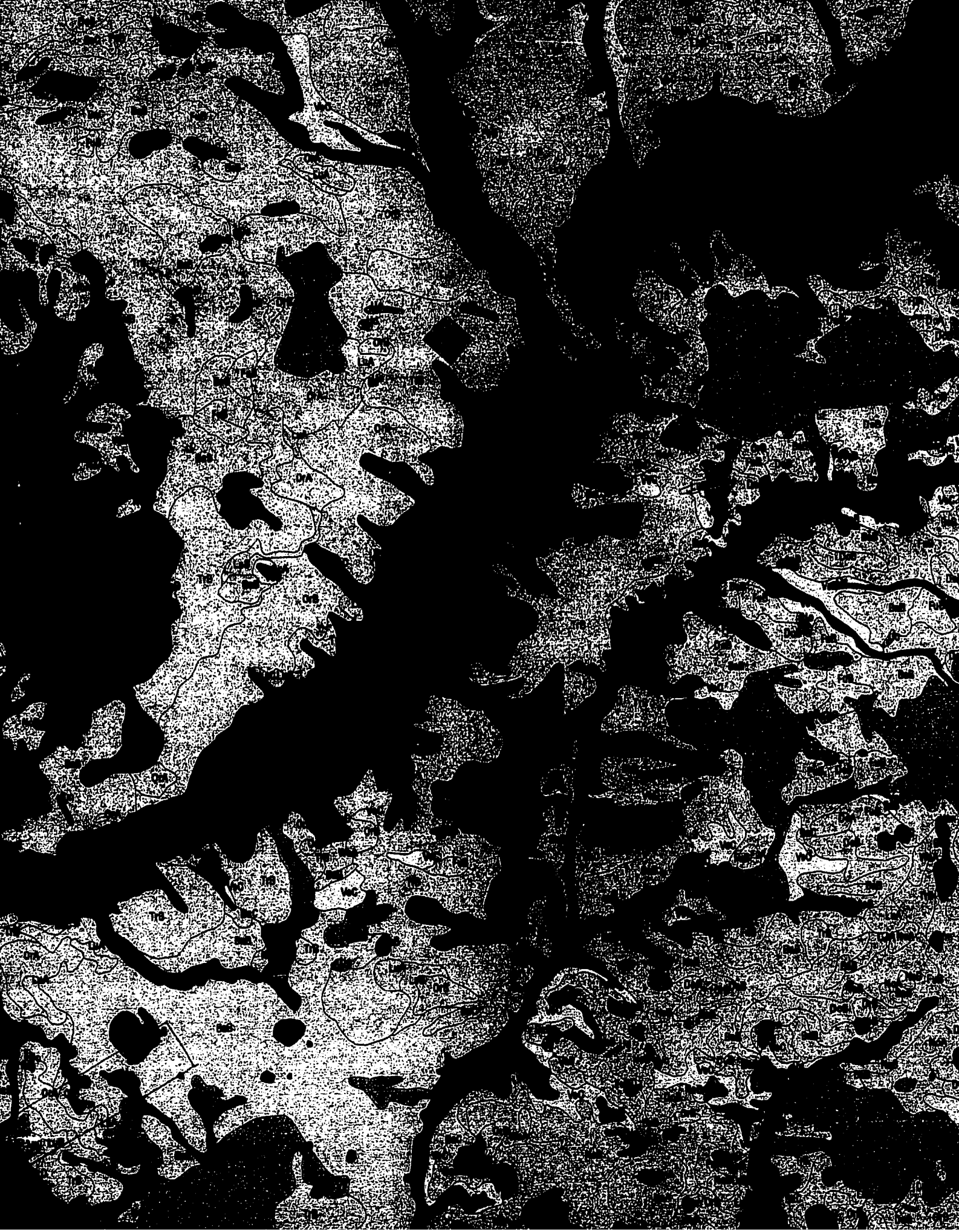
The mostly historical work in Chapter 2 resulted in a map of the presettlement range of longleaf pine. The great extent of this fire-dependent species made it apparent that fire played a role in nearly all of the southeastern landscape. It further became apparent that if you know something about the fire requirements a species needs to survive, that tells you something about its presettlement fire frequency. Then that fire regime can be mapped for those locations where the species was historically known to exist. In Chapter 3, I spent 2 years studying the fire relations of wetland species and communities, considerably more complex that that of upland communities. For Chapter 4 I surveyed the fire history of the rest of the country to accumulate points of known presettlement. I used what I had learned about landscape fire ecology, especially the idea that fire compartment size controls fire frequency, to map a first approximation map of presettlement fire regimes of the U.S. Chapter 5 depicted the extreme fire dependency of Venus flytrap. This demonstrated the value of using certain plants as fire frequency indicator species, the historical locations of which yield another way to put historical fire frequency points on maps. Chapter 5 is a synthesis of all the previous work and my field observations over several years, into an outline of some major concepts of the field of Landscape Fire Ecology. How to interpret original fire regime, along with field remnants of fire dependent species and communities, in order to make maps of presettlement vegetation was the subject of Chapter 7 and the four case studies that follow it. This was the original goal of this dissertation.

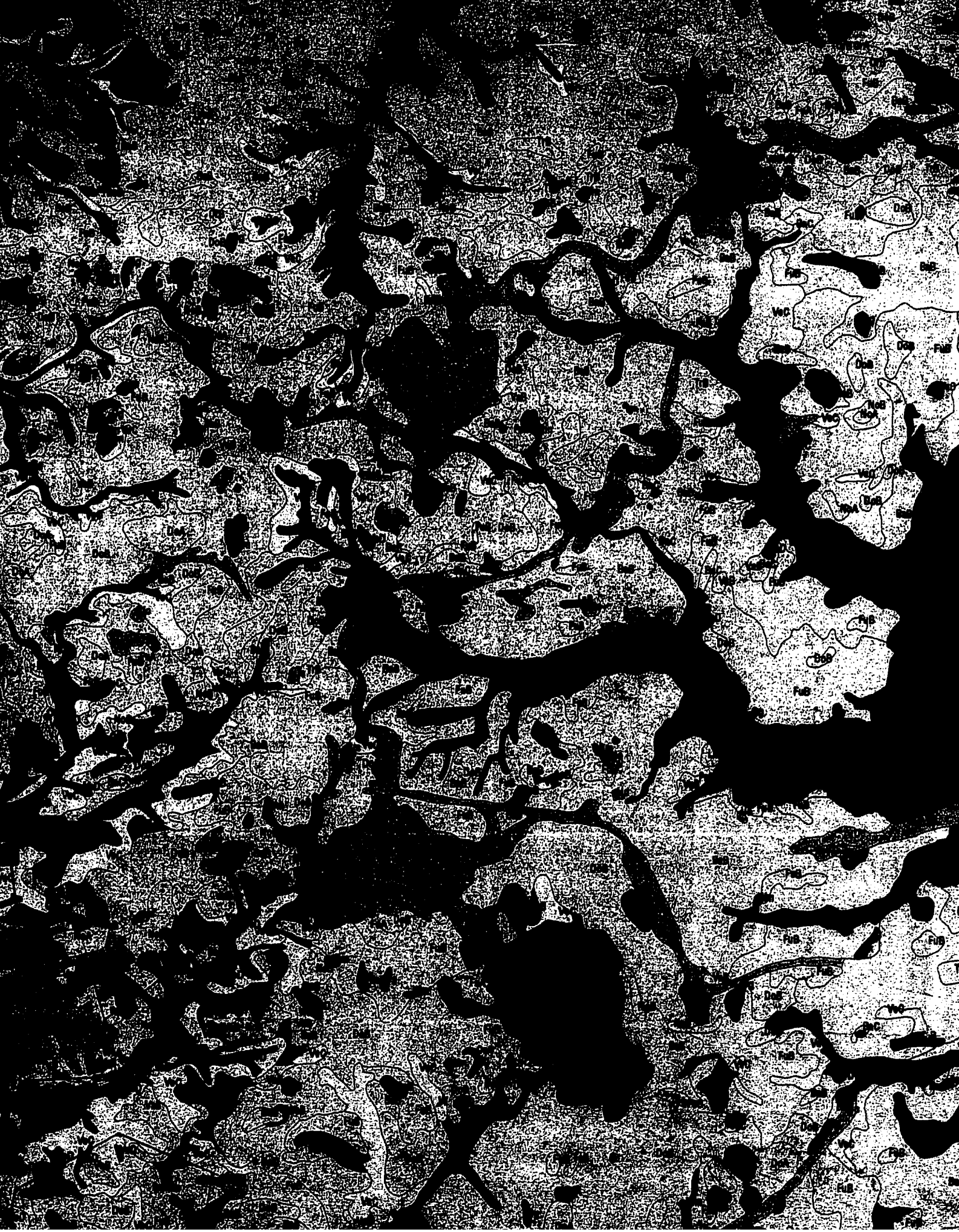
It has become apparent that the presettlement U.S. was a fire landscape. We will need to continue to explore fire relations of species and the principles of landscape fire ecology, in order to successfully manage the fragments of this landscape for survival of all the plant and animal species that once inhabited it.

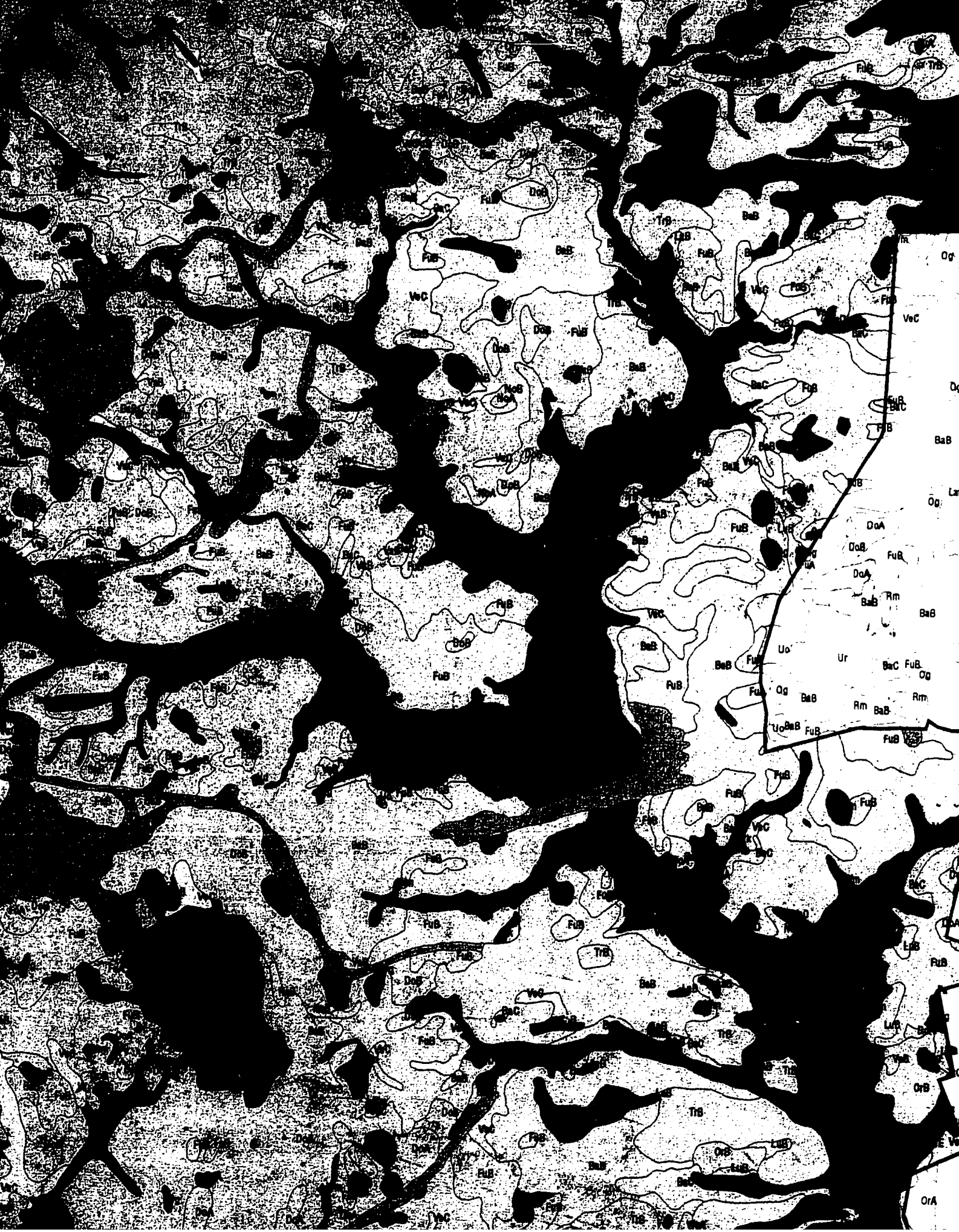








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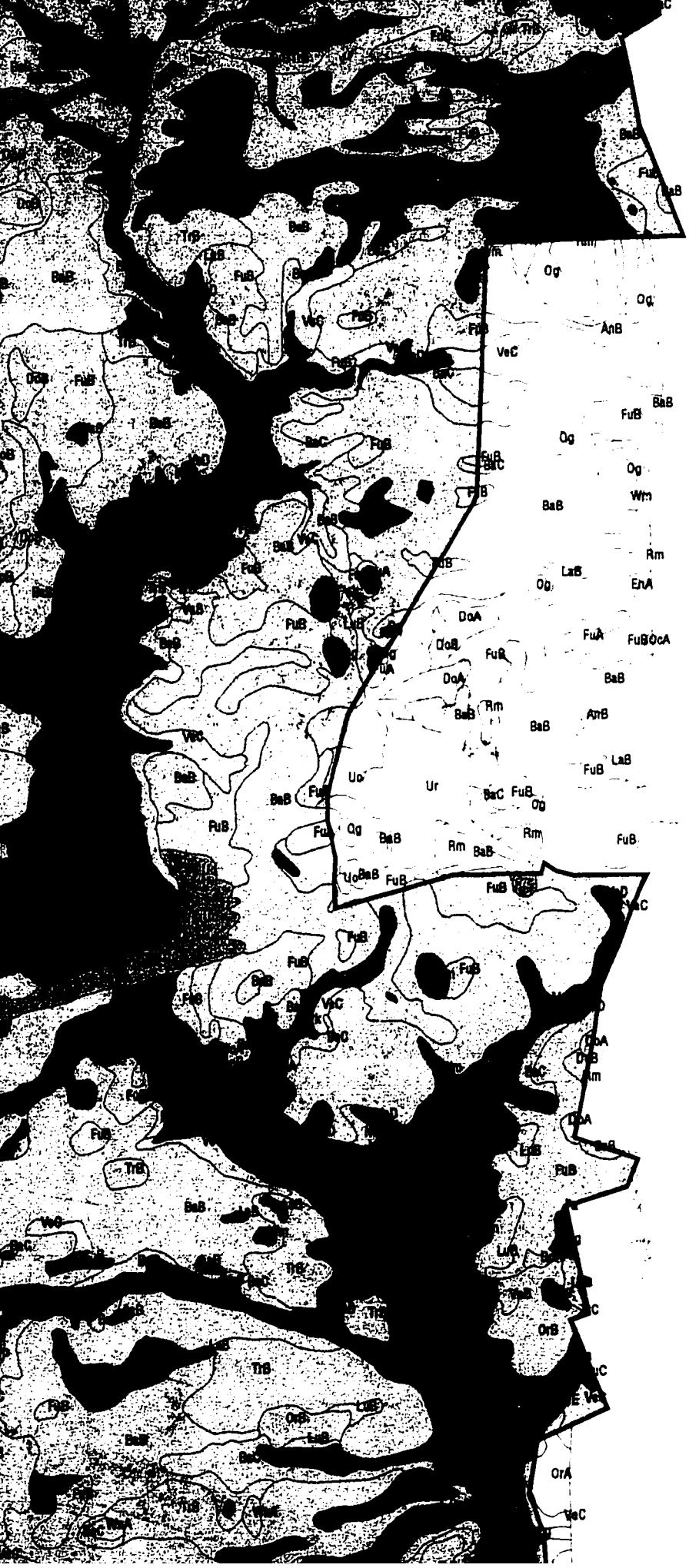
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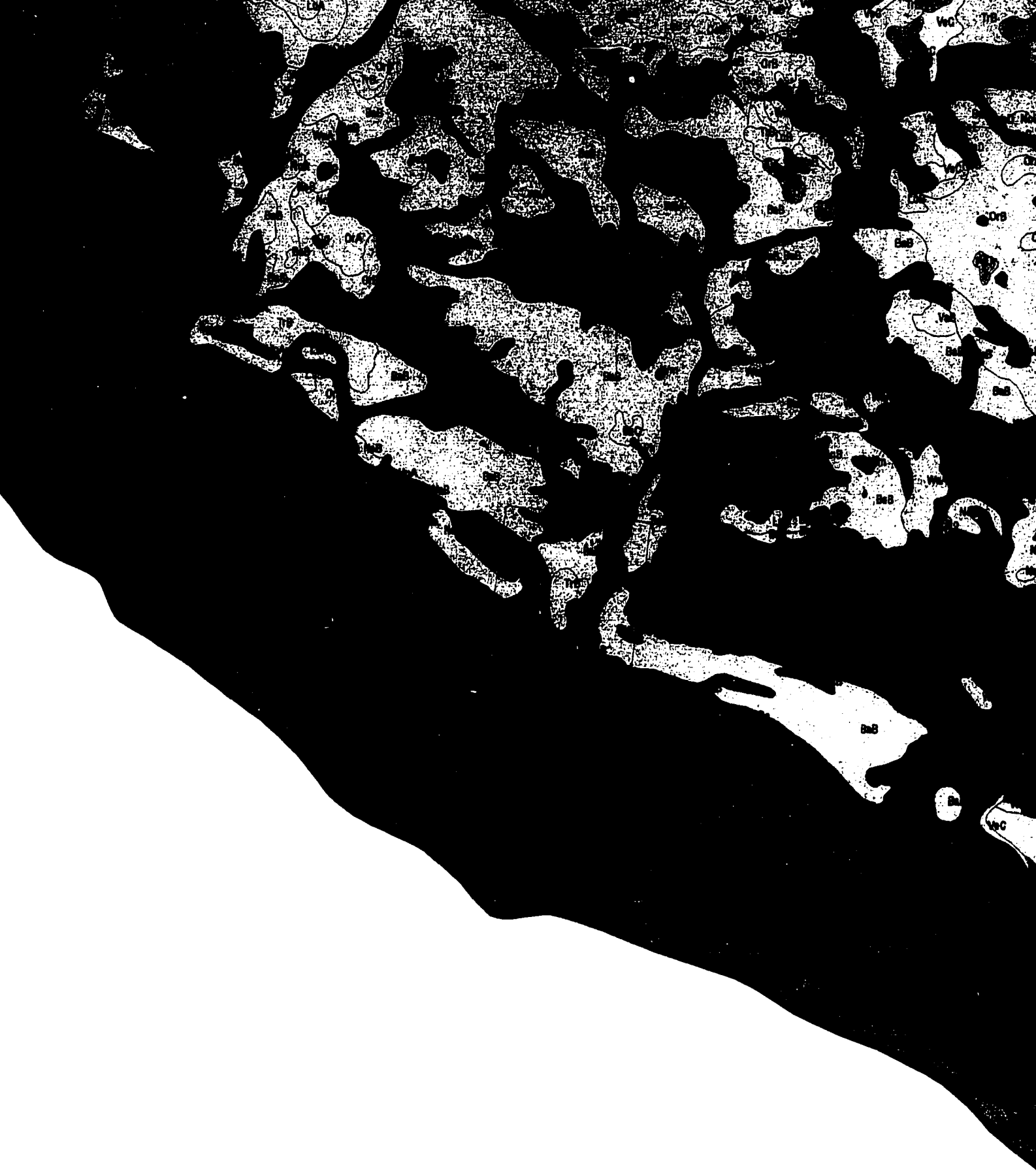
Savannah River Site

Presettlement Vegeta



egetation Types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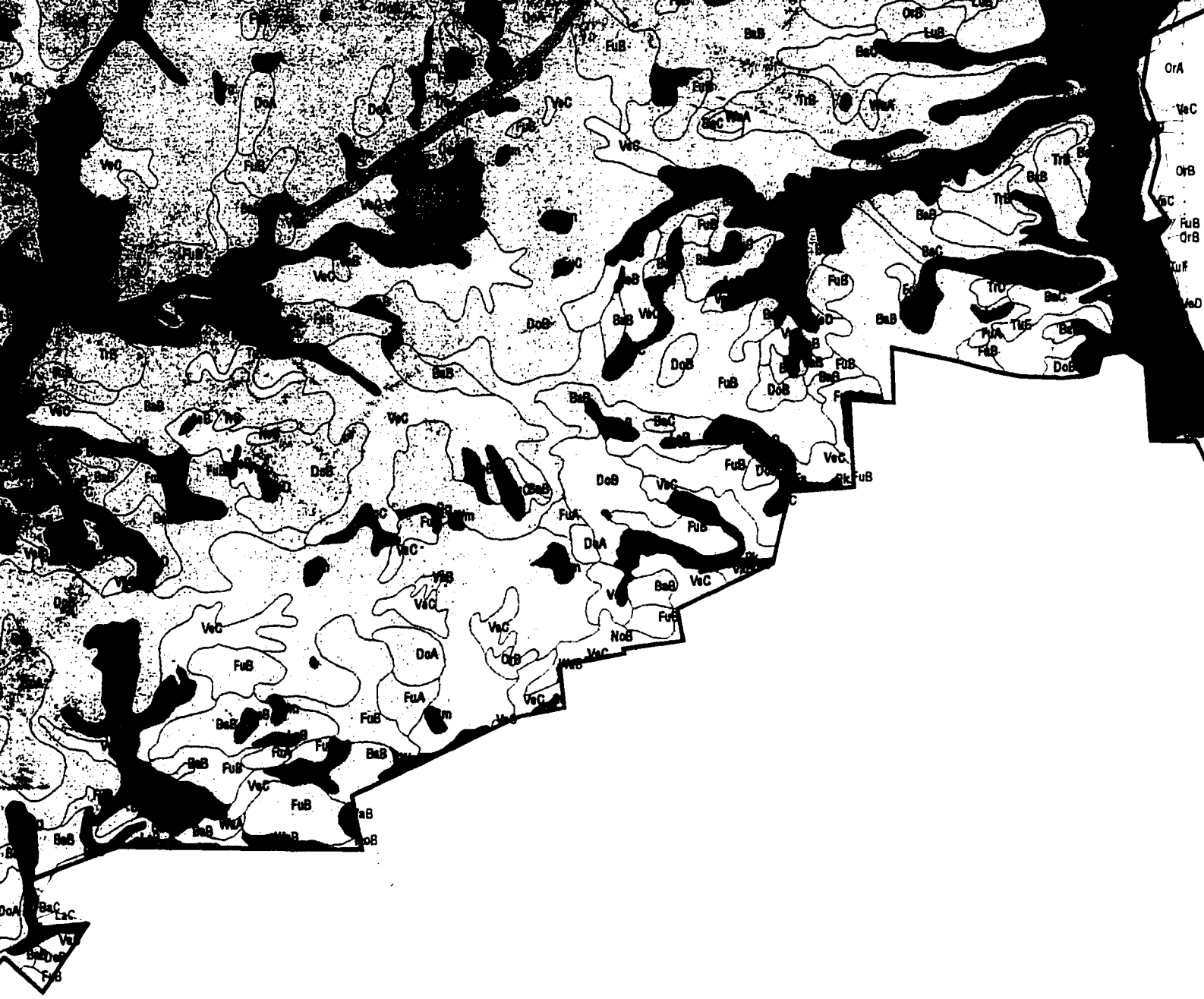
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BoB

Savannah River Site

Presettlement Veget

- Xeric Longleaf Pine and Longleaf-Turkey Oak
- Dry-Mesic and Mesic Longleaf Pine Savanna
- Longleaf Pine-Pyrophytic Woodland Complex
- Pyrophytic Hardwood Woodland
- Mixed Mesic Hardwood Forest
- Wetland Pyromosaic–Sandy or Mucky Soils: Patch Mosaic of Fire-influenced Canebrake, Pocosin, Pond Pine Forest and Loblolly Pine as well as Nonpyrophytic Bottomland Hardwoods, Baldcypress and Nyssa
- Wetland Pyromosaic–Silty or Clayey Soils: Patch Mosaic of Bottomland Hardwoods, Hardwood/Canebrake, Baldcypress, Nyssa biflora
- Bottomland Hardwoods, Levee Forests, Oak Flats
- Swamp Forests and Ponded Sites other than Carolina Bays
- Carolina Bays, Upland Depressions
- Udorthents
- Surface Water - No Type Identified

Vegetation Types

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n Mosaic of Fire-
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Baldcypress and Nyssa

Mosaic of
aldcypress, Nyssa biflora

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Using current GIS Data as of 06/19/97
Vegetation Types Defined by Cecil Frost from Soils,
Historical Data, and Remnant Vegetation.

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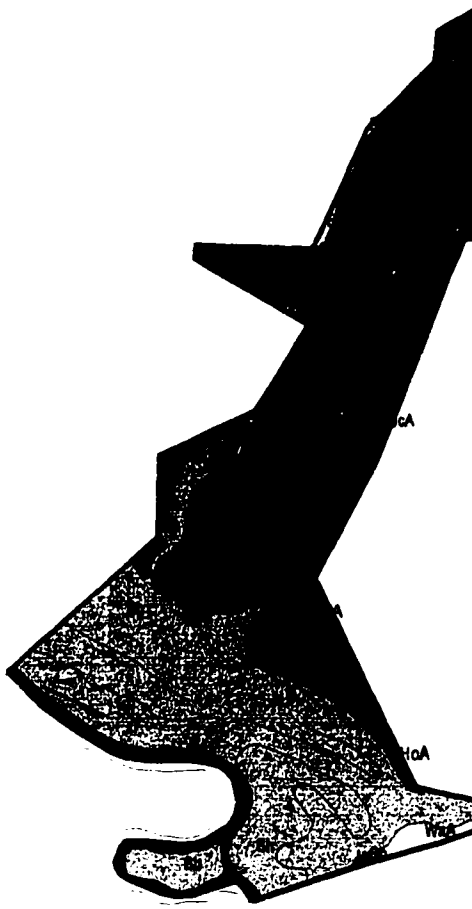

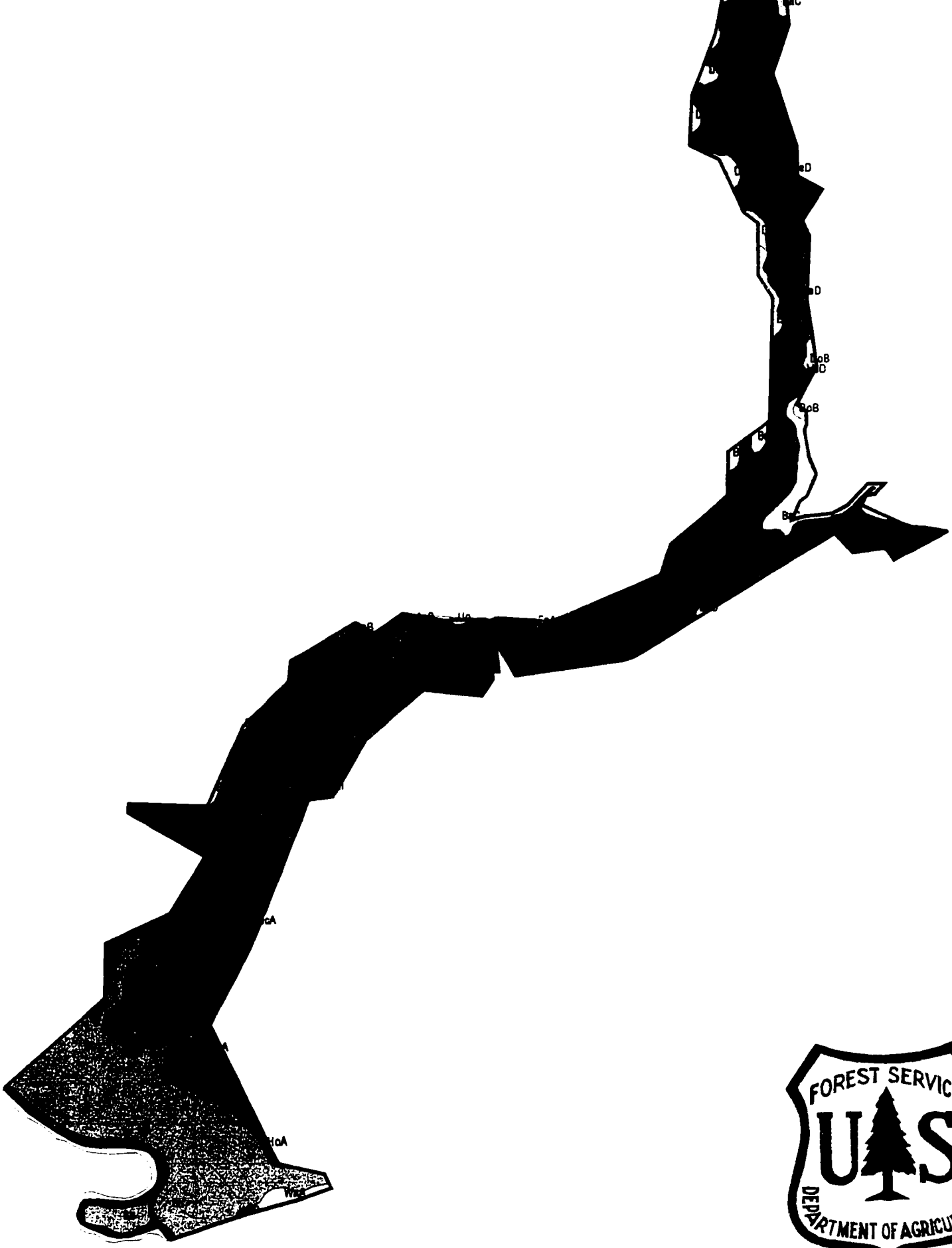
FOREST SERVICE
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DEPARTMENT OF AGRICULTURE

PRESETTLEMENT VEGETATION

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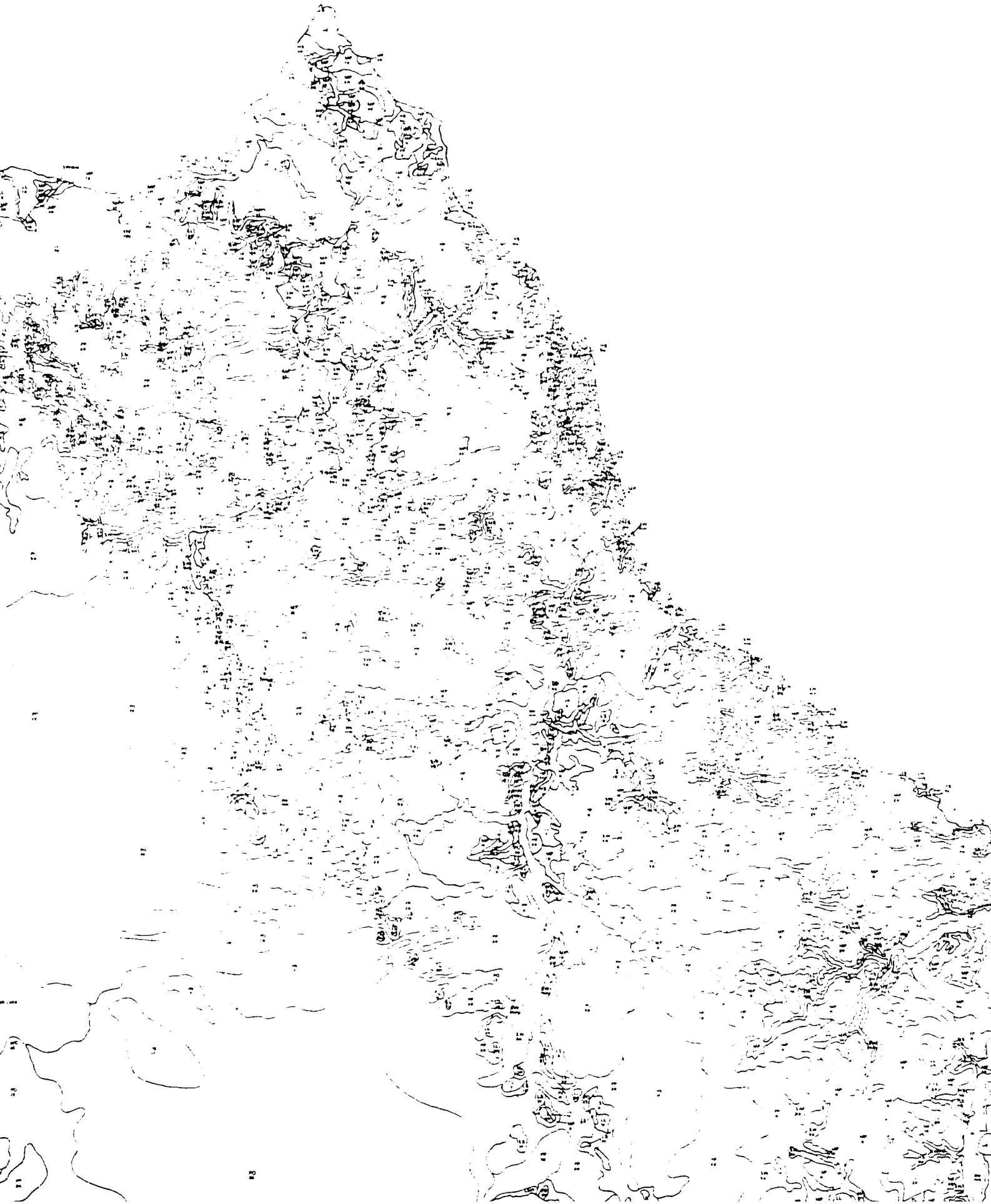

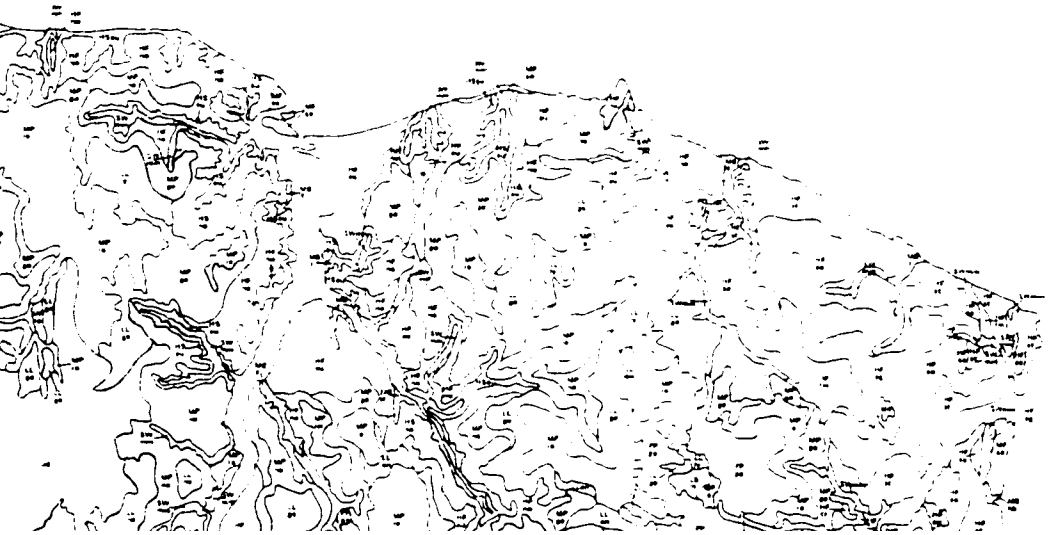

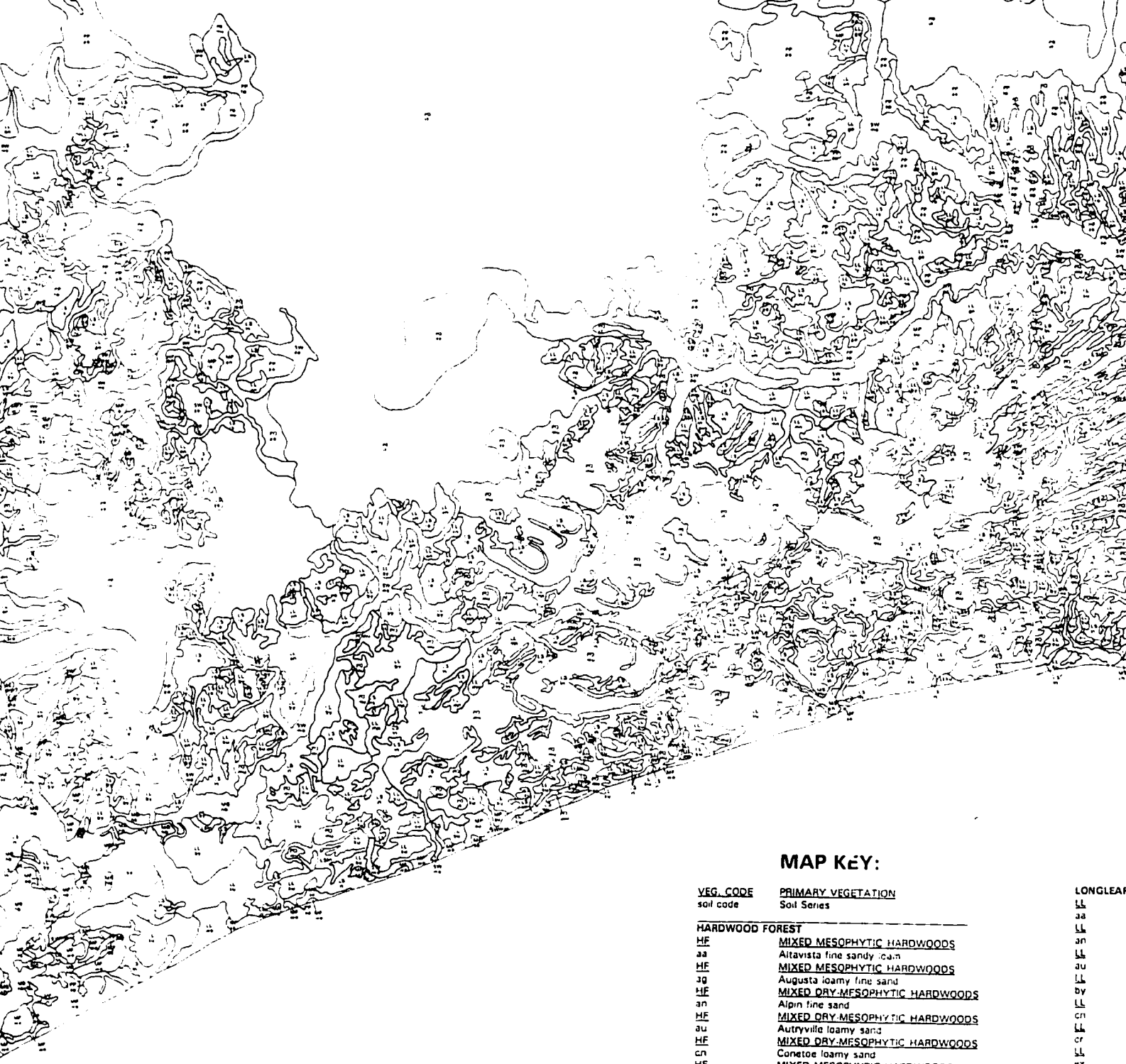

MAP KEY:

VEG. CODE / soil code	PRIMARY VEGETATION / Soil Series
HARDWOOD FOREST	
HF	MIXED MESOPHYTIC HARDWOODS
aa	Altavista fine sandy loam
HF	MIXED MESOPHYTIC HARDWOODS
ag	Augusta loamy fine sand
HF	MIXED DRY-MESOPHYTIC HARDWOODS
an	Alpin fine sand
HF	MIXED DRY-MESOPHYTIC HARDWOODS
au	Autryville loamy sand
HF	MIXED DRY-MESOPHYTIC HARDWOODS
cn	Conetoe loamy sand
HF	MIXED MESOPHYTIC HARDWOODS
go	Goldsboro loamy fine sand
HF	MIXED MESOPHYTIC HARDWOODS
jo	Johns fine sandy loam
HF	MIXED MESOPHYTIC HARDWOODS
ka	Kalmia loamy sand
HF	MIXED DRY-MESOPHYTIC HARDWOODS
ke	Kenansville loamy fine sand
HF	MIXED WET-MESOPHYTIC HARDWOODS
in	Leon sand
HF	MIXED WET-MESOPHYTIC HARDWOODS
me	Meggett sandy loam
HF	MIXED DRY-MESOPHYTIC HARDWOODS
no	Norfolk sand
HF	MIXED MESOPHYTIC HARDWOODS
pc	Pactolus loamy fine sand
HF	MIXED MESOPHYTIC HARDWOODS
ro	Roanoke loam
HF	WATER OAK-LOBLOLLY PINE-MIXED HARDWOODS
se	Seabrook fine sand
HF	MIXED MESOPHYTIC HARDWOODS
st	State loamy fine sand
HF	TULIP POPLAR-OAKS-OTHER HARDWOODS
tm	Tomotley fine sandy loam
HARDWOOD SLOPES	
HS	UPLAND OAKS-HICKORIES
au	Autryville loamy sand
HS	UPLAND OAKS-HICKORIES-BEECH
cr	Craven silt loam
HS	UPLAND OAKS-HICKORIES-BEECH

LONGLEAF
LL
aa
LL
an
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mn
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mv
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sg
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st
LL
ta

LONGLEAF
LS
in
LS
ra

AP KEY:

MARY VEGETATION
Series

ED MESOPHYTIC HARDWOODS
vista fine sandy loam
ED MESOPHYTIC HARDWOODS
sta loamy fine sand
ED DRY-MESOPHYTIC HARDWOODS
fine sand
D DRY-MESOPHYTIC HARDWOODS
vville loamy sand
D DRY-MESOPHYTIC HARDWOODS
toe loamy sand
D MESOPHYTIC HARDWOODS
boro loamy fine sand
D MESOPHYTIC HARDWOODS
fine sandy loam
D MESOPHYTIC HARDWOODS
a loamy sand
D DRY-MESOPHYTIC HARDWOODS
sville loamy fine sand
D WET-MESOPHYTIC HARDWOODS
sand
D WET-MESOPHYTIC HARDWOODS
tt sandy loam
D DRY-MESOPHYTIC HARDWOODS
k sand
MESOPHYTIC HARDWOODS
us loamy fine sand
MESOPHYTIC HARDWOODS
se loam
R OAK-LOBLOLLY PINE-MIXED HARDWOODS
ok fine sand
MESOPHYTIC HARDWOODS
oamy fine sand
POPLAR-OAKS-OTHER HARDWOODS
ey fine sandy loam

D OAKS-HICKORIES
le loamy sand
D OAKS-HICKORIES-BEECH
silt loam
D OAKS-HICKORIES-BEECH
loamy sand
D OAKS-HICKORIES-LOBLOLLY
loamy fine sand
OAK-LOBLOLLY PINE
k fine sand
ICKORIES-BEECH-MAGNOLIA

LONGLEAF PINE SAVANNA AND FOREST

LL	LONGLEAF PINE/MESIC SAVANNA
aa	Altavista loamy fine sand
LL	LONGLEAF PINE/DRY-MESIC SAVANNA
an	Alpin sand
LL	LONGLEAF PINE/DRY-MESIC SAVANNA
au	Autryville loamy sand
LL	LONGLEAF PINE/DRY-MESIC SAVANNA
by	Baymeade sand
LL	LONGLEAF PINE/DRY-MESIC SAVANNA
cn	Conetoe loamy sand
LL	LONGLEAF PINE/MESIC SAVANNA
cr	Craven loam
LL	LONGLEAF PINE/MESIC SAVANNA
ex	Exum silt loam
LL	LONGLEAF PINE/MESIC SAVANNA
go	Goldsboro loamy fine sand
LL	LONGLEAF PINE/MESIC SAVANNA
ka	Kalmia loamy sand
LL	LONGLEAF PINE/DRY-MESIC SAVANNA
ke	Kenansville loamy fine sand
LL	LONGLEAF PINE/DRY SAVANNA
ku	Kureb sand
LL	LONGLEAF PINE/XERIC SAVANNA
ly	Lynchburg fine sandy loam
LL	LONGLEAF PINE/MESIC SAVANNA
mn	Mandarin sand
LL	LONGLEAF PINE/MESIC SAVANNA
mv	Marvyn loamy sand
LL	LONGLEAF PINE/MESIC SAVANNA
no	Norfolk loamy fine sand
LL	LONGLEAF PINE/MESIC SAVANNA
on	Onslow loamy fine sand
LL	LONGLEAF PINE/MESIC SAVANNA
sg	Stallings loamy fine sand
LL	LONGLEAF PINE/MESIC SAVANNA
st	State loamy sand
LL	LONGLEAF PINE/DRY-MESIC SAVANNA
ta	Tarboro sand

LONGLEAF PINE WET SAVANNA

LS	LONGLEAF PINE/WET SAVANNA HERBS
ln	Leon sand
LS	LONGLEAF PINE/WET SAVANNA HERBS
ra	Rains fine sandy loam
LS	LONGLEAF PINE/WET SAVANNA HERBS
wo	Woodington fine sandy loam

BRACKISH MARSH, OLIGOHALINE MARSH, SALT MARSH

MB	MS	BRACKISH MARSH, SALT MARSH
hb	hb	Hobucken muck (shallow muck)

MARITIME FOREST

MF	LONGLEAF-LOBLOLLY PINE-LIVE OAK-YAUPON
aa	Altavista loamy fine sand
MF	LOBLOLLY PINE-LIVE OAK-YAUPON
ap	Arapahoe loamy fine sand
MF	LIVE OAK-LOBLOLLY PINE-YAUPON
au	Autryville loamy sand
MF	LONGLEAF-LIVE OAK-YAUPON
mn	Mandarin sand
MF	LIVE OAK-LOBLOLLY PINE-YAUPON
se	Seabrook fine sand
MF	LONGLEAF-LIVE OAK-YAUPON
st	State loamy sand
MF	LIVE OAK-LOBLOLLY PINE-YAUPON
tm	Tomotley fine sandy loam
MF	LIVE OAK-LOBLOLLY PINE-YAUPON
wa	Wando fine sand

MIXED PINE SAVANNA AND PYROPHYTIC WOODLAND

MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
aa	Altavista loamy fine sand
MP	PURE OR MIXED POND PINE-LOBLOLLY-LONGLEAF
ag	Augusta loamy fine sand
MP	QUERCUS FALCATA MIXED PINES
an	Alpin sand
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
ap	Arapahoe loamy fine sand
MP	LONGLEAF-LOBLOLLY-HARDWOODS
au	Autryville loamy fine sand
MP	LONGLEAF-LOBLOLLY-HARDWOODS
cn	Conetoe loamy sand
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
cr	Craven silt loam
MP	MIXED LONGLEAF-LOBLOLLY HARDWOODS
ex	Exum silt loam
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
go	Goldsboro loamy fine sand
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
jo	Johns loamy sand
MP	MIXED LONGLEAF-LOBLOLLY-HARDWOODS
ka	Kalmia loamy sand
MP	MIXED LONGLEAF-LOBLOLLY-HARDWOODS
ke	Kenansville loamy fine sand
MP	MIXED POND PINE-LOBLOLLY
la	Leaf silt loam
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY-SHORTLEAF
le	Lenoir silt loam
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
ln	Leon sand
MP	MIXED LONGLEAF-POND PINE-HARDWOODS
ly	Lynchburg sand

POND PINE/POCOSIN

Abbreviations: LPOC - Low
MPOC - Medium Pocosin,

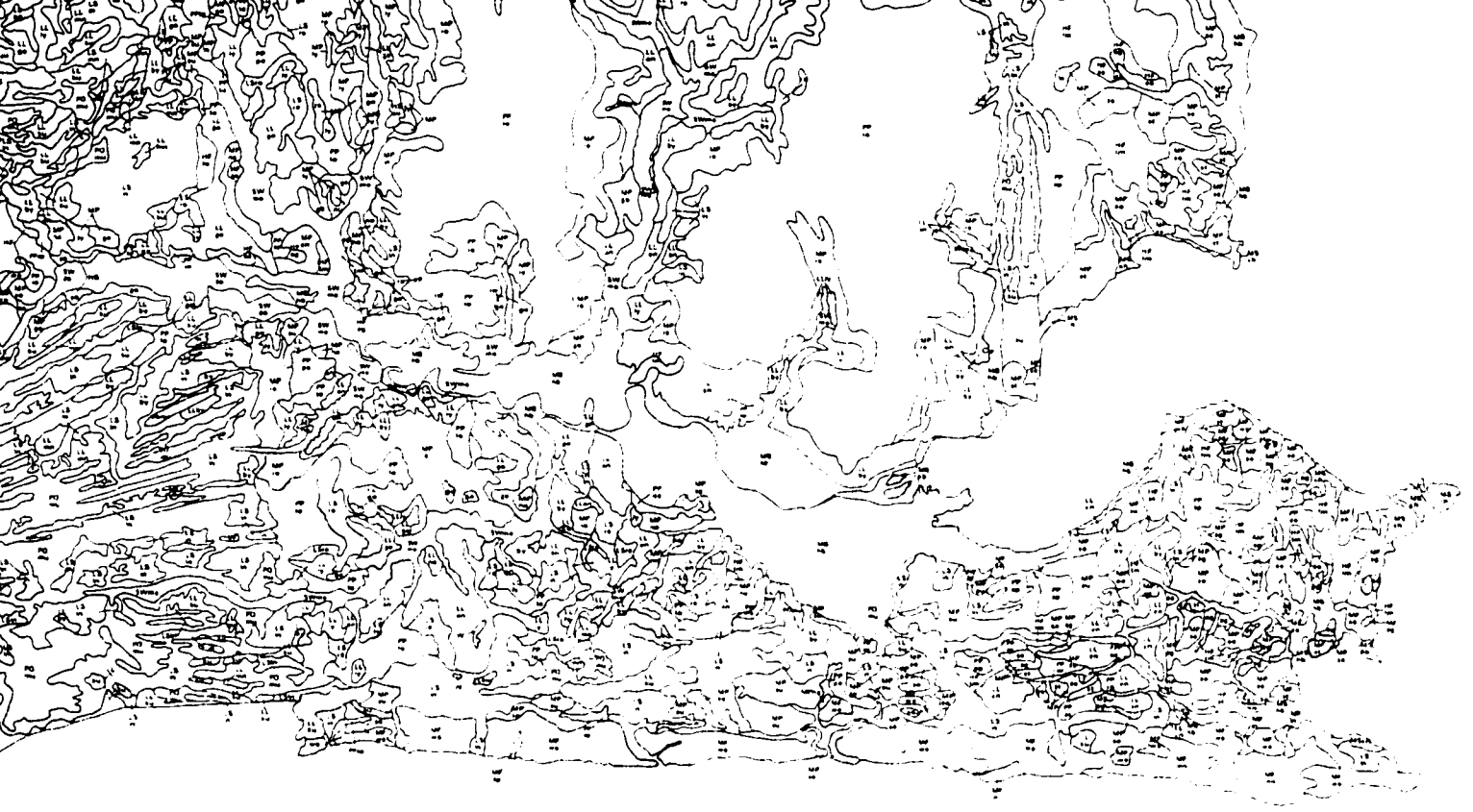
PO	POND PIN
ba	Bayboro r
PO	MPOC, P
ct	Croatan r
PO	LPOC, MI
da	Dare muc
PO	LPOC, MI
de	Deloss fir
PO	LPOC & C
mu	Murville r
PO	POND PIN
pa	Pantego f
PO	POND PIN
to	Torhunta

POND PINE FOREST AND

PP	POND PIN
ap	Arapahoe
PP	POND PIN
ba	Bayboro r
PP	POND PIN
de	Deloss fir
PP	POND PIN
gr	Grantham
PP	POND PIN
la	Leaf silt l
PP	POND PIN
pa	Pantego f
PP	POND PIN
ra	Rains fine
PP	POND PIN
to	Torhunta

SWAMP FOREST AND BO

SW	NYSSA B
ba	Bayboro r
SW	NYSSA B
ct	Croatan r
SW	NYSSA B
do	Dorovan
SW	BALDCYP
ma	Masontov
SW	BALDCYP
mm	Masontov and Muck
SW	SEMI-EVE
me	Meggett s



VANNA AND FOREST

NGLEAF PINE/MESIC SAVANNA	
avista loamy fine sand	
NGLEAF PINE/DRY-MESIC SAVANNA	
in sand	
NGLEAF PINE/DRY-MESIC SAVANNA	
ryville loamy sand	
NGLEAF PINE/DRY-MESIC SAVANNA	
rmeade sand	
NGLEAF PINE/DRY-MESIC SAVANNA	
netoe loamy sand	
NGLEAF PINE/MESIC SAVANNA	
ven loam	
NGLEAF PINE/MESIC SAVANNA	
m silt loam	
NGLEAF PINE/MESIC SAVANNA	
dsboro loamy fine sand	
NGLEAF PINE/MESIC SAVANNA	
mia loamy sand	
NGLEAF PINE/DRY-MESIC SAVANNA	
nansville loamy fine sand	
NGLEAF PINE/DRY SAVANNA	
eb sand	
NGLEAF PINE/XERIC SAVANNA	
chburg fine sandy loam	
NGLEAF PINE/MESIC SAVANNA	
ndarin sand	
NGLEAF PINE/MESIC SAVANNA	
rvyn loamy sand	
NGLEAF PINE/MESIC SAVANNA	
rfolk loamy fine sand	
NGLEAF PINE/MESIC SAVANNA	
slow loamy fine sand	
NGLEAF PINE/MESIC SAVANNA	
llings loamy fine sand	
NGLEAF PINE/MESIC SAVANNA	
te loamy sand	
NGLEAF PINE/DRY-MESIC SAVANNA	
boro sand	

ET SAVANNA

NGLEAF PINE/WET SAVANNA HERBS	
on sand	
NGLEAF PINE/WET SAVANNA HERBS	
ins fine sandy loam	
NGLEAF PINE/WET SAVANNA HERBS	
odington fine sandy loam	

OLIGOHALINE MARSH, SALT MARSH

ACKISH MARSH, SALT MARSH	
bucken muck (shallow muck)	
ACKISH MARSH, OLIGOHALINE M.	
itte muck (deep muck)	

MARITIME FOREST

MF	LONGLEAF-LOBLOLLY PINE-LIVE OAK-YAUPON
aa	Altavista loamy fine sand
MF	LOBLOLLY PINE-LIVE OAK-YAUPON
ap	Arapahoe loamy fine sand
MF	LIVE OAK-LOBLOLLY PINE-YAUPON
au	Autryville loamy sand
MF	LONGLEAF-LIVE OAK-YAUPON
mn	Mandarin sand
MF	LIVE OAK-LOBLOLLY PINE-YAUPON
se	Seabrook fine sand
MF	LONGLEAF-LIVE OAK-YAUPON
st	State loamy sand
MF	LIVE OAK-LOBLOLLY PINE-YAUPON
tm	Tomotley fine sandy loam
MF	LIVE OAK-LOBLOLLY PINE-YAUPON
wa	Wando fine sand

MIXED PINE SAVANNA AND PYROPHYTIC WOODLAND

MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
aa	Altavista loamy fine sand
MP	PURE OR MIXED POND PINE-LOBLOLLY-LONGLEAF
ag	Augusta loamy fine sand
MP	QUERCUS FALCATA-MIXED PINES
an	Alpin sand
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
ap	Arapahoe loamy fine sand
MP	LONGLEAF-LOBLOLLY-HARDWOODS
au	Autryville loamy fine sand
MP	LONGLEAF-LOBLOLLY-HARDWOODS
cn	Conetoe loamy sand
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
cr	Craven silt loam
MP	MIXED LONGLEAF-LOBLOLLY-HARDWOODS
ex	Exum silt loam
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
go	Goldsboro loamy fine sand
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
jo	Johns loamy sand
MP	MIXED LONGLEAF-LOBLOLLY-HARDWOODS
ka	Kalmia loamy sand
MP	MIXED LONGLEAF-LOBLOLLY-HARDWOODS
ke	Kenansville loamy fine sand
MP	MIXED POND PINE-LOBLOLLY
la	Leaf silt loam
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY-SHORTLEAF
le	Lenoir silt loam
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
ln	Leon sand
MP	MIXED LONGLEAF-POND PINE-HARDWOODS
ly	Lynchburg sand
MP	LONGLEAF-POND PINE-LOBLOLLY-POST OAK
na	Nahunta silt loam
MP	MIXED LONGLEAF-LOBLOLLY-OAK-HICKORY

POND PINE/POCOSIN

Abbreviations. LPOC - Low Pocosin, MPOC - Medium Pocosin, HPOC - High pocosin

PO	POND PINE GORDONIA/MPOC,HPOC
ba	Bayboro mucky loam
PO	MPOC, POND PINE/CANEBRAKE
ct	Croatan muck
PO	LPOC, MPOC, HPOC
da	Dare muck
PO	LPOC, MPOC, HPOC
de	Deloss fine sandy loam
PO	LPOC & OPEN BOG, MPOC
mu	Murville mucky loamy sand
PO	POND PINE/MPOC,HPOC
pa	Pantego fine sandy loam
PO	POND PINE/MPOC,HPOC
to	Torhunta fine sandy loam

POND PINE FOREST AND SAVANNA

PP	POND PINE
ap	Arapahoe fine sandy loam
PP	POND PINE
ba	Bayboro mucky loam
PP	POND PINE
de	Deloss fine sandy loam
PP	POND PINE
gr	Grantham silt loam
PP	POND PINE
la	Leaf silt loam
PP	POND PINE
pa	Pantego fine sandy loam
PP	POND PINE
ra	Rains fine sandy loam
PP	POND PINE
to	Torhunta fine sandy loam

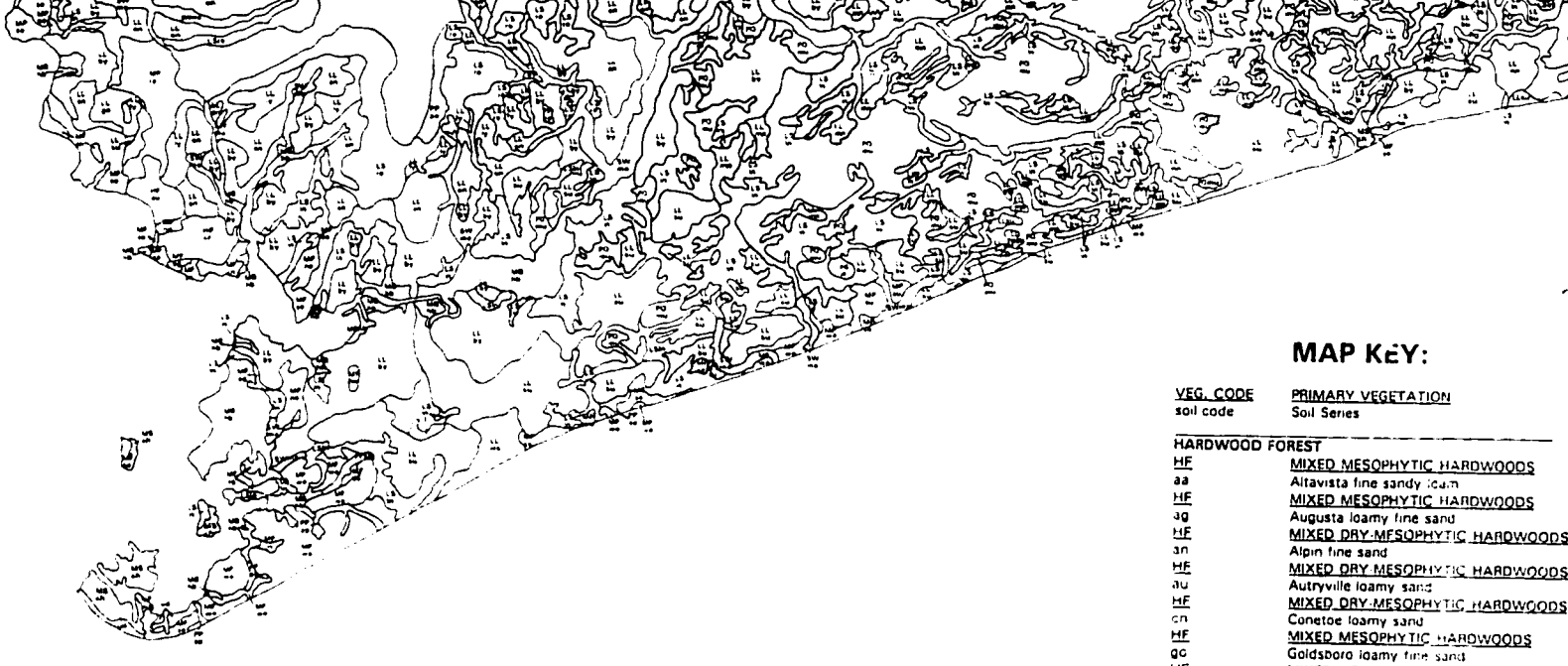
SWAMP FOREST AND BOTTOMLAND HARDWOODS

SW	NYSSA BIFLORA BALDCYPRESS-BOTTOMLAND HARDWOODS
ba	Bayboro mucky loam
SW	NYSSA BIFLORA-BALDCYPRESS
ct	Croatan muck
SW	NYSSA BIFLORA-BALDCYPRESS-RED MAPLE
do	Dorovan muck
SW	BALDCYPRESS-NYSSA SPP -RED MAPLE
ma	Masontown mucky fine sandy loam
SW	BALDCYPRESS-NYSSA-FRAXINUS-BOTTOMLAND OAKS
mm	Masontown mucky fine sandy loam and Muckalee sandy loam
SW	SEMI-EVERGREEN OAKS-NYSSA BIFLORA
me	Meggett sandy loam
SW	BALDCYPRESS-NYSSA-FRAXINUS-SWAMP CHESTNUT OAK
mk	Muckalee sandy loam
SW	LOBLOLLY-TULIP POPLAR-BALDCYPRESS
sx	Stockade fine sandy loam

1996

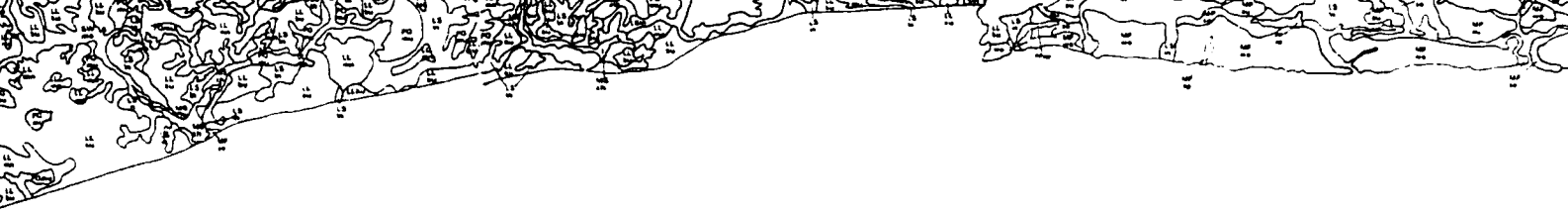
Cecil Frost

Plant Conservation Program
North Carolina Department of Agriculture



MAP KEY:

VEG. CODE	PRIMARY VEGETATION
soil code	Soil Series
HARDWOOD FOREST	
HF	MIXED MESOPHYTIC HARDWOODS
aa	Altavista fine sandy loam
HF	MIXED MESOPHYTIC HARDWOODS
ag	Augusta loamy fine sand
HF	MIXED DRY-MESOPHYTIC HARDWOODS
an	Alpin fine sand
HF	MIXED DRY-MESOPHYTIC HARDWOODS
au	Autryville loamy sand
HF	MIXED DRY-MESOPHYTIC HARDWOODS
cn	Conetoe loamy sand
HF	MIXED MESOPHYTIC HARDWOODS
gg	Goldsboro loamy fine sand
HF	MIXED MESOPHYTIC HARDWOODS
jo	Johns fine sandy loam
HF	MIXED MESOPHYTIC HARDWOODS
ka	Kalmia loamy sand
HF	MIXED DRY-MESOPHYTIC HARDWOODS
ke	Kenansville loamy fine sand
HF	MIXED WET-MESOPHYTIC HARDWOODS
ln	Leon sand
HF	MIXED WET-MESOPHYTIC HARDWOODS
me	Meggett sandy loam
HF	MIXED DRY-MESOPHYTIC HARDWOODS
no	Norfolk sand
HF	MIXED MESOPHYTIC HARDWOODS
pc	Pactolus loamy fine sand
HF	MIXED MESOPHYTIC HARDWOODS
ro	Roanoke loam
HF	WATER OAK-LOBLOLLY PINE-MIXED HAR
se	Seabrook fine sand
HF	MIXED MESOPHYTIC HARDWOODS
st	State loamy fine sand
HF	TULIP POPLAR-OAKS-OTHER HARDWOOD
tm	Tomotley fine sand, loam
HARDWOOD SLOPES	
HS	UPLAND OAKS-HICKORIES
au	Autryville loamy sand
HS	UPLAND OAKS-HICKORIES-BEECH
cr	Craven silt loam
HS	UPLAND OAKS-HICKORIES-BEECH
mv	Marvyn loamy sand
HS	UPLAND OAKS-HICKORIES-LOBLOLLY
no	Norfolk loamy fine sand
HS	WATER OAK-LOBLOLLY PINE
se	Seabrook fine sand
HS	OAKS-HICKORIES-BEECH-MAGNOLIA
su	Suffolk loamy sand



MAP KEY:

VEG. CODE	PRIMARY VEGETATION
soil code	Soil Series

HARDWOOD FOREST

HF	MIXED MESOPHYTIC HARDWOODS
aa	Altavista fine sandy loam
HF	MIXED MESOPHYTIC HARDWOODS
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HF	MIXED DRY-MESOPHYTIC HARDWOODS
an	Alpin fine sand
HF	MIXED DRY-MESOPHYTIC HARDWOODS
au	Autryville loamy sand
HF	MIXED DRY-MESOPHYTIC HARDWOODS
cn	Conetoe loamy sand
HF	MIXED MESOPHYTIC HARDWOODS
go	Goldsboro loamy fine sand
HF	MIXED MESOPHYTIC HARDWOODS
jo	Johns fine sandy loam
HF	MIXED MESOPHYTIC HARDWOODS
ka	Kalmia loamy sand
HF	MIXED DRY-MESOPHYTIC HARDWOODS
ke	Kenansville loamy fine sand
HF	MIXED WET-MESOPHYTIC HARDWOODS
in	Leon sand
HF	MIXED WET-MESOPHYTIC HARDWOODS
me	Meggett sandy loam
HF	MIXED DRY-MESOPHYTIC HARDWOODS
no	Norfolk sand
HF	MIXED MESOPHYTIC HARDWOODS
pc	Pactolus loamy fine sand
HF	MIXED MESOPHYTIC HARDWOODS
ro	Roanoke loam
HF	WATER OAK-LOBLOLLY PINE-MIXED HARDWOODS
se	Seabrook fine sand
HF	MIXED MESOPHYTIC HARDWOODS
st	State loamy fine sand
HF	TULIP POPLAR-OAKS-OTHER HARDWOODS
tm	Tomotley fine sandy loam

HARDWOOD SLOPES

HS	UPLAND OAKS-HICKORIES
au	Autryville loamy sand
HS	UPLAND OAKS-HICKORIES-BEECH
cr	Craven silt loam
HS	UPLAND OAKS-HICKORIES-BEECH
mv	Marvyn loamy sand
HS	UPLAND OAKS-HICKORIES-LOBLOLLY
no	Norfolk loamy fine sand
HS	WATER OAK-LOBLOLLY PINE
se	Seabrook fine sand
HS	OAKS-HICKORIES-BEECH-MAGNOLIA
su	Suffolk loamy sand

LONGLEAF PINE SAVANNA AND FOREST

LL	LONGLEAF PINE/MESIC SAVANNA
aa	Altavista loamy fine sand
LL	LONGLEAF PINE/DRY-MESIC SAVANNA
an	Alpin sand
LL	LONGLEAF PINE/DRY-MESIC SAVANNA
au	Autryville loamy sand
LL	LONGLEAF PINE/DRY-MESIC SAVANNA
by	Baymeade sand
LL	LONGLEAF PINE/DRY-MESIC SAVANNA
cn	Conetoe loamy sand
LL	LONGLEAF PINE/MESIC SAVANNA
cr	Craven loam
LL	LONGLEAF PINE/MESIC SAVANNA
ex	Exum silt loam
LL	LONGLEAF PINE/MESIC SAVANNA
go	Goldsboro loamy fine sand
LL	LONGLEAF PINE/MESIC SAVANNA
ka	Kalmia loamy sand
LL	LONGLEAF PINE/DRY-MESIC SAVANNA
ke	Kenansville loamy fine sand
LL	LONGLEAF PINE/DRY SAVANNA
ku	Kureb sand
LL	LONGLEAF PINE/XERIC SAVANNA
ly	Lynchburg fine sandy loam
LL	LONGLEAF PINE/MESIC SAVANNA
mn	Mandarin sand
LL	LONGLEAF PINE/MESIC SAVANNA
mv	Marvyn loamy sand
LL	LONGLEAF PINE/MESIC SAVANNA
no	Norfolk loamy fine sand
LL	LONGLEAF PINE/MESIC SAVANNA
on	Onslow loamy fine sand
LL	LONGLEAF PINE/MESIC SAVANNA
sg	Stallings loamy fine sand
LL	LONGLEAF PINE/MESIC SAVANNA
st	State loamy sand
LL	LONGLEAF PINE/DRY MESIC SAVANNA
ta	Tarboro sand

LONGLEAF PINE WET SAVANNA

LS	LONGLEAF PINE/WET SAVANNA HERBS
in	Leon sand
LS	LONGLEAF PINE/WET SAVANNA HERBS
ra	Rains fine sandy loam
LS	LONGLEAF PINE/WET SAVANNA HERBS
wo	Woodington fine sandy loam

BRACKISH MARSH, OLIGOHALINE MARSH, SALT MARSH

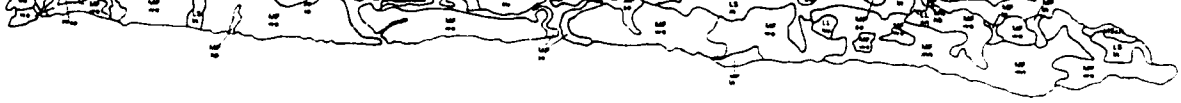
MB	MS	BRACKISH MARSH, SALT MARSH
hb	hb	Hobucken muck (shallow muck)
MB	MO	BRACKISH MARSH, OLIGOHALINE M.
lf	lf	Lafitte muck (deep muck)
MO		OLIGOHALINE M.
ho		Hobonny muck (deep muck)
MS		SALT MARSH
ch		Carteret (high phase)
MS		SALT MARSH
cl		Carteret (low phase)

MARITIME FOREST

MF	LONGLEAF-LOBLOLLY PINE-LIVE OAK-YAUPON
aa	Altavista loamy fine sand
MF	LOBLOLLY PINE-LIVE OAK-YAUPON
ap	Arapahoe loamy fine sand
MF	LIVE OAK-LOBLOLLY PINE-YAUPON
au	Autryville loamy sand
MF	LONGLEAF-LIVE OAK-YAUPON
mn	Mandarin sand
MF	LIVE OAK-LOBLOLLY PINE YAUPON
se	Seabrook fine sand
MF	LONGLEAF-LIVE OAK-YAUPON
st	State loamy sand
MF	LIVE OAK-LOBLOLLY PINE-YAUPON
tm	Tomotley fine sandy loam
MF	LIVE OAK-LOBLOLLY PINE-YAUPON
wa	Wando fine sand

MIXED PINE SAVANNA AND PYROPHYTIC WOODLAND

MP	MIXED LONGLEAF-POND PINE LOBLOLLY
aa	Altavista loamy fine sand
MP	PURE OR MIXED POND PINE-LOBLOLLY LONGLEAF
ag	Augusta loamy fine sand
MP	QUERCUS FALCATA-MIXED PINES
an	Alpin sand
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
ap	Arapahoe loamy fine sand
MP	LONGLEAF-LOBLOLLY-HARDWOODS
au	Autryville loamy fine sand
MP	LONGLEAF-LOBLOLLY-HARDWOODS
cn	Conetoe loamy sand
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
cr	Craven silt loam
MP	MIXED LONGLEAF-LOBLOLLY HARDWOODS
ex	Exum silt loam
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
go	Goldsboro loamy fine sand
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
jo	Johns loamy sand
MP	MIXED LONGLEAF-LOBLOLLY-HARDWOODS
ka	Kalmia loamy sand
MP	MIXED LONGLEAF-LOBLOLLY HARDWOODS
ke	Kenansville loamy fine sand
MP	MIXED POND PINE-LOBLOLLY
la	Leaf silt loam
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY-SHORTLEAF
le	Lenoir silt loam
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
in	Leon sand
MP	MIXED LONGLEAF-POND PINE-HARDWOODS
ly	Lynchburg sand
MP	LONGLEAF-POND PINE-LOBLOLLY-POST OAK
na	Nahunta silt loam
MP	MIXED LONGLEAF-LOBLOLLY-OAK-HICKORY
no	Norfolk sand
MP	MIXED LONGLEAF-LOBLOLLY-OAK-HICKORY
on	Onslow loamy sand
MP	MIXED LONGLEAF-LOBLOLLY-OAK-HICKORY
pc	Pactolus loamy fine sand
MP	LONGLEAF, MIXED LONGLEAF-POND PINE-LOBLOLLY
ra	Rains fine sandy loam
MP	LONGLEAF-LOBLOLLY-HARDWOODS
se	Seabrook fine sand
MP	LONGLEAF-LOBLOLLY-HARDWOODS
sg	Stallings loamy fine sand
MP	LONGLEAF-LOBLOLLY-HARDWOODS
st	State loamy sand
MP	LONGLEAF-LOBLOLLY-HARDWOODS
ta	Tarboro sand
MP	MIXED PINES-OAKS-HICKORY
tm	Tomotley fine sandy loam
MP	LONGLEAF-LOBLOLLY-SHORTLEAF HARDWOODS
wa	Wando fine sand



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VANNA HERBS
VANNA HERBS
m
, SALT MARSH
MARSH
muck)
OHALINE M.
k)

MARITIME FOREST

MF	LONGLEAF-LOBLOLLY PINE-LIVE OAK-YAUPON
aa	Altavista loamy fine sand
MF	LOBLOLLY PINE-LIVE OAK-YAUPON
ap	Arapahoe loamy fine sand
MF	LIVE OAK-LOBLOLLY PINE-YAUPON
au	Autryville loamy sand
MF	LONGLEAF-LIVE OAK-YAUPON
mn	Mandarin sand
MF	LIVE OAK-LOBLOLLY PINE-YAUPON
se	Seabrook fine sand
MF	LONGLEAF-LIVE OAK-YAUPON
st	State loamy sand
MF	LIVE OAK-LOBLOLLY PINE-YAUPON
tm	Tomotley fine sandy loam
MF	LIVE OAK-LOBLOLLY PINE-YAUPON
wa	Wando fine sand

MIXED PINE SAVANNA AND PYROPHYTIC WOODLAND

MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
aa	Altavista loamy fine sand
MP	PURE OR MIXED POND PINE-LOBLOLLY-LONGLEAF
ag	Augusta loamy fine sand
MP	QUERCUS FALCATA-MIXED PINES
an	Alpin sand
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
ap	Arapahoe loamy fine sand
MP	LONGLEAF-LOBLOLLY-HARDWOODS
au	Autryville loamy fine sand
MP	LONGLEAF-LOBLOLLY-HARDWOODS
cn	Conetoe loamy sand
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
cr	Craven silt loam
MP	MIXED LONGLEAF-LOBLOLLY-HARDWOODS
ex	Exum silt loam
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
go	Goldsboro loamy fine sand
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
jo	Johns loamy sand
MP	MIXED LONGLEAF-LOBLOLLY-HARDWOODS
ka	Kalmia loamy sand
MP	MIXED LONGLEAF-LOBLOLLY-HARDWOODS
ke	Kenansville loamy fine sand
MP	MIXED POND PINE-LOBLOLLY
la	Leaf silt loam
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY-SHORTLEAF
le	Lenoir silt loam
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
ln	Leon sand
MP	MIXED LONGLEAF-POND PINE-HARDWOODS
ly	Lynchburg sand
MP	LONGLEAF-POND PINE-LOBLOLLY-POST OAK
na	Nahunta silt loam
MP	MIXED LONGLEAF-LOBLOLLY-OAK-HICKORY
no	Norfolk sand
MP	MIXED LONGLEAF-LOBLOLLY-OAK-HICKORY
on	Onslow loamy sand
MP	MIXED LONGLEAF-LOBLOLLY-OAK-HICKORY
pc	Pactolus loamy fine sand
MP	LONGLEAF, MIXED LONGLEAF-POND PINE-LOBLOLLY
ra	Rains fine sandy loam
MP	LONGLEAF-LOBLOLLY-HARDWOODS
se	Seabrook fine sand
MP	LONGLEAF-LOBLOLLY-HARDWOODS
sg	Stallings loamy fine sand
MP	LONGLEAF-LOBLOLLY-HARDWOODS
st	State loamy sand
MP	LONGLEAF-LOBLOLLY-HARDWOODS
ta	Tarboro sand
MP	MIXED PINES-OAKS-HICKORY
tm	Tomotley fine sandy loam
MP	LONGLEAF-LOBLOLLY-SHORTLEAF HARDWOODS
wa	Wando fine sand

POND PINE/POCOSIN

Abbreviations: LPOC - Low Pocosin, MPOC - Medium Pocosin, HPOC - High pocosin

PO	POND PINE-GORDONIA/MPOC,HPOC
ba	Bayboro mucky loam
PO	MPOC, POND PINE/CANEBRAKE
ct	Croatan muck
PO	LPOC, MPOC, HPOC
da	Dare muck
PO	LPOC, MPOC, HPOC
de	Deloss fine sandy loam
PO	LPOC & OPEN BOG, MPOC
mu	Murville mucky loamy sand
PO	POND PINE/MPOC,HPOC
pa	Pantego fine sandy loam
PO	POND PINE/MPOC,HPOC
to	Torhunta fine sandy loam

POND PINE FOREST AND SAVANNA

PP	POND PINE
ap	Arapahoe fine sandy loam
PP	POND PINE
ba	Bayboro mucky loam
PP	POND PINE
de	Deloss fine sandy loam
PP	POND PINE
gr	Grantham silt loam
PP	POND PINE
la	Leaf silt loam
PP	POND PINE
pa	Pantego fine sandy loam
PP	POND PINE
ra	Rains fine sandy loam
PP	POND PINE
to	Torhunta fine sandy loam

SWAMP FOREST AND BOTTOMLAND HARDWOODS

SW	NYSSA BIFLORA-BALDCYPRESS-BOTTOMLAND HARDWOODS
ba	Bayboro mucky loam
SW	NYSSA BIFLORA-BALDCYPRESS
ct	Croatan muck
SW	NYSSA BIFLORA-BALDCYPRESS-RED MAPLE
do	Dorovan muck
SW	BALDCYPRESS-NYSSA SPP.-RED MAPLE
ma	Masontown mucky fine sandy loam
SW	BALDCYPRESS-NYSSA-FRAXINUS-BOTTOMLAND OAKS
mm	Masontown mucky fine sandy loam and Muckalee sandy loam
SW	SEMI-EVERGREEN OAKS-NYSSA BIFLORA
me	Meggett sandy loam
SW	BALDCYPRESS-NYSSA-FRAXINUS SWAMP CHESTNUT OAK
mk	Muckalee sandy loam
SW	LOBLOLLY-TULIP POPLAR-BALDCYPRESS
sx	Stockade fine sandy loam
ud	Udorthents (man-made/disturbed)
W	Water

WHITE CEDAR

WC	ATLANTIC WHITE CEDAR-GORDONIA-POND PINE
ct	Croatan muck

PRESETTL


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PP pa
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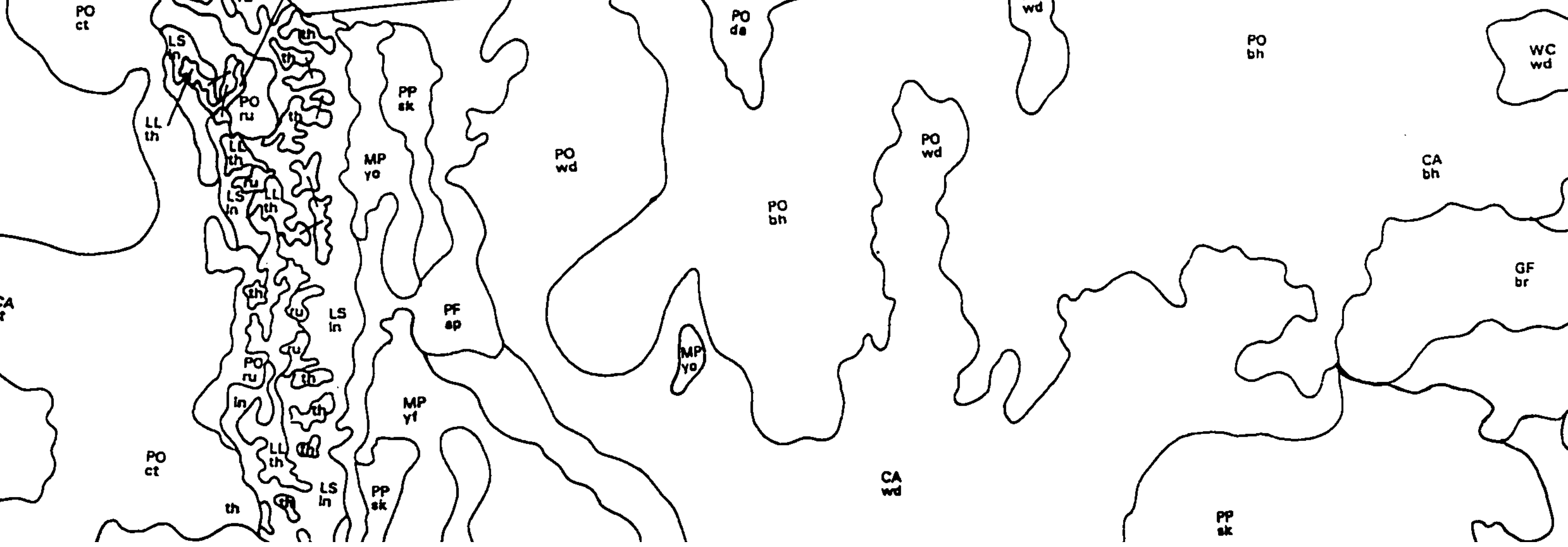
PRESETTLEMENT VEGETATION OF PA

NORTH CAROLINA

2000

Cecil Frost



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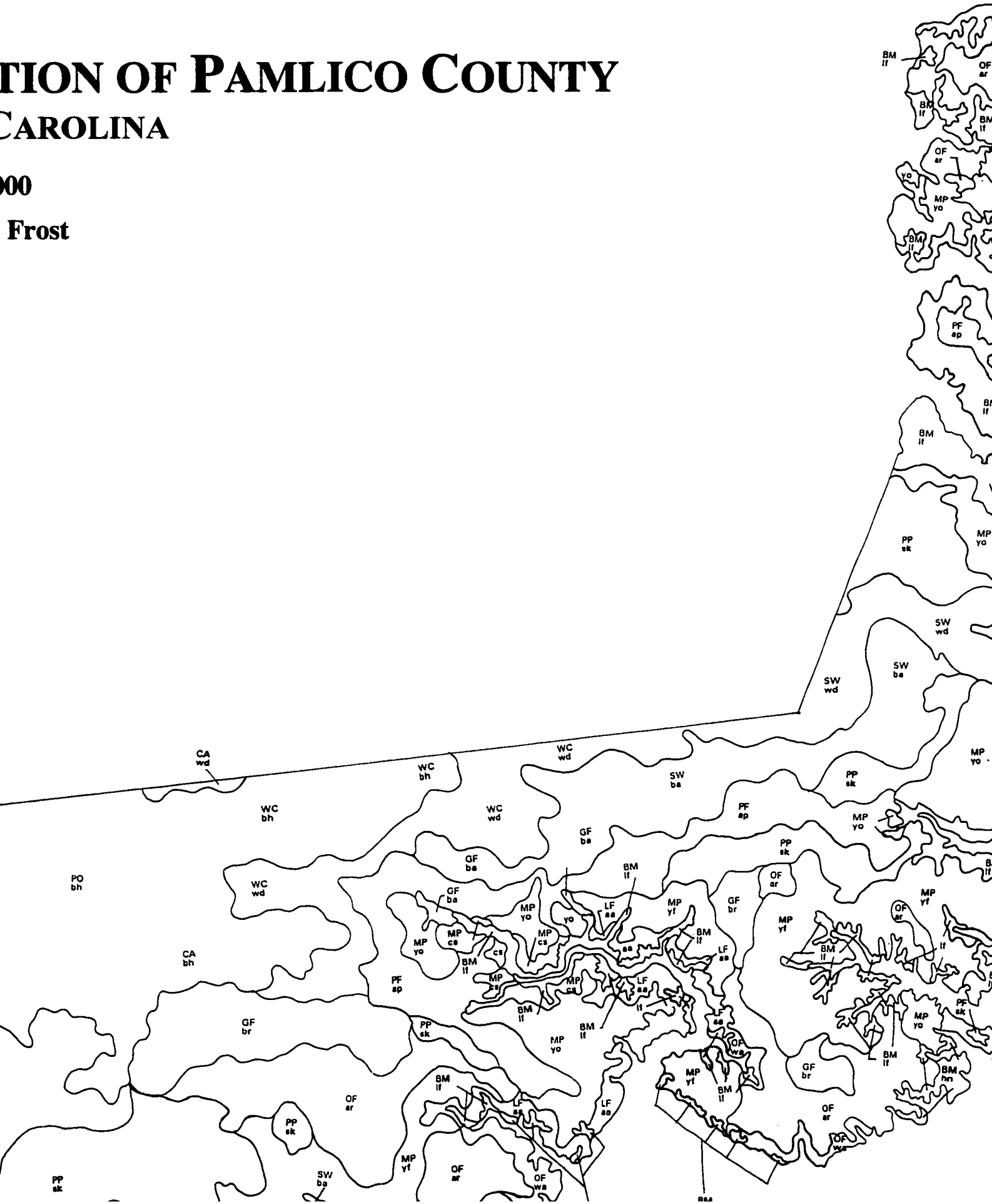


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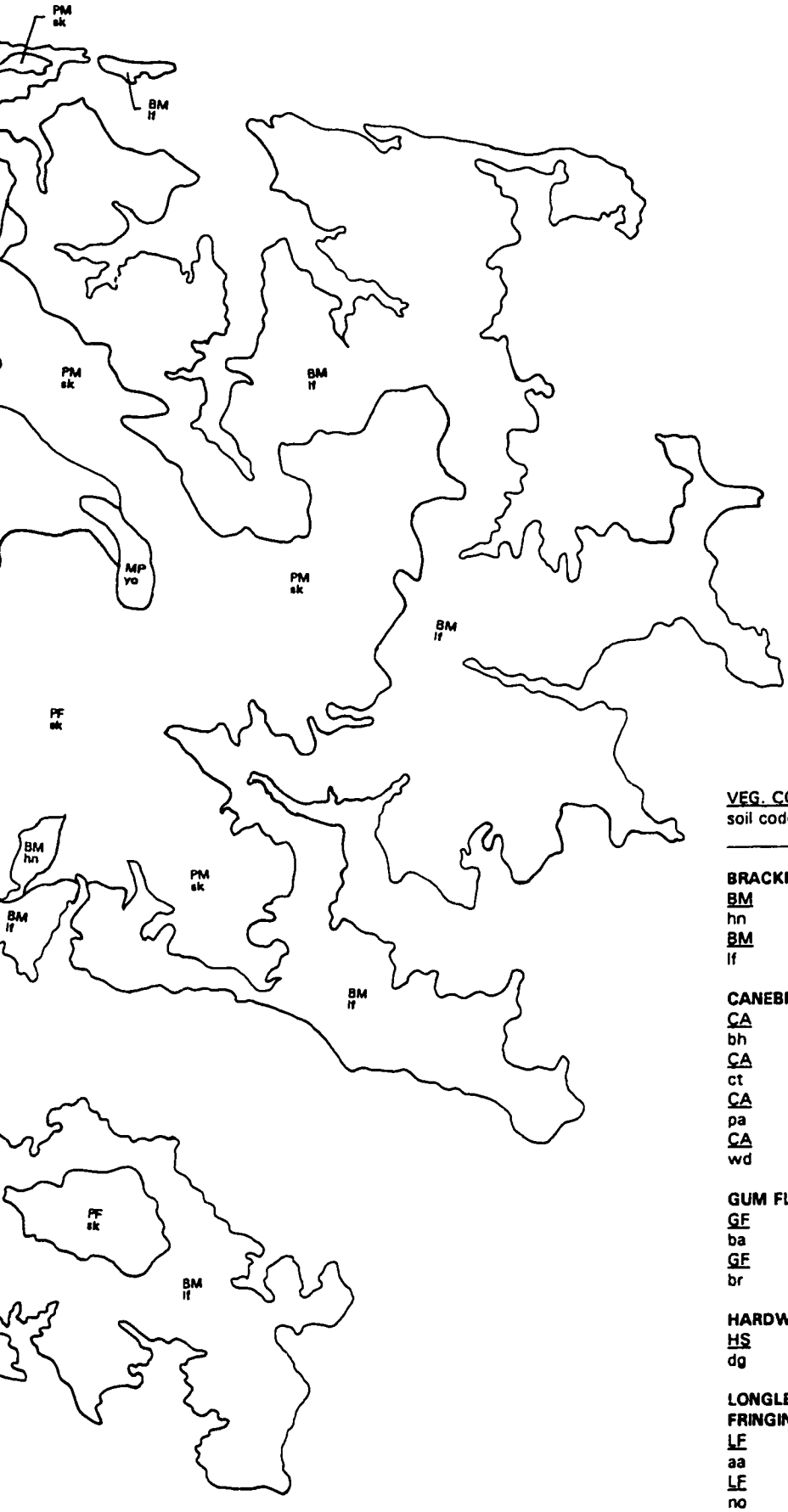

KEY:

VEG. CODE		PRIMARY VEGETATION
soil code		Soil Series

BRACKISH MARSH, OLIGOHALINE MARSH

BM	OM	BRACKISH MARSH, OLIGOHALINE M.
hn	hn	Hobucken muck (shallow muck)
BM	OM	BRACKISH MARSH, OLIGOHALINE M.
lf	lf	Lafitte muck (deep muck)

CANEBRAKE-POND PINE FOREST MOSAIC

CA	CANEBRAKE, PISE-GOLA, HPOC
bh	Belhaven muck
CA	MPOC, HPOC, PISE/CANEBRAKE
ct	Croatan muck
CA	PISE/CANEBRAKE, PISE, HPOC
pa	Paxville mucky fine sandy loam
CA	CANEBRAKE, SWEETGUM, LOBLOLLY
wd	Wasda muck

GUM FLATS

GF	MIXED GUM, POPLAR, CYPRESS
ba	Ballahack fine sandy loam
GF	SWEET GUM-NYSSA-TULIP POPLAR
br	Brookman mucky silt loam

HARDWOOD SLOPES

HS	UPLAND OAKS-HICKORIES-BEECH
dg	Dogue fine sandy loam

LONGLEAF FOREST OR MIXED HARDWOODS ON SOILS FRINGING SOUNDS, SMALL STREAM SWAMPS OR MARSH

LF	LONGLEAF PINE TO OAK-HICKORY-BEECH
aa	Altavista loamy fine sand
LF	LONGLEAF PINE, MIXED PINES
no	Norfolk loamy fine sand

LONGLEAF PINE SAVANNA AND FOREST

LL	LONGLEAF PINE/DRY SAVANNA
an	Alpin fine sand
LL	LONGLEAF PINE/DRY SAVANNA
by	Baymeade sand
LL	LONGLEAF PINE/DRY SAVANNA


ct
SW ma
MP ra
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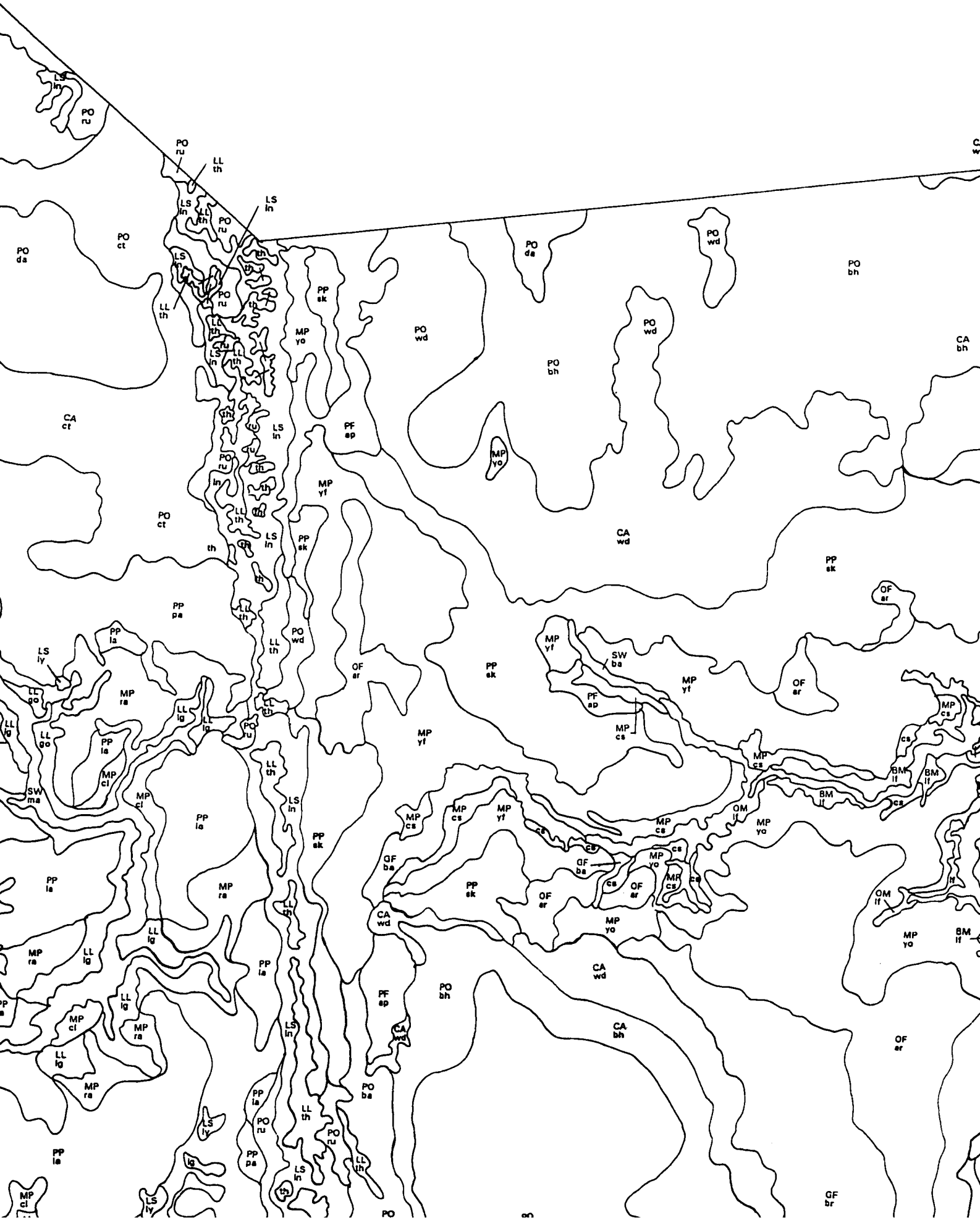
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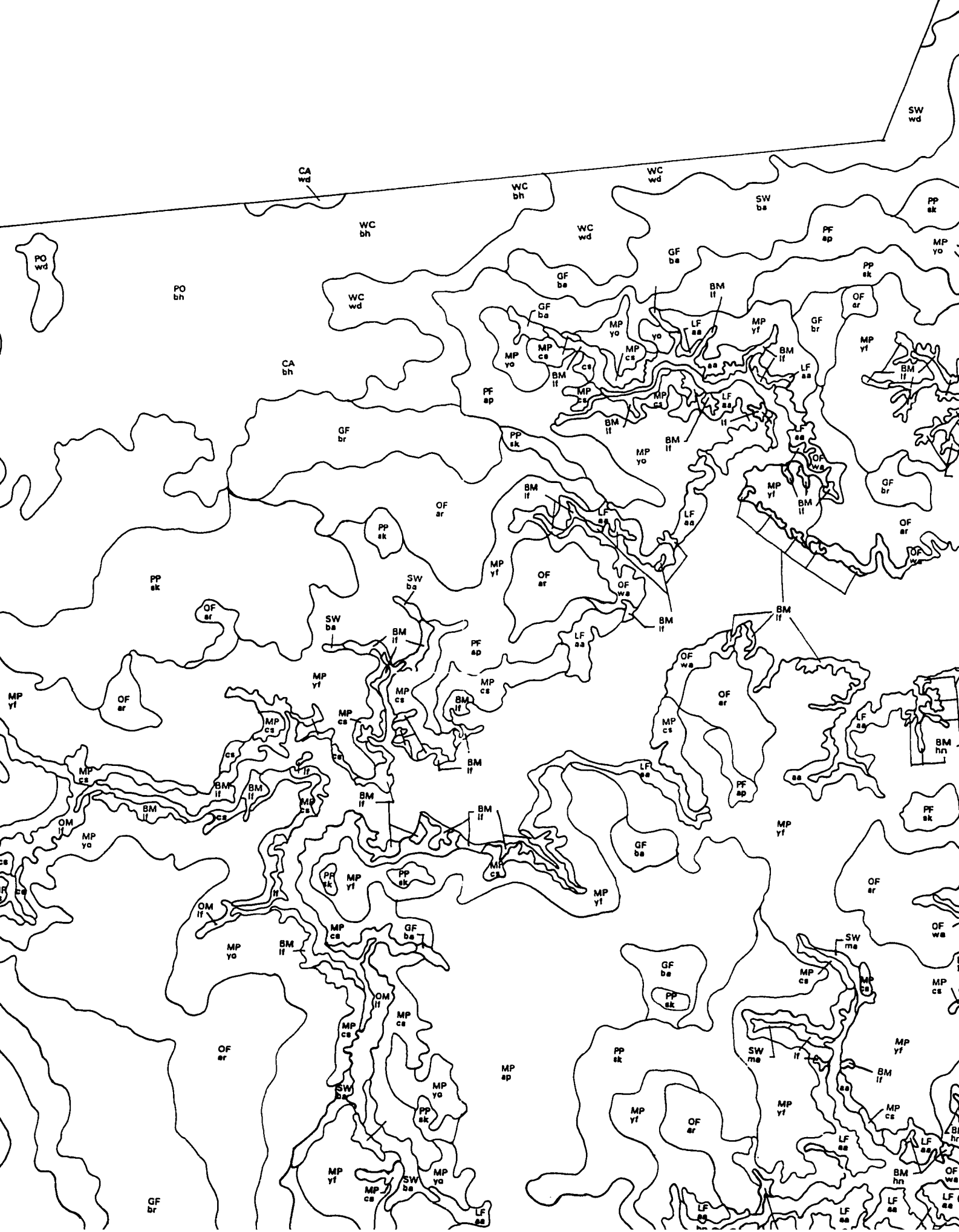
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OF wa
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LF aa
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LF aa
OF ar
OF ar
BM lf

VEG. CODE	PRIMARY VEGETATION
soil code	Soil Series

BRACKISH MARSH, OLIGOHALINE MARSH

BM	OM	BRACKISH MARSH, OLIGOHALINE M.
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lf	lf	Lafitte muck (deep muck)

CANEBRAKE-POND PINE FOREST MOSAIC

CA	CANEBRAKE, PISE-GOLA, HPOC
bh	Belhaven muck
CA	MPOC, HPOC, PISE/CANEBRAKE
ct	Croatan muck
CA	PISE/CANEBRAKE, PISE, HPOC
pa	Paxville mucky fine sandy loam
CA	CANEBRAKE, SWEETGUM, LOBLOLLY
wd	Wasda muck

GUM FLATS

GF	MIXED GUM, POPLAR, CYPRESS
ba	Ballahack fine sandy loam
GF	SWEET GUM-NYSSA-TULIP POPLAR
br	Brookman mucky silt loam

HARDWOOD SLOPES

HS	UPLAND OAKS-HICKORIES-BEECH
dg	Dogue fine sandy loam

LONGLEAF FOREST OR MIXED HARDWOODS ON SOILS FRINGING SOUNDS, SMALL STREAM SWAMPS OR MARSH

LF	LONGLEAF PINE TO OAK-HICKORY-BEECH
aa	Altavista loamy fine sand
LF	LONGLEAF PINE, MIXED PINES
no	Norfolk loamy fine sand

LONGLEAF PINE SAVANNA AND FOREST

LL	LONGLEAF PINE/DRY SAVANNA
an	Alpin fine sand
LL	LONGLEAF PINE/DRY SAVANNA
by	Baymeade sand
LL	LONGLEAF PINE/DRY SAVANNA
cn	Conetoe loamy sand
LL	LONGLEAF PINE/MESIC SAVANNA
cr	Craven loam
LL	LONGLEAF PINE/MESIC SAVANNA
go	Goldsboro loamy fine sand
LL	LONGLEAF PINE/MESIC SAVANNA
ly	Lynchburg fine sandy loam
LL	LONGLEAF PINE/MESIC SAVANNA
lg	Lynchburg + Goldsboro
LL	LONGLEAF PINE/MESIC SAVANNA
th	Tomahawk loamy sand

WET LONGLEAF PINE SAVANNA

LS	LONGLEAF PINE/WET SAVANNA HERBS
ln	Leon sand

MIXED PINE SAVANNA AND FOREST

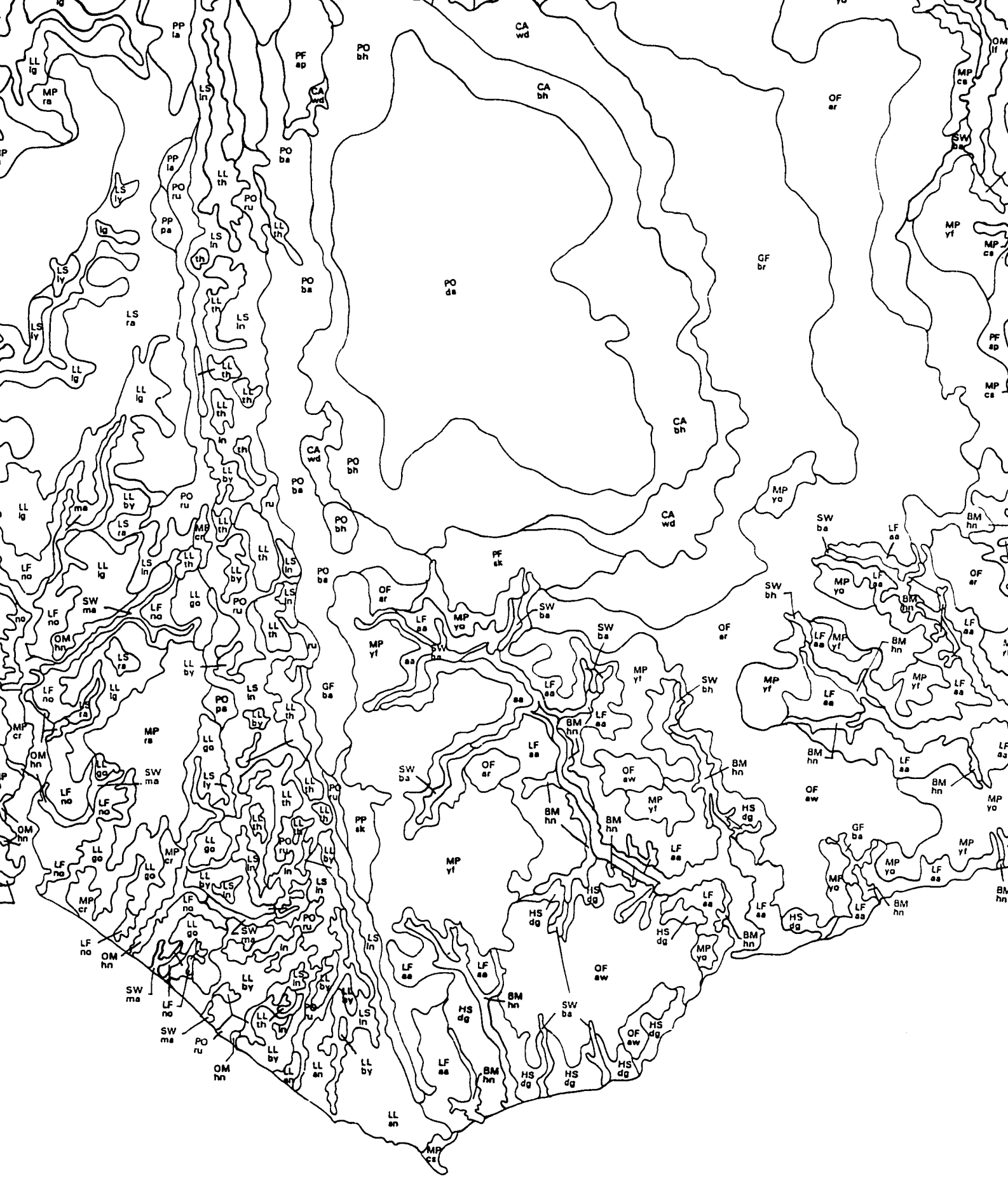
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
ap	Arapahoe loamy fine sand
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
cl	Craven loam + Lenoir silt loam
MP	MIXED LONGLEAF-LOBLOLLY
cs	Charleston loamy fine sand
MP	MIXED LOBLOLLY-POND P., HARDWOODS
fo	Fork loamy fine sand
MP	LONGLEAF, MIXED LONG.-POND P.-LOB.
ra	Rains fine sandy loam
MP	LONGLEAF, MIXED LONGLEAF & POND P.
yo	Yonges loamy fine sand
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
yf	Yonges + Fork (merged)

OAK FLATS

OF	QUERCUS PAGODA-Q. MICHAUXII
ar	Argent loam
OF	MIXED OAK FLAT HARDWOODS
aw	Argent + Wahee (merged)
OF	MIXED OAKS-HICKORY-BEECH
wa	Wahee fine sandy loam

WET PINE FLATS, ESTUARINE PINE MARSH

PF	POND PINE, LOBLOLLY & MIXURES
ap	Arapahoe loamy fine sand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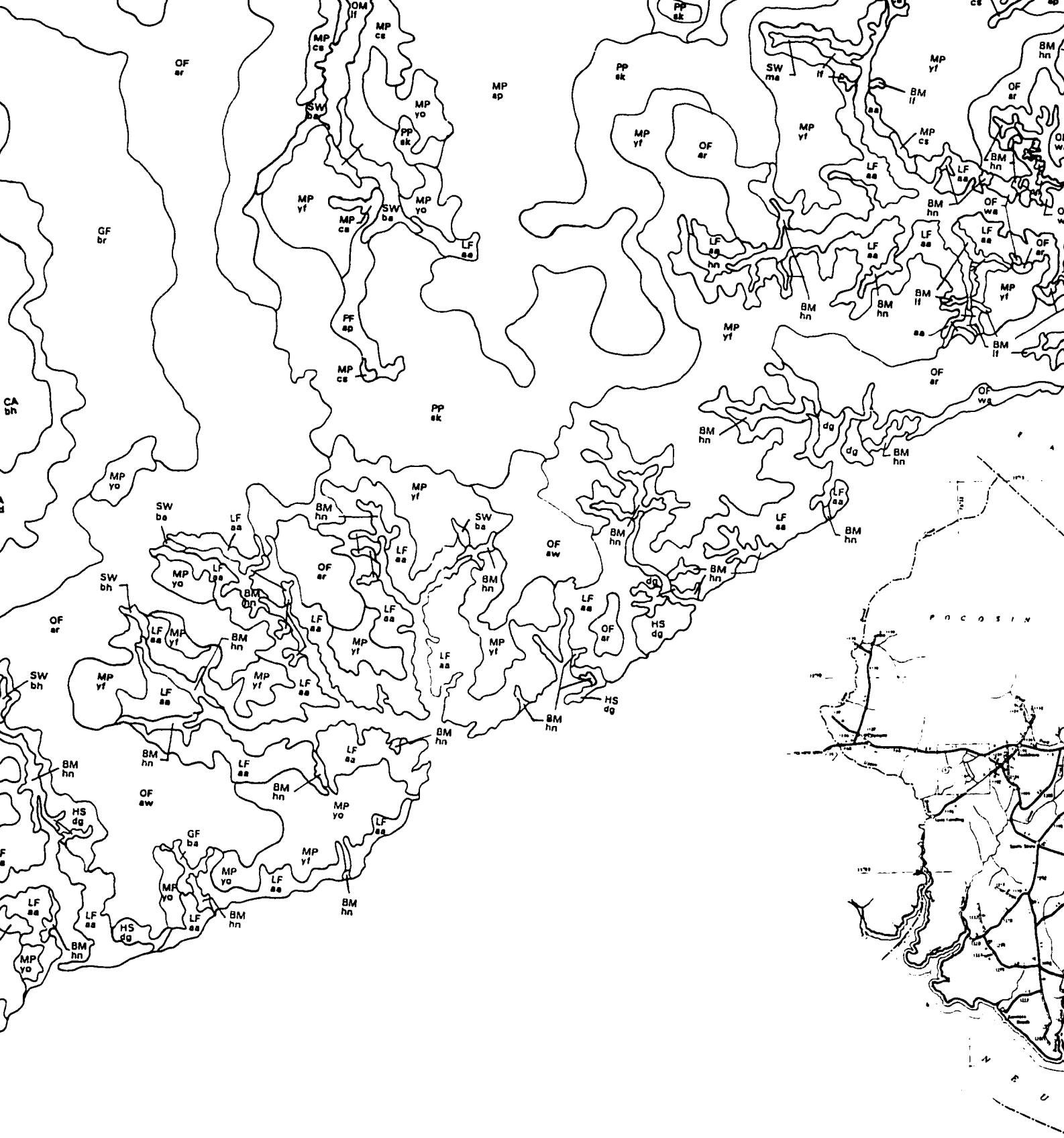
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dg
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B A Y C I T Y
P O C O S I N
HOLLYVILLE
VANDEMERE
BAYBORO
STONEWALL
ALLIANCE
L I G H T
G R O U N D
P O C O S I N
ARAPAHOE
ORIENTAL
MINNESOTT BEACH
N E U S E
R I V E R

ra		Rains fine sandy loam
MP		LONGLEAF, MIXED LONGLEAF & POND P.
yo		Yonges loamy fine sand
[illegible]P		MIXED LONGLEAF-POND PINE-LOBLOLLY
yf		Yonges + Fork (merged)

OAK FLATS

OF		QUERCUS PAGODA-Q. MICHAUXII
ar		Argent loam
OF		MIXED OAK FLAT HARDWOODS
aw		Argent + Wahee (merged)
OF		MIXED OAKS-HICKORY-BEECH
wa		Wahee fine sandy loam

WET PINE FLATS, ESTUARINE PINE MARSH

PF		POND PINE, LOBLOLLY & MIXURES
ap		Arapahoe loamy fine sand
PF	PM	LOBLOLLY PINE
sk	sk	Stockade loamy fine sand
PF		LOBLOLLY PINE, POND PINE
wd		Wasda muck

POND PINE/POCOSIN

PO		POND PINE-GORDONIA/MPOC,HPOC
bh		Belhaven muck
PO		MPOC, POND PINE/CANEBRAKE
ct		Croatan muck
PO		LPOC, MPOC
da		Dare muck
PO		POND PINE/MPOC-HPOC, PISE/CANE
pa		Paxville mucky fine sandy loam
PO		LPOC & OPEN BOG, MPOC
ru		Rutlege mucky loamy fine sand
PO		POND PINE-GORDONIA/MPOC,HPOC
wd		Wasda muck

POND PINE FOREST AND SAVANNA

PP		POND PINE
la		Leaf silt loam
PP		POND PINE, POCOSIN, CANEBRAKE
pa		Paxville mucky fine sandy loam
PP		POND PINE
sk		Stockade loamy fine sand

SWAMP FOREST

SW		BALDCYPRESS, SWAMP HARDWOODS
ba		Ballahack fine sandy loam
SW		BALDCYPRESS, NYSSA, FRAXINUS
ma		Masontown loam
SW		BALDCYPRESS
wd		Wasda muck

ATLANTIC WHITE CEDAR

WC		ATLANTIC WHITE CEDAR
bh		Belhaven muck
WC		ATLANTIC WHITE CEDAR
wd		Wasda muck

Abbreviations:
LPOC - Low Pocosin
MPOC - Medium Pocosin
HPOC - High pocosin
GOLA - *Gordonia lasianthus* (loblolly bay)
PISE - *Pinus serotina* (pond pine)


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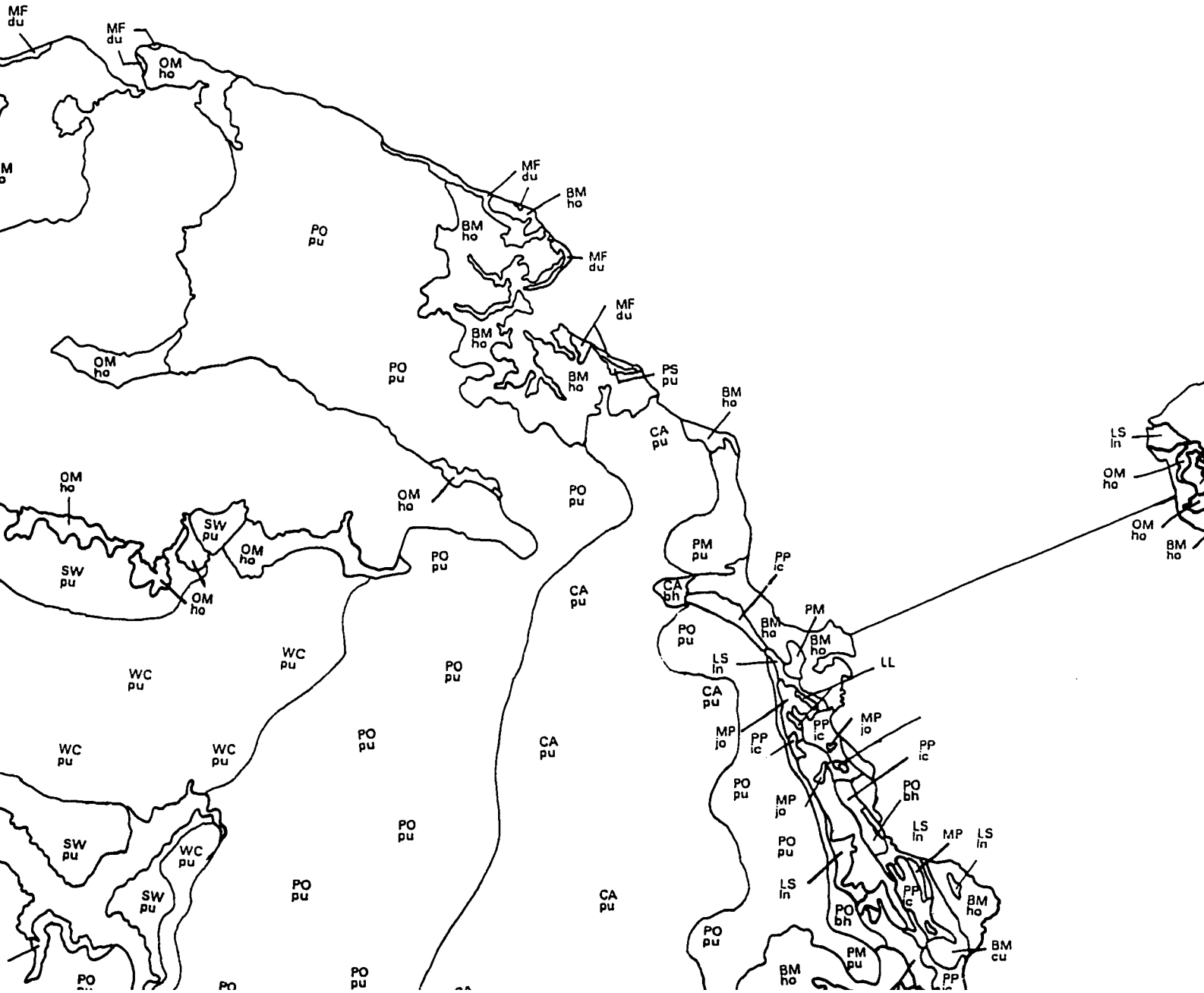
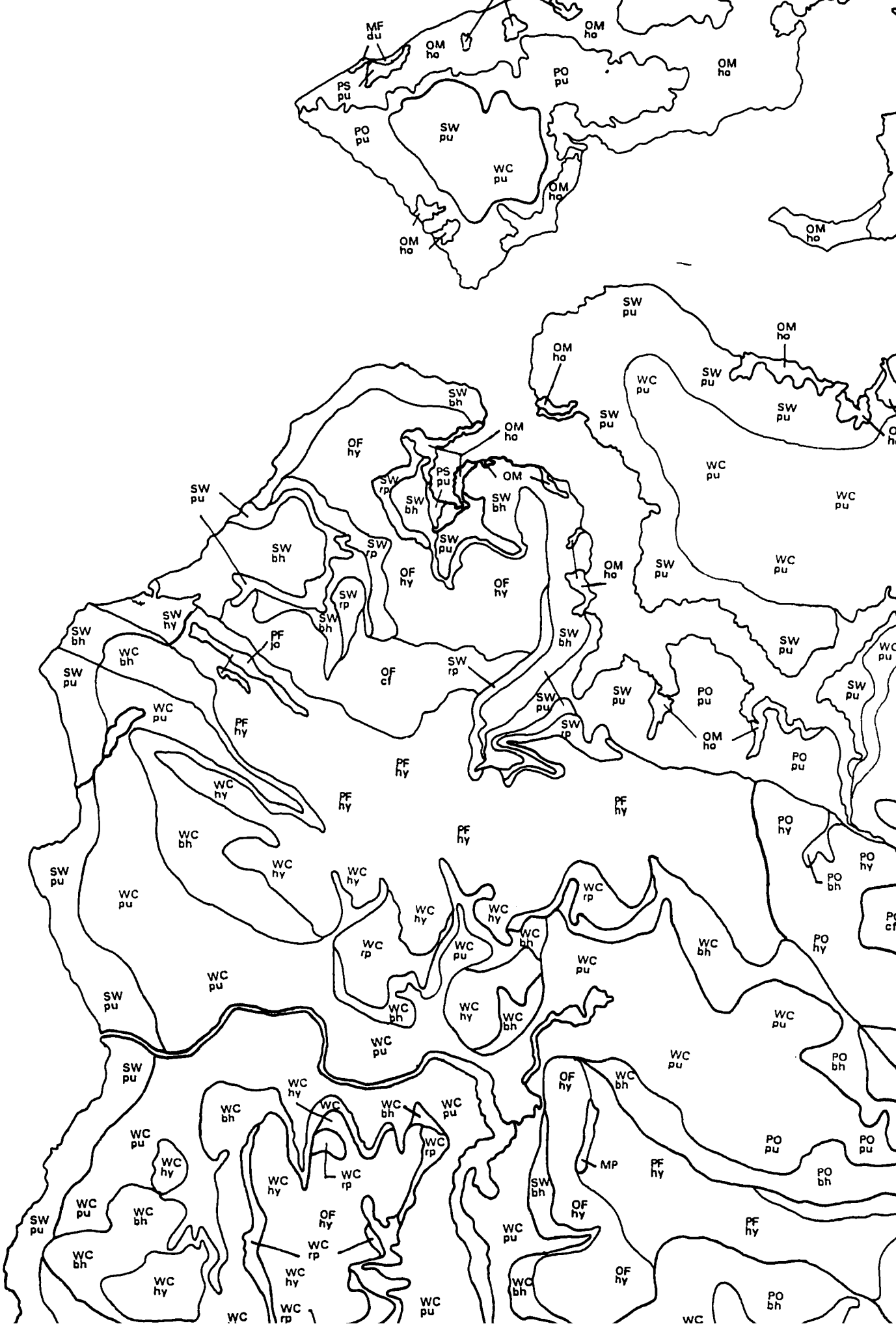


RESETTLEMENT VEGETATION OF ROANOKE ISLAND AND MAINLAND DARE COUNTY

2000

Cecil Frost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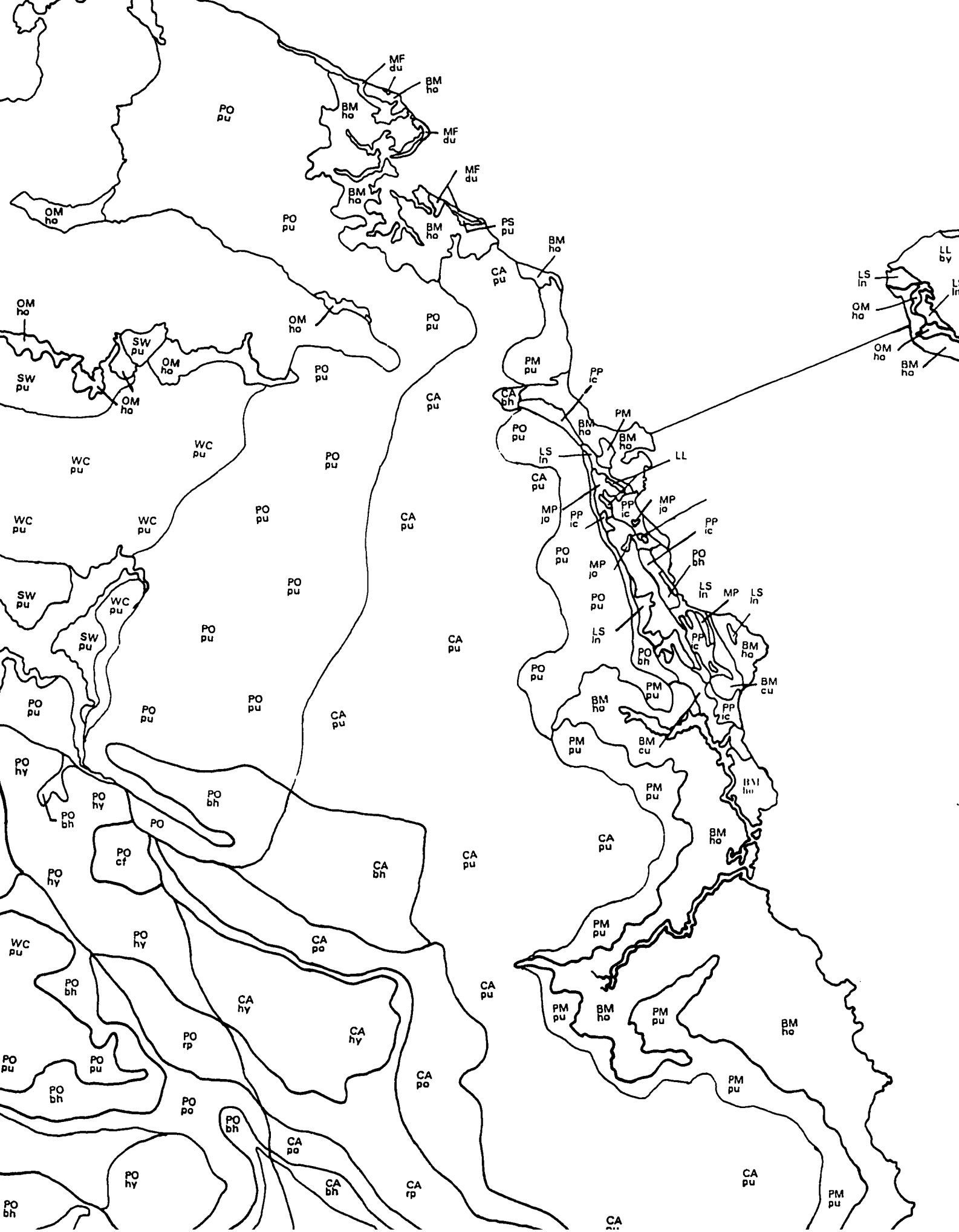
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Cech Frost


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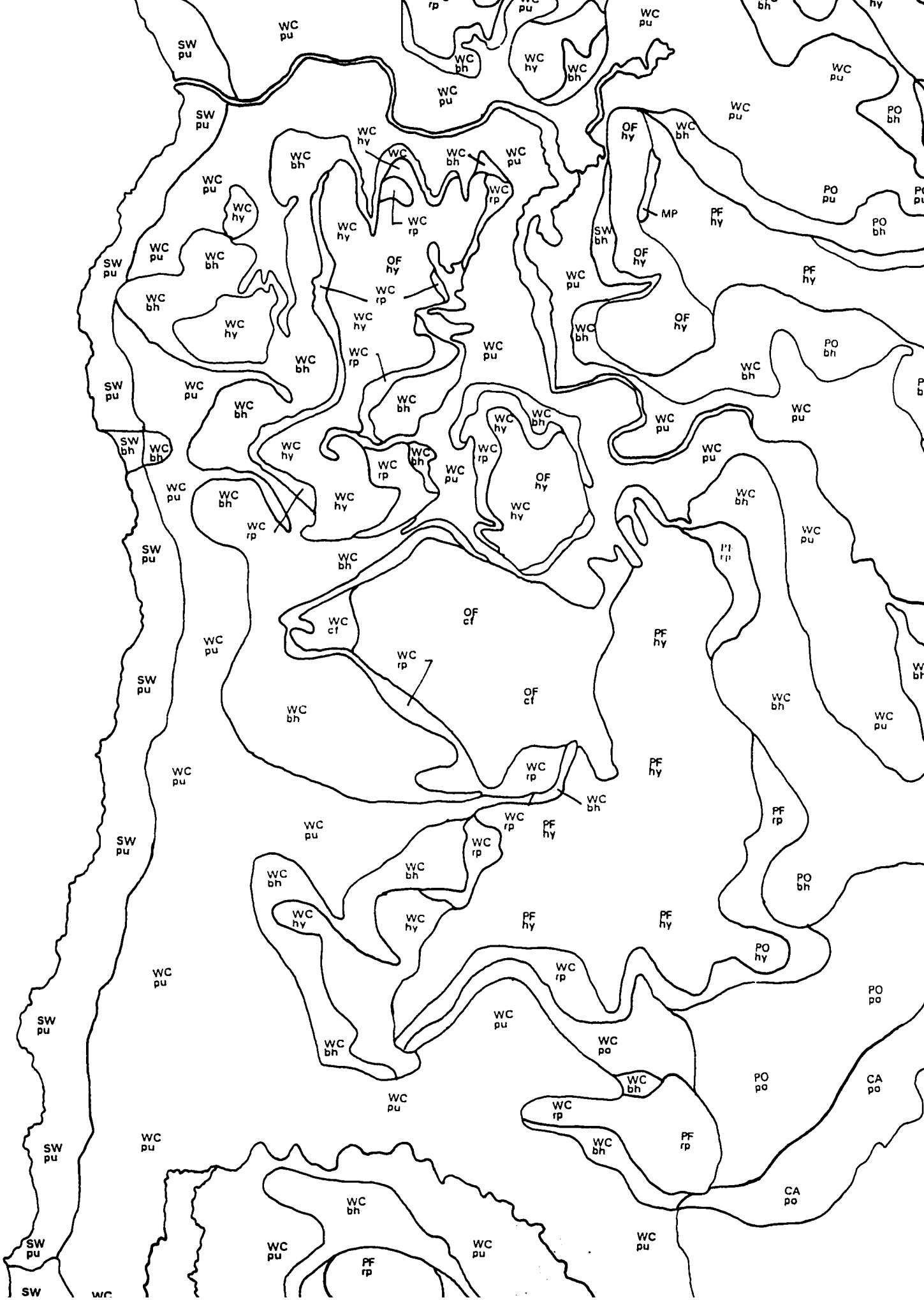
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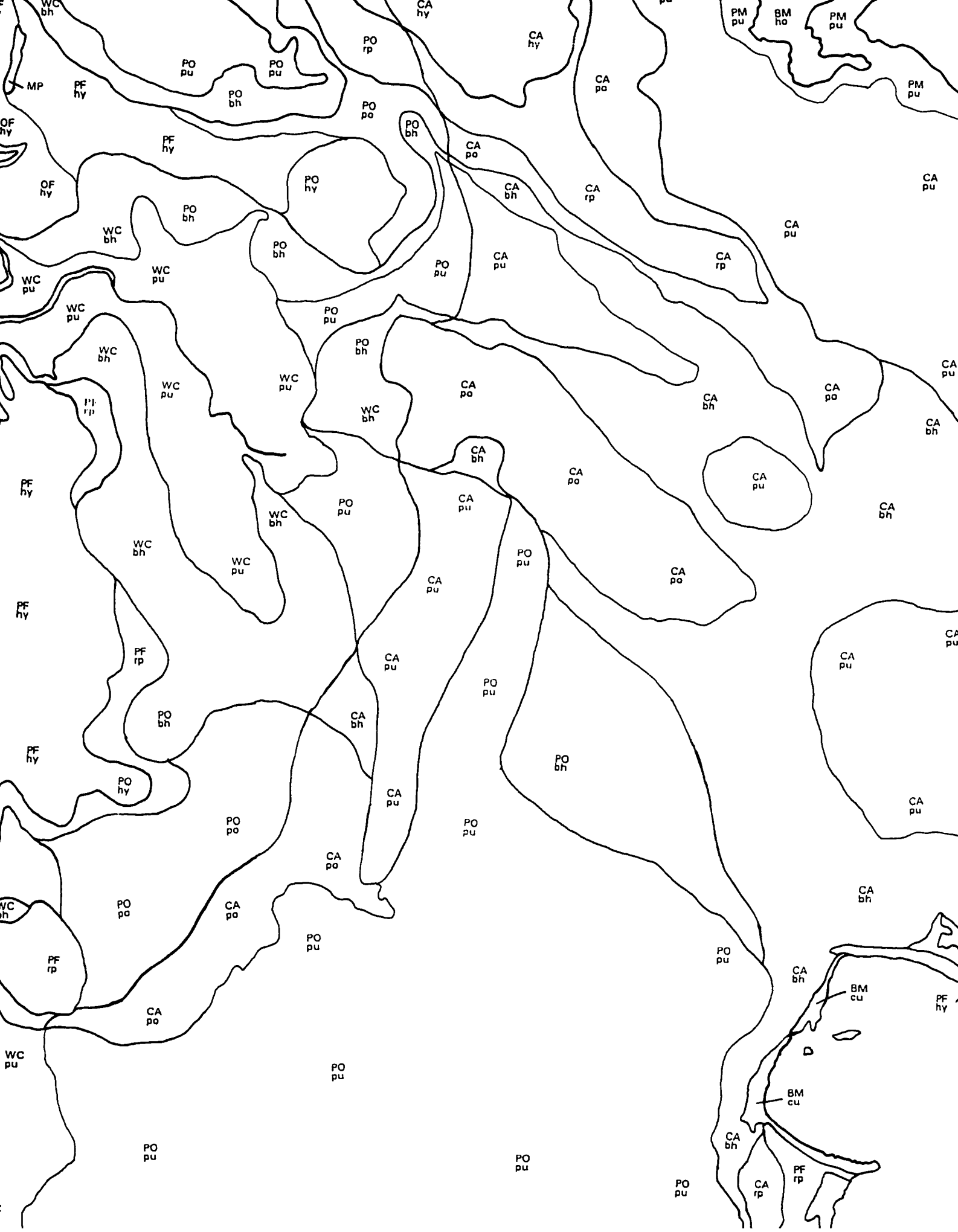
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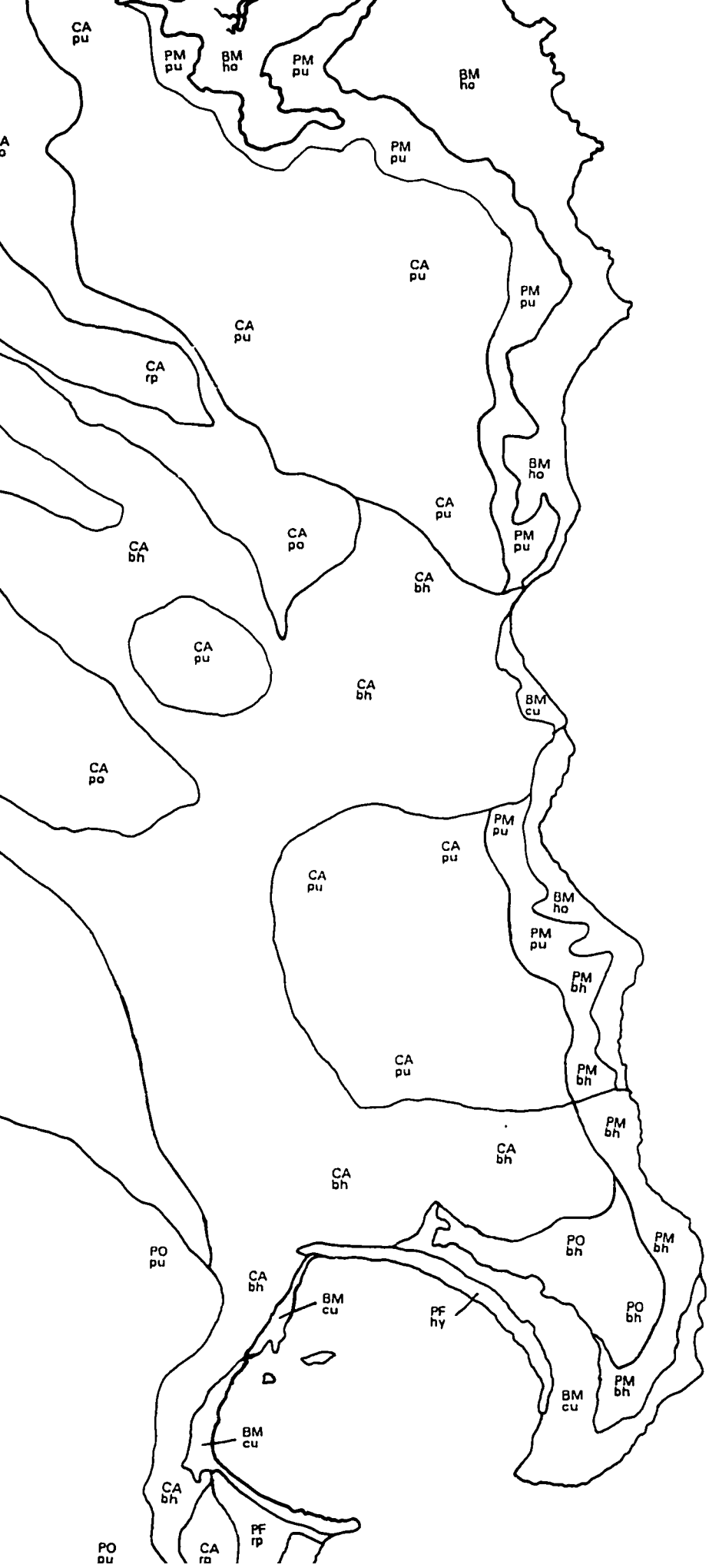
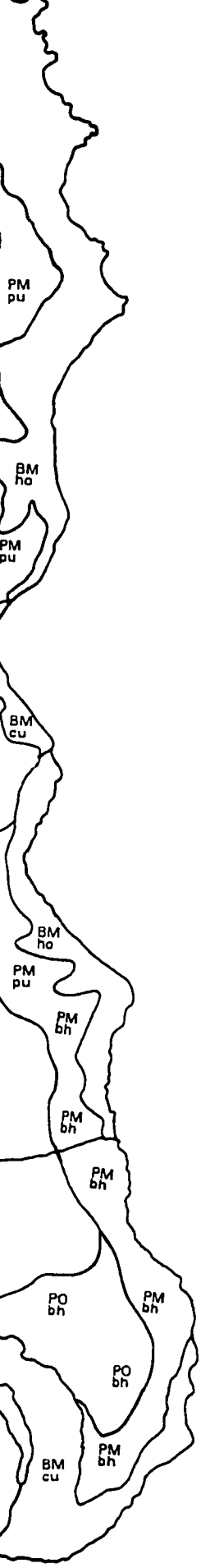
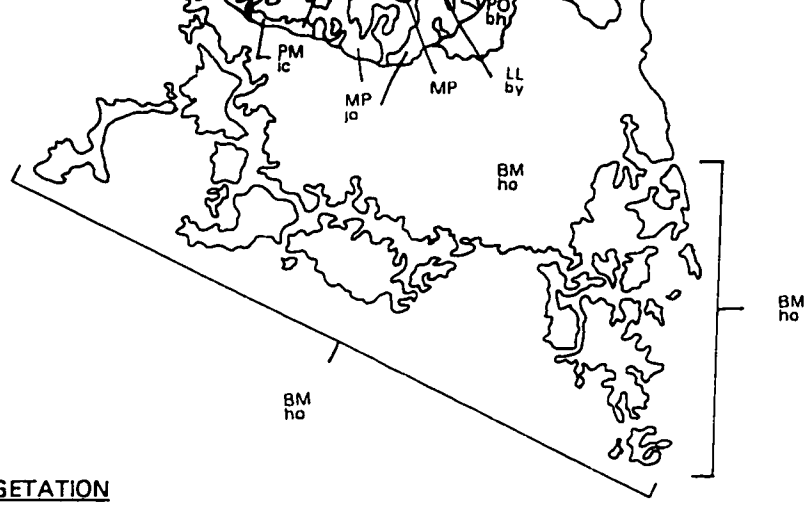


VEG. CODE		PRIMARY VEGETATION
soil code		Soil Series
BRACKISH MARSH, OLIGOHALINE MARSH		
BM	OM	BRACKISH MARSH, OLIGOHA
cu	cu	Currituck muck (shallow muck
BM	OM	BRACKISH MARSH, OLIGOHA
ho	cu	Hobonny muck (deep muck)
CANEBRAKE-POND PINE FOREST MOSAIC		
CA		CANEBRAKE-POND PINE FOR
bh		Belhaven muck
CA		CANEBRAKE-POND PINE FOR
hy		Hyde loam
CA		CANEBRAKE-POND PINE FOR
po		Ponzer muck
CA		CANEBRAKE-POND PINE FOR
pu		Pungo muck
CA		CANEBRAKE-POND PINE FOR
rp		Roper muck
LONGLEAF PINE FOREST AND SAVANNA		
LL		LONGLEAF PINE/DRY SAVAN
by		Baymeade sand
WET LONGLEAF PINE FOREST AND SAVANNA		
LS		LONGLEAF PINE/WET SAVAN
ln		Leon sand
MARITIME FOREST AND SAND BERM		
MF		LOBLOLLY PINE, LIVE OAK, Y
du		Dunes and sand berms: woode
		shrubby, or sparsely vegetated
PYROPHYTIC MIXED PINE FOREST AND SAVA		
MP		MIXED LONGLEAF, POND PIN
jo		Johns loamy sand
OAK FLATS		
OF		SWAMP CHESTNUT OAK, WA
cf		Cape fear loam
OF		SWAMP CHESTNUT OAK, WA
hy		Hyde loam
PINE FLATS and GUM FLATS		
PF		LOBLOLLY PINE, SWEETGUM
hy		Hyde loam
PF		LOBLOLLY PINE, SWEETGUM
jo		Johns loamy sand
POND PINE/POCOSIN		
PO		POND PINE/LPOC, MPOC, HP
bh		Belhaven muck





VEG. CODE	PRIMARY VEGETATION
soil code	Soil Series

BRACKISH MARSH, OLIGOHALINE MARSH

BM	OM	BRACKISH MARSH, OLIGOHALINE MARSH
cu	cu	Currituck muck (shallow muck)
BM	OM	BRACKISH MARSH, OLIGOHALINE MARSH
ho	cu	Hobonny muck (deep muck)

CANEBRAKE-POND PINE FOREST MOSAIC

CA	CANEBRAKE-POND PINE FOREST
bh	Belhaven muck
CA	CANEBRAKE-POND PINE FOREST
hy	Hyde loam
CA	CANEBRAKE-POND PINE FOREST
po	Ponzer muck
CA	CANEBRAKE-POND PINE FOREST
pu	Pungo muck
CA	CANEBRAKE-POND PINE FOREST
rp	Roper muck

LONGLEAF PINE FOREST AND SAVANNA

LL	LONGLEAF PINE/DRY SAVANNA HERBS
by	Baymeade sand

WET LONGLEAF PINE FOREST AND SAVANNA

LS	LONGLEAF PINE/WET SAVANNA HERBS
ln	Leon sand

MARITIME FOREST AND SAND BERM

MF	LOBLOLLY PINE, LIVE OAK, YAUPON
du	Dunes and sand berms: wooded, shrubby, or sparsely vegetated

PYROPHYTIC MIXED PINE FOREST AND SAVANNA

MP	MIXED LONGLEAF, POND PINE, LOBLOLLY
jo	Johns loamy sand

OAK FLATS

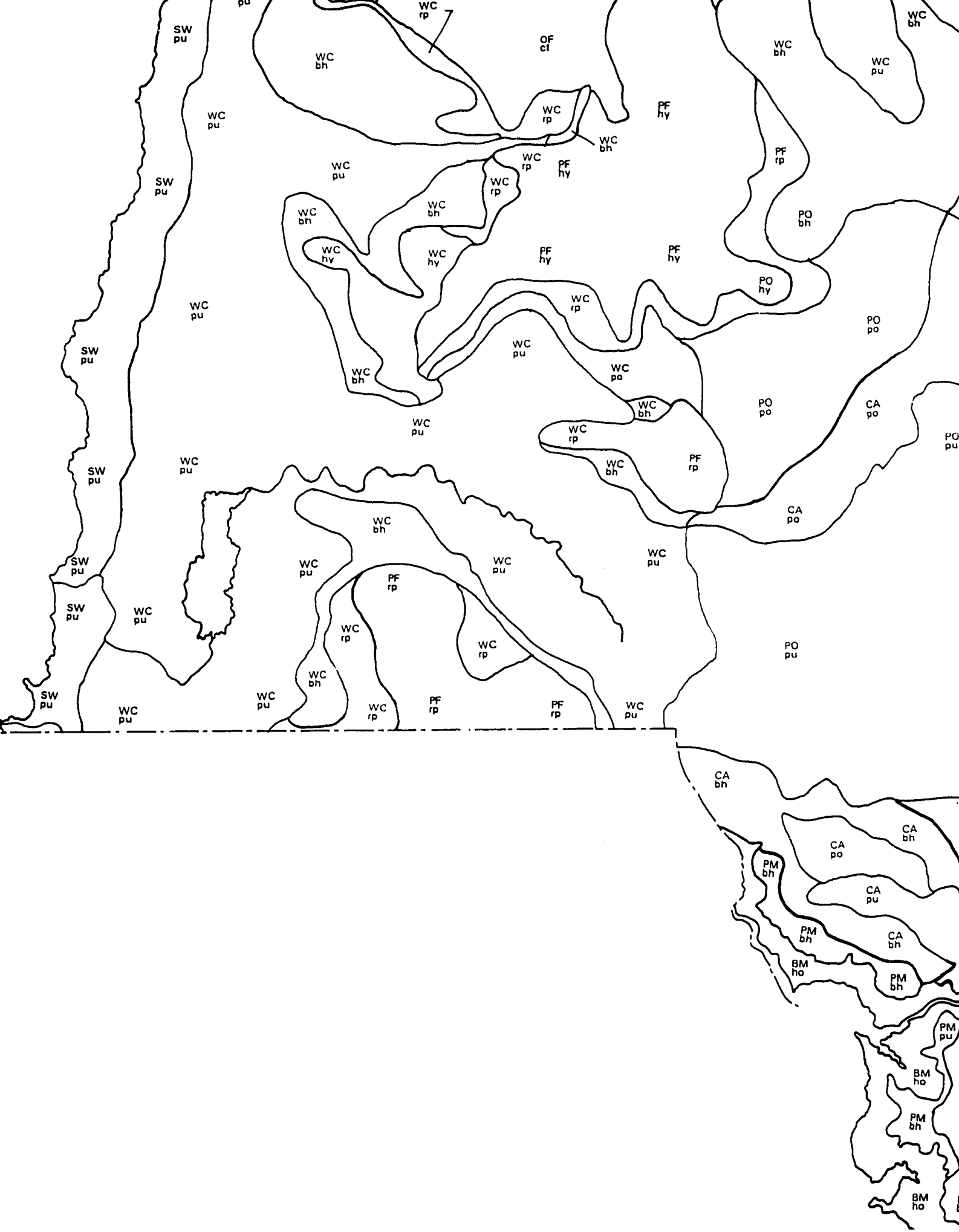
OF	SWAMP CHESTNUT OAK, WATER OAK, BEECH
cf	Cape fear loam
OF	SWAMP CHESTNUT OAK, WATER OAK, BEECH
hy	Hyde loam

PINE FLATS and GUM FLATS

PF	LOBLOLLY PINE, SWEETGUM
hy	Hyde loam
PF	LOBLOLLY PINE, SWEETGUM
jo	Johns loamy sand

POND PINE/POCOSIN

PO	POND PINE/LPOC, MPOC, HPOC
bh	Belhaven muck
PO	POND PINE/MPOC, HPOC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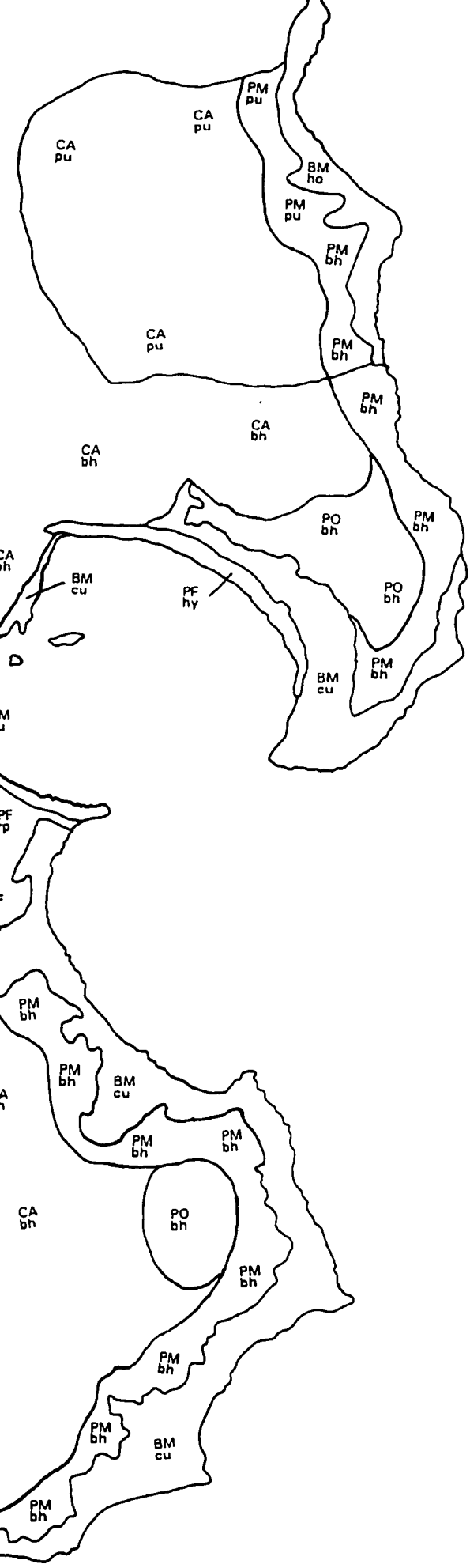

po Ponzer muck
CA CANEBRAKE-POND PINE FOREST
pu Pungo muck
CA CANEBRAKE-POND PINE FOREST
rp Roper muck

LONGLEAF PINE FOREST AND SAVANNA
LL LONGLEAF PINE/DRY SAVANNA HERBS
by Baymeade sand

WET LONGLEAF PINE FOREST AND SAVANNA
LS LONGLEAF PINE/WET SAVANNA HERBS
ln Leon sand

MARITIME FOREST AND SAND BERM
MF LOBLOLLY PINE, LIVE OAK, YAUPON
du Dunes and sand berms: wooded, shrubby, or sparsely vegetated

PYROPHYTIC MIXED PINE FOREST AND SAVANNA
MP MIXED LONGLEAF, POND PINE, LOBLOLLY
jo Johns loamy sand

OAK FLATS
OF SWAMP CHESTNUT OAK, WATER OAK, BEECH
cf Cape fear loam
OF SWAMP CHESTNUT OAK, WATER OAK, BEECH
hy Hyde loam

PINE FLATS and GUM FLATS
PF LOBLOLLY PINE, SWEETGUM
hy Hyde loam
PF LOBLOLLY PINE, SWEETGUM
jo Johns loamy sand

POND PINE/POCOSIN
PO POND PINE/LPOC, MPOC, HPOC
bh Belhaven muck
PO POND PINE/MPOC, HPOC
cf Cape Fear loam
PO POND PINE/MPOC, HPOC
hy Hyde loam
PO POND PINE/MPOC, HPOC
po Ponzer muck
PO POND PINE-GORDONIA/LPOC, MPOC, HPOC
pu Pungo muck
PO POND PINE/MPOC, HPOC
rp Roper muck

POND PINE FOREST AND WET SAVANNA
PP POND PINE & POND PINE/CANE
ic Icaria loamy fine sand

ESTUARINE PINE MARSH, PINE SWAMP
PS PM LOBLOLLY PINE, POND PINE
bh bh Belhaven muck
PM LOBLOLLY PINE, POND PINE
ic Icaria loamy fine sand
PS PM LOBLOLLY PINE, POND PINE
pu pu Pungo muck
PS PM LOBLOLLY PINE, POND PINE
rp rp Roper muck

SWAMP FOREST
SW BALDCYPRESS, POND CYPRESS, NYSSA BIFLORA
bh Belhaven muck
SW NYSSA BIFLORA, RED MAPLE, BOTTOMLAND OAKS
cf Cape Fear loam
SW NYSSA BIFLORA, RED MAPLE, LOBLOLLY PINE
hy Hyde loam
SW BALDCYPRESS, NYSSA BIFLORA, RED MAPLE
pu Pungo muck


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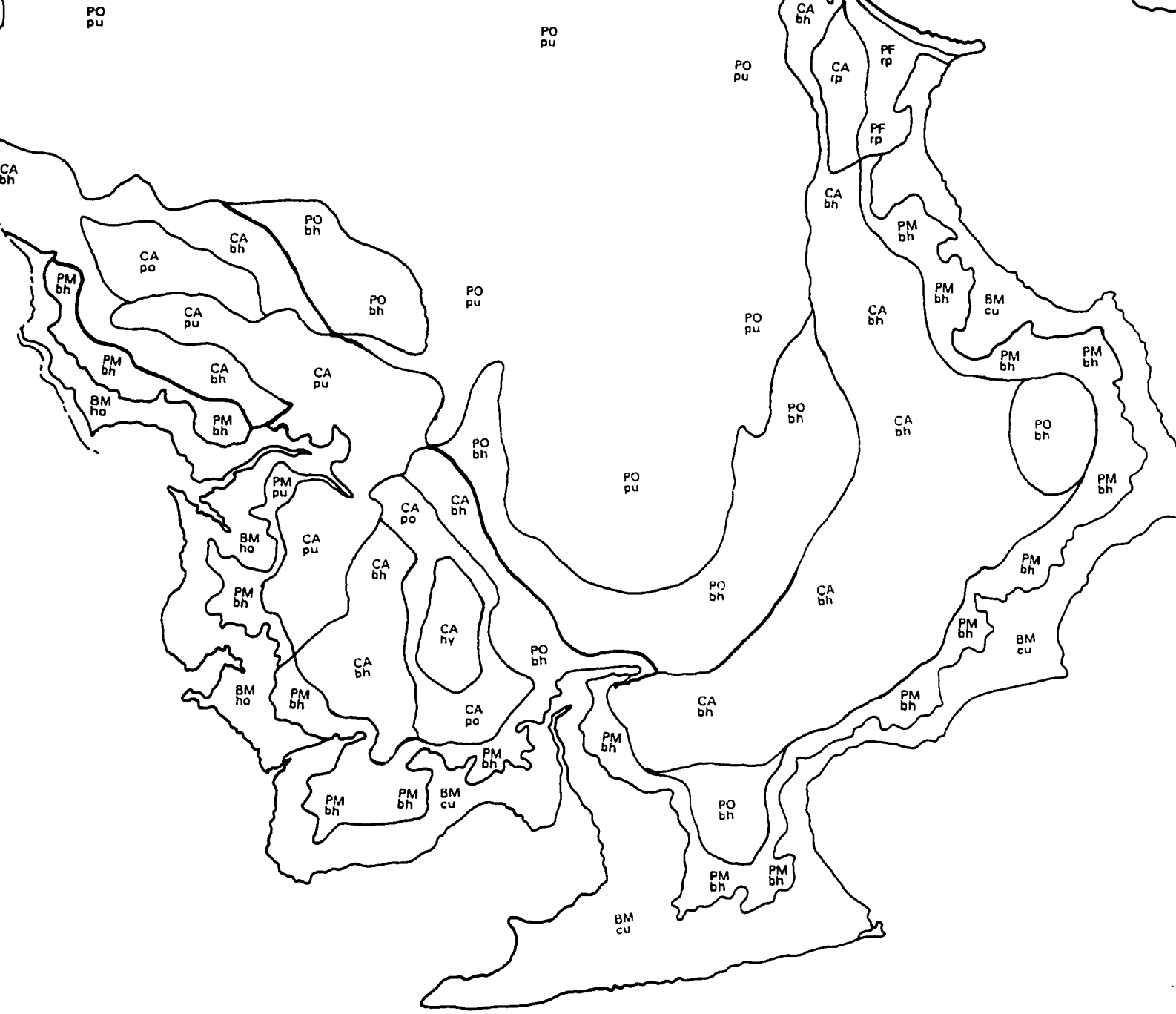
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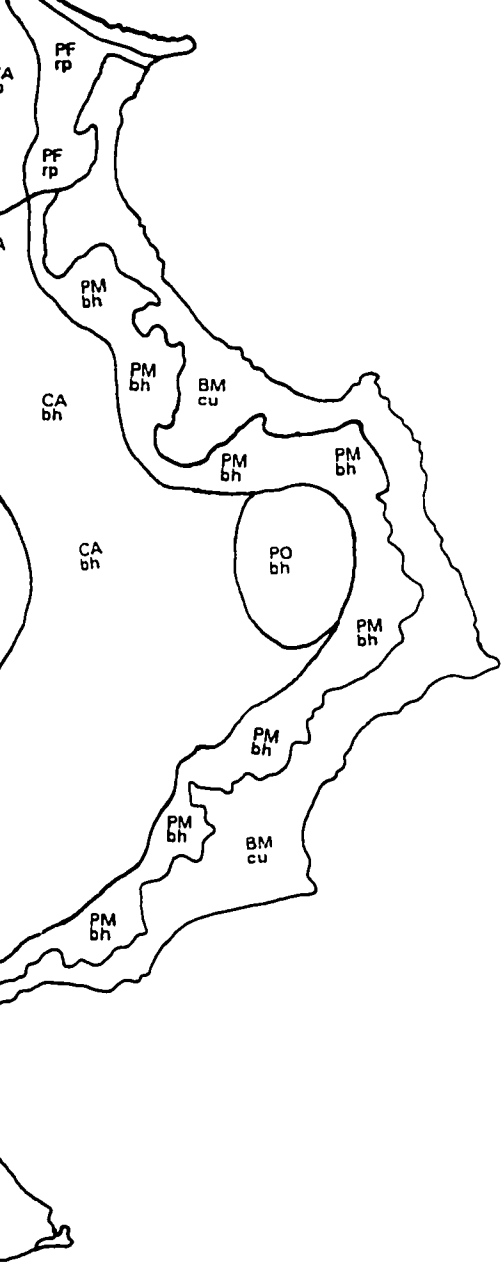

POND PINE/POCOSIN

PO	POND PINE/LPOC, MPOC, HPOC
bh	Belhaven muck
PO	POND PINE/MPOC, HPOC
cf	Cape Fear loam
PO	POND PINE/MPOC, HPOC
hy	Hyde loam
PO	POND PINE/MPOC, HPOC
po	Ponzer muck
PO	POND PINE-GORDONIA/LPOC, MPOC, HPOC
pu	Pungo muck
PO	POND PINE/MPOC, HPOC
rp	Roper muck

POND PINE FOREST AND WET SAVANNA

PP	POND PINE & POND PINE/CANE
ic	Icaria loamy fine sand

ESTUARINE PINE MARSH, PINE SWAMP

PS PM	LOBLOLLY PINE, POND PINE
bh bh	Belhaven muck
PM	LOBLOLLY PINE, POND PINE
ic	Icaria loamy fine sand
PS PM	LOBLOLLY PINE, POND PINE
pu pu	Pungo muck
PS PM	LOBLOLLY PINE, POND PINE
rp rp	Roper muck

SWAMP FOREST

SW	BALDCYPRESS, POND CYPRESS, NYSSA BIFLORA
bh	Belhaven muck
SW	NYSSA BIFLORA, RED MAPLE, BOTTOMLAND OAKS
cf	Cape Fear loam
SW	NYSSA BIFLORA, RED MAPLE, LOBLOLLY PINE
hy	Hyde loam
SW	BALDCYPRESS, NYSSA BIFLORA, RED MAPLE
pu	Pungo muck
SW	NYSSA BIFLORA, RED MAPLE, BAY FOREST
rp	Roper muck

ATLANTIC WHITE CEDAR PATCH MOSAIC

WC	WHITE CEDAR
bh	Belhaven muck
WC	WHITE CEDAR
cf	Cape Fear loam
WC	WHITE CEDAR
hy	Hyde loam
WC	WHITE CEDAR
rp	Roper muck
WC	WHITE CEDAR
pu	Pungo muck

Abbreviations:
LPOC - Low Pocosin
MPOC - Medium Pocosin
HPOC - High pocosin

CASE STUDY 1

PRESETTLEMENT VEGETATION OF PAMLICO COUNTY

On the way to nowhere, on its peninsula between the Pamlico and Neuse River estuaries, Pamlico County has been bypassed by development. By 1880 only 10% of its land area had been domesticated (Hale 1883). The county is still sparsely populated; over half the land area is pocosin and marsh, and low wet pine flats make up much of the eastern third of the county. Pamlico was exemplary for a pilot study for three reasons. First, it occurs at the retreating interface between natural fire vegetation to the south, and lands to the north from which most fire-dependent species have already been extirpated. Second, it has a few representative examples of almost all of the original natural plant communities on each of the soils of the county, facilitating reconstruction of presettlement vegetation using the county soil map as a base. Third, there is a continuum of natural vegetation along the entire moisture gradient from dry sands to wet sea level flats and marsh, including the best remnant lowland communities of the region.[1]

The county is divided into two physiographic provinces by the sandy Minnesott Ridge, a segment of the Suffolk Scarp which marks a late shoreline of the Atlantic Ocean near the end of the Sangamon Interglacial some 40,000 years ago. Geologically, the whole eastern half of the county is only this old, with surficial sediments deposited in lagoons and marshes by the

[1] The lowlands are extensive wet, mineral soil flats, lying nearly at sea level, well-exemplified on the Lowlands Peninsula in the northeastern corner of the county.

retreating sea at the start of the Wisconsin Glacial epoch. Across the scarp to the west is the broad Northwest Pocosin, occupying the entire northwest quadrant, while in the southwest quarter near New Bern are found the former longleaf pine uplands--the only well-drained part of the county--long settled and farmed. Along the scarp itself are remnant longleaf pine savannas and a few species like Venus' flytrap and the endangered Lysimachia asperulifolia (rough-leaf loosestrife), both indicators of a high fire frequency in the past. To the east of the scarp, the whole center of the county is occupied by Light Ground Pocosin and the southern fringe of Bay City Pocosin and Gum Swamp, great peatlands which are just now being carved up and drained. The southeastern fringe of the county along the Pamlico River presents a shoreline elevated a few feet above sea level, formerly covered with pyrophytic pine woodlands, oak flats and even some beech forest in the most fire-protected sites. The northeastern quarter, where the Pamlico River opens into Pamlico Sound, features the Goose Creek Game Lands and the nearly uninhabited Lowland-Hobucken peninsula, including extensive marshes and perhaps the best examples anywhere of pyrophytic loblolly pine marsh, a community type heretofore undescribed. This area lies just across Goose Creek[2] near the eastern fringes of the former Beecham Savanna in Beaufort Co., described by a retired forester as a large open, moist wiregrass savanna with scattered pines. Some hint of its original flora may be found along roadsides in the Goose Creek Game Land on the Beaufort side of the creek, where there are small wet savanna remnants with pitcher plants (Sarracenia flava and S. purpurea), sundews, and Pinguicula caerulea (butterwort), here at the northern extremity of its range.

PRESETTLEMENT VEGETATION MAPPING USING THE SITE FIRE HISTORY APPROACH

[2] Not to be confused with the Goose Creek on the north side of the Pamlico River in Beaufort County or the Goose Creek on the south side of the county, which drains into the Neuse, or the seven other Goose Creeks in the state.

The method included identifying remnant natural vegetation, especially on those sites that were still maintained by fire, on every soil series in the county. Five major steps led to production of the final map (enclosed). Historical information was reserved until after completion of a first approximation version of the vegetation map, in order to have a way to assess the accuracy of estimating original vegetation simply by mapping what appeared to be natural remnants and making adjustments based on site fire history. Insights gained in pilot studies here and at Dare County led to development of the more involved landscape fire ecology method applied later at the Savannah River Site.

1. Approximating presettlement community types. Over a 10 year period I sampled 93 examples of natural vegetation in the county both by land and by boat. Tenth hectare plots were used in 15 plant communities and a less intensive sampling method in 78 others, for a total of 93 plots; numerous other areas were examined informally. Soil maps on aerial photos were used to locate remnant natural vegetation on all of the soils of the county. Complete species lists were compiled for each soil series at each site examined. Dominant plant species were recorded by stratum and a variety of fire history information was taken. Trees were cored and shrubs were examined to determine time since last fire. Successional trends under fire suppression were observed on each soil series here and in other counties, and extrapolated into the past to get an estimation of previous vegetation. A first approximation species list and description of presettlement plant communities was prepared for each soil series.

2. First approximation vegetation map. As tentative or predicted presettlement community types were built up for each soil series during field work, additional sites were visited to test the predictions, and the community descriptions were periodically refined as needed. A preliminary map was then constructed using all of the 32 soil series of the county and vegetation types were assigned to each series. Another round of field work was then required to provide answers to unresolved questions. In particular, it became obvious that in the large peatlands there was often

more than one community type on the same soil series, and it was necessary to visit and document each of these.

3. Second approximation vegetation map. With these questions addressed, revised vegetation descriptions were prepared for each soil series. These were not descriptions of existing vegetation but were refined estimates of presettlement vegetation. Many kinds of evidence were weighed, including remnant fire-frequency indicator species, and fire-frequency indicator communities like canebrake, which was once extensive in the county[3]. For example, a number of areas were found around the perimeter of Light Ground Pocosin with no living cane but having mats of dead cane stems on the ground beneath young, successional red maple or loblolly pine forest. Successional status of each site under fire suppression was considered, as was evidence from tree cores, including fire scars and evidence of cyclic wildfires from fire-scarred baldcypress up to 600-700 years old found near the Goose Creek Game Land. Decisions were also influenced by evidence from remnant fire communities on the same soil series in nearby counties.

4. Accuracy testing with historical records. In order to have some test of the accuracy of presettlement vegetation mapping by field methods alone, no historical records were used up to this point. For both Pamlico and Dare counties, all such records were reserved for accuracy testing as discussed below. For more practical mapping it would make sense to skip this step and use all available historical information from the start to help interpret vegetation remnants.

5. Final vegetation map. Plotting historical records on the map and making adjustments to mapping units based on the additional historical information produced the final map. Remarkably, only two substantial changes were required after examining the historical record. Both were in the Gum Swamp peatland lying between the Bay River and northern boundary of

[3] See paired plots discussed under peatlands above.

Pamlico County. The second approximation map failed to recognize the amount of peatland cypress here. While an old growth pyrophytic cypress stand was examined in this area during field work, the extent of the historical stand was a surprise. Ashe (1894) reported cypress dominant on 2,800 ha (7,000 a) or essentially all of the Wasda and Ballahack soils from just east of Vandemere, northeast to the Goose Creek Game Land. These were not fluvial bottomlands but cypress flats on broad peatlands with shallow organic soils. Some fire, soil and vegetation dynamics of pyrophytic peatland cypress was discussed earlier in Chapter 3.

The second adjustment involved white cedar. Not a single tree was seen in the county during the study, but Gum Swamp ranges across a distinct and long-attenuated fire frequency gradient from low pocosin on the west and the former Beecham Savanna on the north, to the fire-infrequent baldcypress just described, on the east and small oak flats to the southeast. This gradient includes fire-return intervals which support white cedar stands elsewhere (26-50 yrs, 50-100 yrs) and includes the shallow organic soils preferred by the species. County forest service personnel knew of no white cedar in the county when consulted, but aerial photos of the remote interior of Gum Swamp showed scattered single trees or small clumps that resembled white cedar, with their very black photographic signature. Not having been able to reach any of these during field work, I commented on the likelihood of a zone of white cedar in this region but was forced to omit it from mapping in the absence of any remnants to examine. It was gratifying then to discover the following from Ashe (1894) "Pamlico County has 3,000 acres of white cedar swamp, partly lumbered, lying near Vandemere and along the western edge of Big Gum swamp in the northern part of the county." Map area calculations show that this would have taken up all of the organic Belhaven (Terric Medisaprist) and Wasda soils between Vandemere and the Beaufort County line. Being bounded on the west by the more frequently burned canebrake and pocosin vegetation of Bay City Pocosin, and on the east by the cypress-dominated zone mentioned above, the white cedar zone is clearly delimited and so was added to the final map. Other than these two instances, consideration of historical information resulted in a few minor

changes in some community descriptions, but not in the communities themselves.

Mapping Unit Example.

Map unit codes consist of couplets with the uppercase letters indicating vegetation type and lowercase indicating the soil series, usually the same code as used on the county soil map. For example BM/lf is the code for brackish marsh on Lafitte muck (see descriptions below and key on enclosed vegetation map supplement).

There is not room to go into all of the evidence and rationale for each mapping unit, but it may be appropriate to explain one unit as an example. LS/ln is the coding for wet longleaf pine savanna on Leon sand. These soils occur as part of the intricate pocosin-savanna mosaic running all along the Suffolk Scarp from the Beaufort County line south to the Pamlico River, and thence over a broader region upstream to the Craven County line. The presettlement vegetation type is described below as species-rich, frequently burned, wet longleaf pine savanna. The fire frequency map, discussed in the fire ecology chapter above, indicates the presettlement fire frequency for the Suffolk Scarp in this vicinity as 1-3 years, the highest fire frequency class. It seems likely that a long, body of sand with high fuel-continuity types like longleaf pine litter and wiregrass, would burn at a higher frequency than adjacent types because it could be ignited by local fires in adjacent pocosin anywhere along its length. These fires could then carry along the more flammable savanna for many miles, so these soils would be expected to have a higher fire frequency than those of the adjacent pocosin and canebrake, which are estimated to have burned at 4-6 yrs on average, the next lower fire-frequency class. Most of the Leon sand near the Pamlico River has now been fire-suppressed for up to 50 years, and from Minnesott Beach northward along the scarp, natural communities have been almost entirely displaced by houses, farming, and loblolly pine. Along the northern half, however, there are remnant savannas, including a small area along the highway on both sides of the Beaufort County line, which has been burned. As discussed below, a large number of typical southeastern savanna herbs were

found in this area, including several at the northern limit of their range. Most of the nearby Leon savanna remnants have been long fire-suppressed, so all stages of fire-suppressed succession are available for inspection. Typically, the oldest trees on the sites examined sites were longleaf, but the understory has filled in with young pond pine, Nyssa biflora, Gordonia, and dense shrubs, mostly species of the adjacent pocosins. These woody pocosin species are ordinarily kept reduced to fire-dwarfed forms in regularly burned Leon savannas. The overall pattern was typical of artificially fire-excluded sites on Leon sand seen also in the Croatan National Forest and other sites to the south. The herb layer was shaded, litter-buried and very depauperate in most areas. Along mowed roadsides, and on a few burned remnants of the same soil, however, savanna species abounded. In several interior savannas surrounded by pocosin, Lysimachia asperulifolia and Venus' flytrap were found, both obligate pyrophytes and indicator species for the highest fire-frequency class. Lysimachia is a federally endangered species, believed to be endangered primarily because of its dependence upon frequent fire (Frantz 1994). Venus' flytrap, likewise, is listed as a Special Concern species in North Carolina and is declining as a result of habitat loss and fire suppression (Boyer 1994). The two species were barely surviving, having been excluded from their original habitats to small sunny patches where logging roads and hunting trails were carved through the heavy shrub cover on the Leon sand. A remnant population of Lysimachia also persists on the edge of the settlements on the southern part of the scarp, and a few miles away in the southwestern part of the county, an 80 year-old resident told me about Venus' flytraps occurring in her youth on her father's land near Reelsboro, a pocosin-fringe region now thoroughly converted to loblolly pine and farm land for around 40-50 years. None of the savanna species found are weedy or known to be rapid colonizers. The entire assemblage on the Leon sand remnants seemed clearly indicative of fire-suppressed remnants of a once extensive, much more open, frequently burned, species-rich longleaf pine savanna system.

Equally involved rationale supports conclusions about each of the other 44 mapping units. These are grouped into the 14 vegetation association or alliances described below. The

descriptions focus on community dominants, but complete lists of all species found, by vegetation layer are available to support the classification. One or more specific community types are also given for each group mapped. These individual community types are not described further here but complete species lists and cover values for the 93 samples are available in the appendices.

Vegetation Descriptions

There were 14 major presettlement vegetation types of the county, distributed over the 32 soil series, which, in various combinations produced the 45 mapping units listed below (see enclosed map supplement). The mapping units do not correspond strictly with either soil series or community types. There are more mapping units than soil series because more than one plant community was found on several of the organic soils in large peatlands. Also, in four cases, pairs of very similar soils with nearly identical vegetation were combined into one mapping unit, especially where there was too much fine detail for the map scale. All of the rest of the mapping units represent vegetation on a single series. Some 46 community types were distinguished, but mapping is not necessarily by community type, which would be too fine-textured for this map scale. Some mapping units, especially on uplands, do correspond to a single community type but most include two or three. The fourteen types described below are mostly vegetation groups at something like the plant Association or Alliance level. No attempt has yet been made to fit these into existing classification systems since many of these communities do not agree well with current classifications, which are based in part on fire-suppressed replacement communities, which include most existing wetland vegetation. Also, a number of communities found here, on wet, clayey Alfisols and extensive wet flats with histic surface layers, do not occur in the southern half of the state where the best remaining fire communities have been studied. In this approximation I have tried to let the evidence define the presettlement, pyrophytic community groupings rather than to tease them into an existing classification.

BRACKISH MARSH and OLIGOHALINE MARSH

BM	OM	BRACKISH MARSH, OLIGOHALINE MARSH
hn	hn	Hobucken muck
BM	OM	BRACKISH MARSH, OLIGOHALINE MARSH
lf	lf	Lafitte muck

Community types observed:

___Juncus roemerianus.

___Juncus roemerianus-Distichlis spicata.

___Spartina patens-Distichlis spicata.

___Spartina alterniflora.

___Cladium jamaicense.

___Brackish mud flats with Salicornia-mixed brackish marsh herbs.

___Red cedar/brackish marsh herbs in marsh-upland transitions

Wide marshes fringe most of the eastern half of the county, especially along the Pamlico Sound, but inland, along the Pamlico and Neuse River estuaries where shorelines are higher, wave action has carved bluffs into adjacent uplands, relegating marshes to small patches near the mouths of streams and small swamp drains. On the county soil map all marshes are assigned to only two soil series. The Lafitte is a deep muck, typically around 80 inches thick and is the most extensive mapping unit for brackish marshes all around the Pamlico Sound. Hobucken is a shallower muck, with a surface organic layer typically 16 inches thick, but there was much variation in the areas probed, with organic matter ranging from a few inches thick to nearly as deep as Lafitte.

Most of the marshes of the county fall into the brackish range, with typical salinometer readings around the eastern periphery ranging from 1 to 1.3% and decreasing upstream into the headwaters of longer tributaries like the Bay River. No examples of true freshwater marsh were

seen. Rounding the point near the ferry landing at Minnesott Beach, salinity decreases rapidly upstream and most of the marshes there are oligohaline (salinity 0.05 to 0.5%). All of these marshes are fire suppressed, the brackish marshes heavily dominated by Juncus roemerianus and Distichlis spicata, with the oligohaline marshes upstream toward New Bern being dominated by Spartina cynosuroides (tall cordgrass) in dense stands, sometimes with interiors of sawgrass at the marsh-upland interface.

Marsh-upland transition zones. These are some of the most interesting vegetation in terms of unusual species, and form distinctive communities. The salinity gradient may be quite steep in brackish marshes, and in most places the zone of transition between tidal brackish marsh and the interior fresh groundwater pool is too narrow to show on the vegetation map. Typical marsh-upland transitions along the Bay River have a zone of red cedar, sometimes with an understory of palmetto (Sabal minor) on moist sand. Wetter places and shallow pools may have an intermixture of herbs native to brackish marshes, fresh marshes and freshwater swamps. Triglochin striata forms dense mats in shady pools under red cedar and pine, and this may be the primary natural habitat for this unusual species.

In some places the marsh-upland transition may be attenuated into a wider zone, and a tenth hectare plot (PA10) was used to document one such situation. This transition is bordered by Juncus marsh on the east and fire-suppressed loblolly pine flats on the west. In the eastern half of the transition zone Juncus marsh gives way to a meadow of Spartina patens and other marsh plants, with scattered shrubs. On the landward side it becomes a cedar-palmetto woodland with shrubs beginning to shade out the fairly diverse herb layer. Most of the marshes and uplands of the county have been successfully fire suppressed for the past 40 years, with the consequence that these zones are filling in with cedar, loblolly pine, wax myrtle, Baccharis and other shrubs. Similarly, many of the marshes bordering brackish streams are also succeeding to shrubs (see photo of Spice Creek in Chapter 3). Despite the susceptibility of red cedar to

elimination by fire in upland communities, many of the oldest cedars have survived past marsh fires as evidenced by considerable basal scarring. These trees, some up to 75 or 100 years old, and predating modern fire suppression, indicate that red cedar may have been a natural component of this zone under the original fire regime.

In other places, where brackish marsh adjoins longleaf pine forest and savanna on sandy soils, the transition zone may be only 1-2 meters wide. At Goose Creek Game Land in the northeastern corner of the county longleaf pine woods and marsh have been regularly burned during the winter at about five-year intervals, and growing season burns were begun there around 1985. At the boat landing on N.C. highway 33, just into Beaufort County, a longleaf pine stand directly abuts Juncus marsh with only a 2-meter band of shrubs, including swamp rose (Rosa palustris) and wax myrtle (Myrica cerifera) separating the two communities. On the east side of Goose Creek, nearer the Pamlico River, there are longleaf pine flats with an herb layer that grades directly into marsh with no shrub barrier.

CANEBRAKE-POND PINE FOREST MOSAIC

CA	CANEBRAKE, POND PINE-GORDONIA, HIGH POCOSIN
bh	Belhaven muck
CA	MEDIUM POCOSIN, HIGH POCOSIN, POND PINE/CANEBRAKE
ct	Croatan muck
CA	POND PINE/CANEBRAKE, POND PINE, HIGH POCOSIN
pa	Paxville mucky fine sandy loam
CA	CANEBRAKE, SWEETGUM, LOBLOLLY
wd	Wasda muck

Community types:

___Canebrake (Arundinaria gigantea), trees lacking.

___Pond pine/canebrake.

___Sweet gum/canebrake.

___Loblolly pine/canebrake.

___Pond pine forest.

___Pond pine-Gordonia forest.

___Medium pocosin.

___High pocosin.

Canebrake, once one of the principal and most extensive types of presettlement coastal peatlands has largely vanished as pocosin, red maple and bay forest replace the cane rhizome mats waiting vainly for the next fire. Paired plots (Figures 4.1 and 4.2 seen previously) compare recently burned and fire suppressed canebrake in Northwest Pocosin. Aerial photos and recent fires reveal the typical pattern of the pond pine-canebrake mosaic. In the original situation there were patches of dense pond pine, patches of pure, treeless canebrake and areas with cane having only scattered pond pine. This pattern is confirmed on old black and white photos used for soil maps of the Dismal Swamp and elsewhere. While canebrake is more common on shallow peats, there was no accounting for the patch distribution for a given site based on any readily observable characteristics of peat depth, drainage, or past logging. Using fiberglass probes I took peat depth measurements in numerous places. In Light Ground Pocosin there was no difference in peat depth between dense pond pine and adjacent low pocosin or canebrake. On black and white photography recently burned cane shows as almost pure white. The patches of pure canebrake without pond pine often succeed to red maple, which gives a light gray signature on photos, allowing estimation of the original extent of canebrake.

GUM FLATS

GF	SWAMP HARDWOODS
ba	Ballahack fine sandy loam

GF SWEET GUM, SWAMP BLACK GUM, TULIP POPLAR

br Brookman mucky silt loam

Community types:

___Swamp black gum.

___Swamp black gum-sweet gum.

___Sweet gum-swamp black gum-tulip poplar.

___Swamp black gum-baldcypress-Quercus laurifolia.

Gum-tulip poplar flats occur as transitional communities in the fire tension zones between canebrake and non-pyrophytic oak flats. Hot pocosin and canebrake fires have to go to ground somewhere, and along the western border of Light Ground Pocosin former canebrakes are fringed with a narrow belt of loblolly pine, red maple, and Gordonia forest, which seems to have absorbed the impact of the last major fire around 1950. These stands which may be in part killed to the ground in major fires, are transitional to a wide zone of sweet gum, black gum and tulip poplar on wet brown alfisols with a clayey circumneutral basement. These in turn are transitional to fire-free oak flats on light-colored wet clay soils (Argent and Wahee series). The presence of tulip poplar in gum flats appears to be related to fire. The poplar occurs in zones toward the less fire-exposed side of fire-tension zones, but in situations reached by fire at intervals around 13-25 years, creating numerous canopy openings large enough for the species to colonize under a chronic, non-catastrophic fire regime. Similarly Ashe (1894) described poplar and gum on similar soils on the north side of the Bay River, in the fire-tension zone between frequently burned mixed pine flats and white cedar stands of Gum Swamp.

HARDWOOD SLOPES

HS UPLAND HARDWOODS

dg Dogue fine sandy loam

Community types:

___Mixed oak-hickory-beech.

There are virtually no areas of mesophytic upland hardwoods in the county except for narrow bands of rolling slopes along streams and on adjacent uplands which are undergoing succession from pine-dominated fire communities in the long absence of fire. Natural hardwoods of the Dogue slopes occur along the Neuse River shoreline. Typical species are cherrybark oak, swamp white oak, white oak, bitternut hickory, pignut hickory and a few beech. Beech is scarce in the county, the original landscape too prone to fire to permit its establishment except in the few fire-protected places in the landscape. Only two such refugia were seen: the interiors of large moist oak flats, and the most fire-protected slopes adjacent to wet swamps or bodies of water.

LONGLEAF OR MIXED HARDWOODS ON SOILS FRINGING SOUNDS, SMALL STREAM SWAMPS OR MARSH

LF	LONGLEAF PINE, OAK-HICKORY-BEECH
aa	Altavista loamy fine sand
LF	LONGLEAF PINE
no	Norfolk loamy fine sand

Community types.

___Longleaf pine/mixed mesic savanna, wet savanna & marsh herbs.

___Mixed longleaf-loblolly-shortleaf-pond pine/mixed mesic savanna and swamp herbs.

___Pyrophytic woodland with up to 4 species of mixed pines with mixed oaks and hickories (Quercus falcata, Q. stellata, Q. margaretta, Q. marylandica, Carya tomentosa, C. cordiformis, C. pallida and C. glabra).

___Beech-mixed hardwoods.

The Altavista soils had the most extreme variation in vegetation that can be found on one soil series, ranging from longleaf pine on the most fire-exposed sites to beech in the most fire-protected situations. This diversity was a result of its great variability in slope and topographic situation, occurring on small sandy flats and hummocks, rolling shoreline margins and peninsulas. Longleaf in this topographic situation, on rolling sands along low stream borders, is too prone to succession for any good examples to persist. As mentioned above, the name Tarkiln Creek on the southern edge of the county suggests that enough longleaf originally occurred there for making tar and pitch. The Altavista is the only soil in the vicinity which could have had longleaf, the others being moist clayey oak flat types.

Judging from remnant vegetation on Norfolk soils around the periphery of the Croatan, the original forests of this soil series were of three types; pure longleaf pine, mixed pine savanna (longleaf, loblolly and pond pine, with a few shortleaf) or pyrophytic woodland (pines, oaks and hickories), depending upon the degree of natural protection from fire and the local fire frequency as determined by surrounding vegetation and topography. Virtually all these sites have been logged and fire suppressed, so that the original mixed pine forests have been replaced by loblolly pine, sweet gum and oaks.

LONGLEAF PINE FOREST AND SAVANNA

LL	LONGLEAF PINE/DRY SAVANNA
an	Alpin fine sand
LL	LONGLEAF PINE/DRY SAVANNA
by	Baymeade sand
LL	LONGLEAF PINE/DRY SAVANNA
cn	Conetoe loamy sand
LL	LONGLEAF PINE/MESIC SAVANNA

cr	Craven loam
LL	LONGLEAF PINE/MESIC SAVANNA
go	Goldsboro loamy fine sand
LL	LONGLEAF PINE/WET-MESIC SAVANNA
lg	Lynchburg + Goldsboro
LL	LONGLEAF PINE/WET-MESIC SAVANNA
ly	Lynchburg fine sandy loam
LL	LONGLEAF PINE/WET-MESIC SAVANNA
th	Tomahawk loamy sand

Community types:

___Longleaf pine/wiregrass dry savanna herbs.

___Longleaf pine/wiregrass-bluestem-diverse savanna herbs.

___Longleaf pine/wiregrass-Vaccinium crassifolium.

With representative, but fire-suppressed remnants on each, this group of soil series were clearly dominated by classic longleaf pine savanna and woodland. The eight series are listed from dry to moist. While wiregrass remnants can be found on most of these, all except a few small burned areas have deep pine needle buildup which has largely smothered the herb layer. Virtually no longleaf pine reproduction was seen anywhere in the county. Even with a group of soil series all dominated by longleaf pine, separate mapping units were retained for each soil series where possible. This allows more precise future mapping of individual natural areas because specific communities can be defined on most of these. For instance, a distinctive longleaf pine/Vaccinium crassifolium type with up to 75% cover of creeping blueberry occurs only on the Tomahawk series.

WET LONGLEAF PINE FOREST AND SAVANNA

LS	LONGLEAF PINE
ln	Leon sand

Community type:

___Longleaf pine/species-rich wet savanna.

Good examples of moist, species-rich longleaf pine savanna persist as part of the Tomahawk (mesic), Leon (moist to wet), Rutledge (wet) mosaic of low sands along the Minnesott Ridge. The Prescott Ridge Natural Area at the northern end, extending into Beaufort County, is the northernmost remnant longleaf pine savanna in the country. This is the northern limit for the federally endangered Lysimachia asperulifolia (rough-leaf loosestrife), as well as Lysimachia loomisii, Dionaea muscipula (Venus' flytrap), Fothergilla gardenii, Carex elliottii, Carex striata, Pterocaulon virgatum, Spiranthes brevilabris var. floridana, Rhynchospora ciliaris, Rhynchospora baldwinii, Rhynchospora plumosa, Carphephorus paniculatus and Rhexia lutea. A large number of other wet savanna species are also present.

MIXED PINE FOREST AND SAVANNA

MP	MIXED LONGLEAF, POND, LOBLOLLY
ap	Arapaho loamy fine sand
MP	MIXED LONGLEAF, LOBLOLLY, POND
cl	Craven loam + Lenoir silt loam
MP	MIXED LONGLEAF, LOBLOLLY, POND
cs	Charleston loamy fine sand
MP	MIXED LOBLOLLY, POND, HARDWOODS
fo	Fork loamy fine sand
MP	MIXED LONGLEAF, POND, LOBLOLLY
ra	Rains fine sandy loam

MP	LONGLEAF, MIXED LONGLEAF & POND
yo	Yonges loamy fine sand
MP	MIXED LONGLEAF, POND, LOBLOLLY
yf	Yonges + Fork (merged)

Community types.

___Mixed longleaf-pond pine-loblolly/diverse wet savanna herbs.

___Mixed loblolly pine-pond pine-oaks-hickories.

___Longleaf pine/mixed wet savanna and marsh herbs.

The existence and role of mixed pine savannas in presettlement vegetation is little appreciated, since only small remnants persist, and are readily confused with fire-suppressed former longleaf pine communities that have been logged and invaded by other pine species. Of those that occurred on the better soils (finer textured sands and loams), most were converted to agriculture 100 to 200 years ago. The stands on moist mineral flats too wet to farm were logged, fire suppressed, and grew up in loblolly pine. Ashe (1915) described the following various mixtures of loblolly, longleaf, pond pine and shortleaf pine in original mixed pine forest and savanna.

> "Only in a few localities are all four pines found growing together. Near the coast [as in the Pamlico lowlands, which Ashe seemed to know a lot about] the loblolly, pocosin, and longleaf pines are sometimes associated on sandy hummocks [like the Altavista soils]; the wettest places, however, are as a rule occupied by the pocoson pine; the pocoson and the loblolly pines are associated on savannas and slightly drier knolls; on better drained soils the longleaf replaces the pocoson pine in the mixture and on thoroughly drained soils only the longleaf pine is found."

Examples of all these types were predicted in the maps with the site fire history approach used,

and in Beaufort County near Nevil Creek I found a remnant (now logged) of mixed pine savanna with all four of the above pines on Lenoir loam, a classic soil for mixed pine savanna communities. Mixed pine forest and savanna was formerly represented extensively in west central Pamlico County in the transition zone between the pocosins and canebrakes of Northwest Pocosin, and the former longleaf pine sands of the southwest corner. In the east they occurred on the wet sandy soils just high enough and burned often enough to avoid surface accumulation of an organic surface layer that would give the edge to pond pine.

OAK FLATS

OF	QUERCUS PAGODA-Q. MICHAUXII
ar	Argent loam
OF	MIXED HARDWOODS
wa	Wahee fine sandy loam
OF	MIXED OAK FLAT HARDWOODS
aw	Argent + Wahee (merged)

Community types:

___Quercus pagoda-Q. michauxii.

___Quercus pagoda-Q. michauxii-beech.

___Quercus laurifolia-Q. michauxii-beech/Leucothoe axillaris.

A few remnants of old-growth oak flats persist on the lenses of wet clayey soil forming the eastern rim of Light Ground Pocosin and eastern Gum Swamp. A few patches are true second growth, only one step away from virgin oak forests logged around 1870 immediately after the Civil War, and there are single remnant trees of the virgin forest. As discussed in the chapter on lowlands, these communities acted as fire suppressors in an otherwise frequent-fire landscape. They appear to have never been much influenced by fire, other than infrequent litter fires, which

may have done little beyond preventing establishment of beech. While beech may be an important component in the wet interior, large areas with only oaks often occur in the regions transitional to fire-influenced vegetation.

WET PINE FLATS, PINE MARSH

PF		LOBLOLLY PINE, POND PINE
ap		Arapahoe loamy fine sand
PF	PM	LOBLOLLY PINE
sk	sk	Stockade loamy fine sand
PF		LOBLOLLY PINE, POND PINE
wd		Wasda muck

Community types:

___Loblolly pine/Chasmanthium laxum.

___Loblolly pine-pond pine/Myrica cerifera/marsh & swamp herbs.

___Loblolly pine-red cedar/Sabal minor/brackish marsh herbs.

___Canebrake fringe pyrophytic loblolly pine flats.

Loblolly pine marsh. Loblolly pine marsh (pine savanna, pine meadow, pine swamp) is found as nearly pure stands on wet, dark clayey muck and sandy clay soils at sea level. Perhaps the best examples known occur at Jones Island, a private preserve that has been burned occasionally. This occurs as a true fire-maintained bilayer with only two strata, the pine canopy and a grassy herb layer. A number of examples, needing only fire for restoration, occur on the Goose Creek Game Land and the rest of the Lowlands peninsula lying between Jones Bay and the Pamlico River. Most of these have been fire-excluded since stand origin (around 1954, perhaps following damage by Hurricane Hazel) and consist of only a single vegetation layer, the tightly interlaced pine-vine canopy.

Pyrophytic loblolly pine flats. During field work considerable evidence was accumulated to support the existence of fire-dependent loblolly pine flats as a natural vegetation type. One example was found in the fire tension zone on the eastern side of Light Ground Pocosin, between former canebrake and the slightly less fire-influenced sweetgum-tulip poplar flats. Remnant large old loblolly pines were found, obviously not recent successional invaders. One explanation seemed to be that loblolly pine may have been able to grow large enough to resist fairly frequent fires from the nearby pocosin and canebrakes. Ashe (1915) described even aged peatland loblolly stands 100-150 years old which he believed to date to past fires, and several contemporary photos show stands of very large old loblolly pines with an understory of low cane (Anon. 1907).

POND PINE/POCOSIN

PO	POND PINE,-GORDONIA/MEDIUM POCOSIN, HIGH POCOSIN
bh	Belhaven muck
PO	MEDIUM POCOSIN, POND PINE/CANEBRAKE
ct	Croatan muck
PO	LOW POCOSIN, MEDIUM POCOSIN
da	Dare muck
PO	POND PINE/MEDIUM POCOSIN-HIGH POCOSIN, POND PINE/CANE
pa	Paxville mucky fine sandy loam
PO	LOW POCOSIN, MEDIUM POCOSIN, WET SAVANNA AND BOG
ru	Rutlege mucky loamy fine sand
PO	POND PINE,-GORDONIA/MEDIUM POCOSIN, HIGH POCOSIN
wd	Wasda muck

Community types:

___Pitcher plant bog.

___Low pocosin.

___Medium pocosin.

___High pocosin.

___Pond pine-Gordonia/medium pocosin.

___Pond pine-Gordonia/high pocosin.

___Pond pine-Gordonia forest.

Pocosin is presently one of the two or three largest natural remnant community types in the county. Much of it, however, represents succession from canebrake and, in Gum Swamp, from white cedar, now all gone but for an occasional tree. The terms cane and canebrake were unknown to the Coastal Plain settlers but came into use about 100 years later, around 1750, so names like Cane Creek (of which there are 16 in North Carolina) are found only in the mountains and Piedmont. Cane was called reeds and was included in what the settlers called pocosin. Since there was no word for canebrake for the first 100 years, the inhabitants improvised with place names like Reedy Pocosin in nearby Beaufort County, Reedy Glade, Reedy Meadow or the Green Sea. All of these sites have now succeeded to pocosin or forest.

The areas mapped here as pocosin are all sites believed to have been shrub pocosin and not canebrake in presettlement times. These include most of the deep peats and the more sterile sites on shallow organics, as well as more fertile soils in fire-tension zones where fire frequency was too low to support canebrake. Ashe (1884) described one such site. "The central part of Big Gum swamp is open, covered with scattered savanna pines and an undergrowth of gallberries, huckleberries, brambles, etc." This is the region now known as Bay City Pocosin, and includes a large remnant of low pocosin with an odd species composition and structure, very different from that of the better known Sheep Ridge Low Pocosin in the Croatan National Forest.

POND PINE FOREST AND SAVANNA

PP	POND PINE
la	Leaf silt loam
PP	POND PINE, POCOSIN, CANEBRAKE
pa	Paxville mucky fine sandy loam
PP	POND PINE
sk	Stockade loamy fine sand

Community types:

___Pond pine forest.

___Pond pine/diverse wet savanna herbs.

True pond pine forest seems to have occurred primarily on wet sandy soils having a surface organic layer. At Goose Creek Game Land on the east side of Swift Creek there can be seen a continuum from brackish marsh to longleaf pine forest, across highway 33 to mixed longleaf and pond pine, and then to extensive pure pond pine forest. This grades to the south into a zone of wet, fire maintained Taxodium forest, a remnant of the 7,000 acres described by Ashe in 1884. In the original situation the pond pine forest/savanna would have been burned nearly as frequently as the longleaf forest with which it intergrades, and the original understory flora of these stands is virtually unknown. The present stand has been fire suppressed and is floristically depauperate but at the edge of a clearing I found Iris prismatica, a rare species seen nowhere else in the region during my studies. Stands of pure pond pine also occur as a component of the vegetation mosaic on other soils, particularly the Arapahoe and Wasda (see pine flats and mixed pines above).

SWAMP FOREST

SW	BALDCYPRESS, SWAMP HARDWOODS

ba	Ballahack fine sandy loam
SW	BALDCYPRESS, NYSSA, FRAXINUS
ma	Masontown loam

Community types:

___Baldcypress-Nyssa biflora-Fraxinus pennsylvanica.

___Baldcypress-Nyssa biflora-Quercus laurifolia/Sabal minor.

___Baldcypress-tulip poplar-pine-gum fire-disturbance community.

Linear swamps. There are no large fluvial swamps in the county, those of the Pamlico and Neuse Rivers having emptied into the estuary upstream in Craven and Beaufort Counties. Linear small stream swamp occurs in only two situations in the county. The longest is Upper Broad Creek, the linear swamp that forms the western boundary with Craven County. The other is in the headwaters of the short, narrow, drowned creek valleys draining the broad interior upland pocosins and flats south into the Neuse River. Typically short tidal streams bordered by brackish marshes occupy the lower halves of these valleys. These terminate abruptly upstream, heading in marsh-swamp transition vegetation in which Sabal minor can often be found in the understory. Short, narrow connector swamps join the marshes and upland flats, often with a fairly steep elevational gradient. Some of these are less than a kilometer long. Tall cypress, Quercus laurifolia, Nyssa biflora and Fraxinus spp. are common dominants.

Peatland Swamps. In eastern Gum Swamp and in fire-tension zones around the periphery of the large peatlands, there are remnant examples of chronically disturbed baldcypress forest. Found where fires hot enough to reach the interior only occur every 25-35 years, these fire-scarred stands record the local fire history for hundreds of years before settlement. These stands, primarily on Wasda soils grade into the gum flats described above on the Ballahack and Brookman soils.

ATLANTIC WHITE CEDAR

WC	ATLANTIC WHITE CEDAR
ba	Ballahack fine sandy loam
WC	ATLANTIC WHITE CEDAR
wd	Wasda muck

Community type:

Chamaecyparis thyoides.

There are no known stands of white cedar remaining in the county. An anonymous writer described vegetation of the county in 1882.

"The prevailing growth is on our outlands, long and short straw pine [longleaf and others], with oak (red and white), hickory, holly, etc.; and in the swamp, yellow poplar, sweet and black gum, ash, juniper, and the over-cup and chestnut oak, etc. The wooded acreage of our county is at least nine-tenths of the whole" (Hale 1883).

Unfortunately, no location was given for the "juniper' (white cedar). Eastern Gum Swamp was probably named for the black gum-sweet gum-tulip poplar flats, which still occur in extensive stands there. This swamp, on shallow organic soils lies adjacent to frequent-fire communities on deep peats to the west and sandy longleaf pine soils to the north but may have had interior areas that were only rarely reached by fire. Some of the area along the resulting fire-frequency gradient would have been appropriate for Atlantic white cedar, and aerial photos suggest that a few tiny clumps of second growth trees may persist there still in the interior. None were reached during the study, but in a subsequent review of the historical literature, it was found that this area was occupied by a 1,200 ha (3,000 a) stand of white cedar as late as 1884 (see below).

The final vegetation map illustrates two of the main points of pyrographic vegetation mapping: on uplands or wetlands with mineral soil, and given a known historic fire regime, it was possible to assign a narrowly defined vegetation type to each soil series. On upland soil series no variation in vegetation was found which could not be explained by evident differences in logging history or other past land use, or by variation in the degree of natural fire exposure or fire protection in the landscape. On the other hand, in large peatlands there were usually more than one potential community type on the same series. This last phenomenon is explored more fully below with the map of mainland Dare County.

Testing Mapping Accuracy for Pamlico County

Historical data sources. The following kinds of historical information were used for comparison with expected vegetation types:

1. Historical place names often date to the early Colonial Period, and may provide valuable information on original fire frequency and vegetation types. For example, the name Tarkiln Creek on the south side of Pamlico County is particularly revealing, as tar kilns were places for burning down longleaf pine lightwood into tar and pitch. This small creek is completely bounded by rolling soils of Altavista sand, the only soil in the vicinity likely to have supported longleaf. Since the Altavista, which occurs over a wide range of fire-exposure situations, supports the most variable vegetation in the region, ranging from longleaf pine to beech, evidence that longleaf was a once important component here contributes a valuable datum about original fire frequency at this location. Similarly, in the Goose Creek Game Land, Cuff Tarkiln Creek adjoins Altavista and Tomotley soils, and in this case there are still some remnant trees and patches of longleaf pine.

2. The N.C. Dept. of Archives and History facsimile map collection was used to document marshes and pocosins (Cumming 1966). This set covers most of the study area with a series of 15 large maps, dating from 1585 to 1896. Historical maps, while not necessarily about vegetation, often use vegetation symbols to distinguish open wetlands like the large canebrakes and pocosins, from wooded land. The Mac Rae - Brazier map of 1833 accurately shows the limits of the interior pocosins of Pamlico County for the first time. The Collet map of 1770

shows the wide marshes fringing the shorelines of Dare and Pamlico Counties. Historical maps also show major landscape changes such as the disappearance of the whole Brant Island chain of marshes with rising sea level in the Pamlico Sound. Scanning the maps from first to last illustrated the unfolding of knowledge about the land, as well as providing a kind of time-lapse photography showing the melting away of marsh islands and shorelines as sea level rises.

3. Sargent (1884) prepared a map of major pine stands of the region, which he divided into three types: longleaf dominant stands, loblolly dominant but mixed with longleaf, and former pine lands from which merchantable pine had already been removed by 1882. The band of longleaf running down the Minnesott Ridge (the local name for the Suffolk Scarp) can be clearly discerned, even though it is somewhat misplaced in comparison with modern maps. Besides cartographic inaccuracies, there are also matters of vegetation interpretation in all historical records. In this case, Sargent did not distinguish pond pine from loblolly pine except where found in its stunted pocosin form (which Ashe [1894] called "savanna pine"), so many of the areas mapped mixed loblolly and longleaf were actually mixed stands of pond pine and longleaf, or of all three species. Sargent showed no pine at all on mainland Dare. While this was clearly just a lack of information, pine would have been much less abundant there under the original fire regime, the majority of the land being marsh, canebrake, white cedar and other wetland forests. The landscape fire ecology method, however, predicted loblolly pine to be a major species on estuarine fringes and isolated mineral soil flats in west central and northern mainland Dare (see dare County case study and map), and this was confirmed by Ashe (1894).

4. W.W. Ashe (1884), one of the first trained graduates of the Biltmore School of Forestry in Asheville, provides the most reliable descriptions of 19th century vegetation of the region. Fifty years before initiation of fire control programs in the region, and at a time when perhaps 50% of virgin forests remained, many of Ashe's observations are essentially descriptions of presettlement vegetation. He provides a number of specific references to community types for both Pamlico and Dare Counties. In Pamlico County this included enough information to specifically map two large bodies of white cedar and cypress which have since been converted to pocosin and gum swamp.

5. Ashe (1915) produced a second regional map of loblolly, longleaf and "pocosin pine" (this is

pond pine--he had abandoned the name "savanna pine" by 1915). While also very general, this map includes Pamlico County, and shows mainland Dare divided into pine wetlands and open wetlands, thus filling in some of the landscape that was missing from Sargent (1884). Ashe also describes four combinations of mixed pine savanna, confirming the conclusions reached about mixed pine forest and savanna in preliminary mapping.

6. Pinchot and Ashe (1897) comment on deforestation of shallow organic soils in both Dare and Pamlico Counties. The sites they describe occurred at the interface between white cedar on shallow peat, and the tulip poplar-gum flats on loamy muck soils like Brookman and Ballahack, and so can be mapped.

7. Roper Lumber Company (Anon. 1907) owned or leased vast amounts of land, including tracts in Pamlico County, where they operated a steam-powered sawmill at Oriental. While not precisely locatable, photos of some of their lands show examples of virgin loblolly pine flats with an understory of low cane, agreeing with Ashe's comments on pyrophytic origin of certain loblolly pine flats. The photos also support the preliminary community description of pyrophytic pine flats in the present study.

An additional historical source not taken advantage of in this study was boundary tree records compiled from early surveys. In areas such as these, where no systematic public surveys were done, searching out individual survey plat descriptions is very time-consuming. Such a study would be expected to contribute a number of additional data points.

Method. The historical records specific to Pamlico County were not used in preparation of the first community descriptions or the first or second approximation vegetation maps but were reserved for testing accuracy of mapping. For test purposes, 100 random points were plotted on the map, using a random numbers table to determine x and y coordinates. A method that was developed for use with remote sensing data was used for calculating total accuracy and confidence limits (Congleton 1991). This involves determining the number of correct or incorrect identifications for each vegetation type. Since eight vegetation types could be distinguished in the historical record, communities in the 45 mapping units in the present study were grouped accordingly. Canebrake and pocosin, for instance, were combined because there

was no word for canebrake in the colonial vocabulary in this region, and all such openings in the landscape were just called pocosin (pocosin means "opening" in Algonquian), or "lights" (such as Light Ground Pocosin) which applied to light or unshaded areas. Such areas are also simply represented as openings on the two original forest maps, or with a marshy symbol on other historic maps.

The ten vegetation classes used for testing were:

1. Marshes.
2. Canebrake and pocosin.
3. Longleaf pine savanna and forest.
4. Loblolly pine flats (includes pond pine forest where it occurs on flats because neither Ashe nor Sargent distinguished it from loblolly except where it occurred in pocosins in the stunted, twisted form).
5. Mixed pine savanna and forest.
6. Oak flats and oak slopes.
7. Sweet gum-black gum-tulip poplar flats.
8. Baldcypress flats.
9. Cypress-gum-Fraxinus swamp forest.
10. White cedar.

The method above was designed for use in classifying forest vegetation types with remotely sensed data, either in pixel form or from photos. In the usual method, vegetation on aerial photos or satellite images is classified and then taken to the field for ground truthing. The process was reversed for testing the present method. In this case the field work was done first, vegetation was then classified, and finally taken to the historical record for truthing.

A ground truth table (historical truth table) was compiled using the 10 types and for each point for which historical information was available, it was recorded whether the identification was correct or whether another type was indicated. The percent of correct identifications as predicted for each vegetation type was calculated. Overall accuracy was calculated by the formula $P=1/2(P1+P2+P3...P10-(10-2)100))$, where Pi is the percent of correct identifications for each type. There were not enough points for calculating confidence intervals using Student's t for

each of the 10 types.

A certain amount of subjectivity was unavo.dable in scoring results. In a few cases, e.g. Tarkiln Creek, and some sites described specifically by Ashe (1894, 1915), a vegetation class could be precisely associated with a particular soil pedon. More commonly, if a random point on the map fell in longleaf pine savanna, and this site occurred in a general region mapped as dominated by longleaf pine in Ashe or Sargent, it was scored as correct. In a more ambiguous situation, a random point fell in a narrow small stream swamp, dominated by cypress, gum and Fraxinus, too small to appear on the historic maps, which were extremely general, or to be mentioned specifically elsewhere in the historical record. Such cases were either discarded from the analysis for lack of information or, in this case, scored as correct because Ashe described such swamps in the region, and no known process on the time scale of the historical period could have resulted in producing swamp forest from some other original type on this kind of site. Of the 200 points some were discarded as ambiguous or having no relevant historical record.

CONCLUSION

Using the methods above, the overall accuracy of mapping was 83%. In satellite remote sensing, 50% correct identification is considered good (S. Khorram, per. comm.). General Land Office surveys give only 1 to 4 trees at every 1/2 mile or mile, and only occasionally a description of the understory vegetation. The best efforts, using quantitative data from such surveys have resulted in regional vegetation maps with around 5 to 12 major vegetation classes. While providing excellent background, this is not sufficient for practical application, even at the scale of a national forest.

In the studies of Pamlico and Dare Counties, there were substantial remnants of natural vegetation, and detailed maps were created, at the community type level, using soil series to put boundaries on vegetation. In areas having General Land Office or historical survey plats, boundary tree information could be used along with the method to produce presettlement vegetation maps at a practical level of resolution. Using the landscape fire ecology method and soil series maps, presettlement vegetation can be approximated even in areas without any natural remnants, so long as sufficient remnants occur on each soil series in surrounding counties to

reconstruct presettlement fire frequency and flora.

Inclusion of subjectively-assigned data may not be as satisfying as the mathematical treatment that can be applied to witness tree data, but such data is severely limited in its usefulness anyway, since it does not yield a practical level of resolution. Despite a certain amount of unavoidable subjectivity, the current approach permitted mapping presettlement vegetation at the soil series level, at least an order of magnitude better resolution than any previous method. This pilot study and the case study of Dare County suggested some of the principles of landscape fire ecology that were later applied in mapping presettlement vegetation and fire regimes of the Croatan National Forest and at the Savannah River Site.

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CASE STUDY 2

PRESETTLEMENT VEGETATION OF ROANOKE ISLAND AND MAINLAND DARE COUNTY

Two very different counties, Pamlico and Dare, were chosen for pilot studies using the Landscape fire ecology method of reconstructing presettlement vegetation. Pamlico County illustrated the full range of upland soils, interspersed with small and large peatlands. Dare County involved a more difficult situation, a set of wetland fire-mosaic communities distributed across a landscape-scale fire frequency gradient.

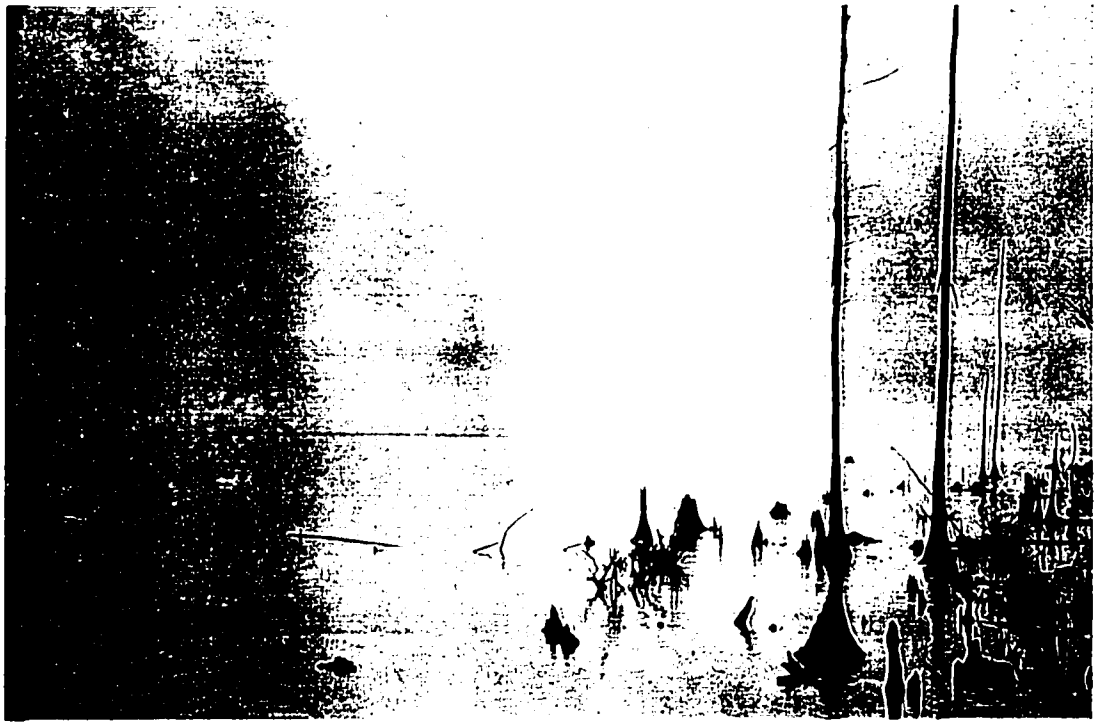
Dare County falls into three disjunct regions of land separated by bodies of water: the Outer Banks, Roanoke Island, and the mainland. The enclosed map supplement covers presettlement vegetation of Roanoke Island and mainland Dare. Virtually all of the Dare mainland lies barely above sea level and consists of Holocene and recent sediments and peat. Older soils, including Spodosols like the Baymeade and Leon sands on Roanoke Island and at Mann's Harbor on the mainland, suggest that these two sites are Pleistocene remnants in a mostly Holocene and recent landscape (Riggs et al. 1992). The gap between the mainland and Roanoke Island created by the shallow waters of Roanoke Sound appears to be a very recent development. Before closure of all three northern inlets from Albemarle and Currituck Sounds to the sea in historical times, there would have been no hydrologic necessity for the water channels on either side of Roanoke Island. These two channels, Roanoke Sound and Croatan Sound, now serve as outlets for the northern sounds. While one of the earliest maps shows a channel labeled the "Thorofare", some historical maps show nearly continuous marshes between the mainland and the

southern end of Roanoke Island (Cumming 1966). It may be that Roanoke Island and the mainland comprised a continuous fire compartment at or shortly before time of settlement.

Vegetation of Roanoke Island and mainland Dare appear to have been profoundly affected by sea level rise over the past several centuries. World sea level is believed to be rising at a rate of about 10 cm (4 inches) per century. This is the amount contributed to the world ocean by melting glaciers. In the mid Atlantic area, however, near the mouth of the Chesapeake Bay, measurements from 1940 to 1970 recorded the highest rate of land subsidence on the east coast, about 0.21 cm per year or 21 cm (8.4 inches) per century (Hicks 1972). This would give a maximum rate of land submergence (land subsidence + sea level rise) in the area of about 30 cm (12 inches) per century. Dramatic effects on the low-lying Dare mainland include loss of land area, fragmentation and isolation of islands such as Durant's and Roanoke Islands, and flooding of low-lying areas. Elimination of fire or reduction in fire frequency occurs as islands are carved off from the large fire compartment on the mainland. As sea level rises, the water table in the Dare mainland interior rises and large areas of mineral soil, supporting upland fire communities like longleaf pine have probably been converted to wetter soil types, and the most low lying are being mantled with peat. Soils with shallow histic epipedons are trending toward true peat soils.

Mainland Dare is essentially a huge peninsula 47 km (29 miles) long, bounded by Roanoke Sound on the east, Albemarle Sound on the north and the Alligator River on the west. Alligators may still be found in small tributaries like Milltail Creek, the present northern limit for the species. The peninsula is connected to Hyde County at its southern end. Fire vegetation comprises virtually all of the plant cover of this large peninsula. The sole exceptions are a region of oak flats in the vicinity of East Lake in the northwestern quarter and a narrow zone of tidal cypress-gum swamp immediately bordering the Alligator River along its whole length. The entire landscape also comprises essentially a single fire compartment. On the northern end, Durant's Island appears to have only recently been separated by sea level rise from the pocosin to the south and may be still within range of ignition by firebrands carried by convection during pocosin fires. Within the mainland fire compartment, however, vegetation is conspicuously zoned from frequent-fire types like marsh and canebrake on the east, to long fire-return interval types like Atlantic white cedar on the west.

Figure C2.1. Dead cypress trees along highway 64 near the mouth of the Alligator River provide evidence of rising sea level. Since baldcypress typically germinates on wet mud and cannot become established in standing water, the bases of trees indicate maximum sea level at time of establishment. Several medium sized cypress that I cored at various points around the shorelines had become established 100-300 years ago, but were now growing in water up to 30 inches deep. Recent mortality of trees may be due to increasing exposure to salinity, especially during pulses of salt water incurred during hurricanes and other storms.



A Landscape-scale Fire Frequency Gradient

Oddly enough, the pronounced east-west fire frequency gradient seems to have been set up entirely by salinity. The brackish water along the eastern margin maintains Juncus marshes which form a continuous, wide shoreline band stretching some 80 km (50 miles), all the way from the Albemarle Sound, down the length of mainland Dare, south along the border of Hyde County to the Pamlico Sound. This 50 mile fire corridor was augmented by flammable canebrake in the next vegetation band immediately to the west. The beginning of salt-intolerant canebrake may mark the western limit of storm overwash. On the west side, in contrast, non-pyrophytic cypress-gum swamp fringes the fresh waters of the Alligator River in a narrow band. The frequent-fire marsh and cane communities of the eastern side and this river swamp on the west comprise the extremes of a cross-peninsula fire frequency gradient. For a cross-section of this gradient see Figure 6.4. Vegetation components of the fire frequency gradient from east to west were as follows. Salt marsh was composed of several distinct communities, of which black needle-rush (*Juncus roemerianus*) was dominant. Just inland from the marshes was the canebrake zone, originally up to a kilometer or more wide. In the marsh-canebrake transition there were islands of loblolly pine marsh, apparently in places where mineral soil approached the surface, or pockets of pond pine with a marshy or pocosin understory. Inland, canebrake graded first into low pocosin, then medium and high pocosin. Next to the west, pocosin graded into a large-scale patch mosaic of wooded wetland types. The individual components of the pyrophytic patch mosaic were tall pocosin, pond pine forest, *Nyssa biflora* forest, *Taxodium ascendens*, bay forest and Atlantic white cedar. Figure 3.9 in Chapter 3 is a black and white version of a color infrared aerial photo showing a virgin patch mosaic composed of the above elements. Finally, the patch mosaic was bounded on the west by a relatively narrow band of cypress-gum swamp, only 100-300 meters wide, along the Alligator River.

Following is an annotated checklist of presettlement vegetation types of mainland Dare and Roanoke Island. The descriptions are based on landscape fire ecology (Chapter 6) and presettlement vegetation methods (Chapter 7). Field investigations included 1/10 ha plots in several of the major vegetation types, along with extensive exploration by land and by boat over several years. From 1986-2000 I owned a small piece of land on mainland Dare at East Lake and

sometimes camped in an old cabin there while doing field work. In 1989 and 1990 I gained familiarity with much of the mainland while conducting a natural areas inventory of the Hyde County portion of the peninsula for the N.C. Natural Heritage Program.

During this time I had opportunity to explore all components of the fire mosaic. I was able to core trees and determine fire dates of some of the stands in the virgin patch mosaic depicted in Chapters 3 and 6 (Figures 3.9 and 6.4). Historical documentation of mainland vegetation was sparse, but I was able to use recollections of some local residents as well as 19th and early 20th century observations by Ashe (1894), Pinchot and Ashe (1897), Anon (1907), Hale (1883) and Sargent (1884). Study of canebrake-pocosin-pond pine dynamics was aided by several wildfires in different kinds of vegetation, including a fire in 1982 that rejuvenated a large canebrake along the east side of highway 264 just south of its juncture with US 64. I did not start this fire or any of the others that occurred during my several years' exploration of the region.

ANNOTATED KEY TO VEGETATION OF DARE COUNTY

BRACKISH MARSH AND OLIGOHALINE MARSH

BM	OM	BRACKISH MARSH
cu	cu	Currituck muck
BM	OM	BRACKISH MARSH
ho	ho	Hobonny muck

Community types:

___Juncus roemerianus.
___Juncus roemerianus-Distichlis spicata.
___Spartina cynosuroides-mixed tall marsh.
___Spartina patens-Distichlis spicata.
___Spartina alterniflora.
___Cladium mariscus var. jamaicense.
___Mixed Eleocharis-Spartina alterniflora brackish mud flats.
___Myrica cerifera-Cladium mariscus var. jamaicense-Osmunda regalis.

Marshes. The two marsh soils are the Hobonny, a deep muck soil and Currituck, a shallow marsh peat underlain by sand. The two series are distinguished by organic matter depth, not by salinity, so both may be found in either brackish or oligohaline situations. The marshes on the

east side of the mainland are generally brackish, running around 1/3 to 1/2 the strength of seawater. Marshes on the north along the Albemarle Sound are oligohaline and on the west there is so little salinity in the Alligator River that swamp forest comes right down to the water's edge in all but a few places.

CANEBRAKE-POND PINE FOREST MOSAIC

CA	CANEBRAKE-POND PINE FOREST
bh	Belhaven muck
CA	CANEBRAKE-POND PINE FOREST
hy	Hyde loam
CA	CANEBRAKE-POND PINE FOREST
po	Ponzer muck
CA	CANEBRAKE-POND PINE FOREST
pu	Pungo muck
CA	CANEBRAKE-POND PINE FOREST
rp	Roper muck

Community types:

___Canebrake (Arundinaria gigantea), trees lacking.
___Pond pine/canebrake.
___Sweet gum/canebrake.
___Loblolly pine/canebrake.
___Pond pine forest.
___Pond pine-Gordonia forest.
___Medium pocosin.
___High pocosin.

Canebrake. Judging by remnant canebrakes that have been regenerated from time to time by wildfires, there appears to have been a vast canebrake along the east side of the county in a broad zone bordered on the east by brackish marsh and pine marsh, and on the west by pocosin. This canebrake, which may have been the largest in the South, ran from near Durant's Island, down the length of the east side of Dare and Hyde Counties (see enclosed map supplement). Most of this zone has succeeded to pond pine forest or pocosin but the occasional fire still regenerates portions of the canebrake. My plot DA05, sampled in 1984, documents a canebrake along US64 that was regenerated from pocosin in a wildfire two years before in 1982 (Figures C2.2 and C2.3). Cane appears unable to tolerate either standing water or salinity. While a few stems can sometimes be found in fresh or oligohaline marsh, canebrake never occurs as a marsh type. Even where it occurs within a hundred meters of marsh or brackish waters, there is always a zone of buffer

Figure C2.2. Fire patterns in canebrake and the Roanoke Marshes. White area to right is sunlight reflected off the waters of Roanoke Sound. The light areas along the shoreline are brackish marshes, also illuminated by the unusual glare of the sun, which happened to be reflected into the camera at this angle. The blackened areas east of U.S. 264 represent a fire in former pond pine canebrake that had started to succeed to pocosin shrubs. Fire plow lines that extinguished the fire faintly outline the burned area. This fire, driven by winds from northwest to southeast, can be seen to cross the streaky patterns from an earlier fire through former canebrake, that was driven from southwest to northeast. National Wetlands Inventory color infrared aerial photo 367402 taken April 24, 1982.

vegetation between canebrake and marsh. In Dare County this buffer community is usually pond pine marsh or mixed loblolly pine-pond pine marsh (when burned frequently) or a swampy version of pond pine/high pocosin. The occasional overwash of brackish water during storms probably helps maintain this zone free of cane. Place names are often useful indicators of past vegetation. Reed was the name used for cane in the Colonial Period, and Reeds Point between Mashoes and Mann's Harbor may indicate a place where canebrake came close enough to be seen from the water.

LONGLEAF PINE FOREST AND SAVANNA

LL LONGLEAF PINE/DRY SAVANNA HERBS
by Baymeade sand

Community type:
Longleaf pine/dry savanna herbs

Longleaf Pine. An early engraving of one of the drawings of John White, made during the 16th century Roanoke voyages, shows a dancing Indian brandishing a pine branch with long needles and a thick stem resembling longleaf pine (Harriot 1590). The only remnant today, other than scattered longleaf pines in the loblolly pine-dominated woods of Roanoke Island, is a small longleaf pine stand on the Fort Raleigh National Historic Site at Manteo. The original herb layer dominants are unknown, the site having been long fire suppressed and covered with a deep accumulation of pine needle litter. Besides a few clumps of *Andropogon*, practically the only herbs in a study plot were a few specimens of *Cnidoscolus stimulosus*, which is rarely absent from the Baymeade soil. As a fire compartment, Roanoke Island is too small to expect a high fire frequency from lightning ignitions. The presence of longleaf pine there is strongly indicative of either the use of fire by the Indians or a former marsh connection with the mainland. Both causes appear to be likely.

Little's Atlas of U.S. Trees (1971) shows an occurrence of longleaf in central Dare County. According to staff of the Alligator River National Wildlife Refuge, longleaf pine was completely extirpated from mainland Dare before establishment of the refuge (Nofsinger pers. comm.). The most likely location is an isolated ridge of Baymeade sand in the west central part

of the peninsula, surrounded by kilometers of organic soils. Before settlement the species probably also occurred at Mann's Harbor, the only other place on the mainland where suitable soils appear, and may have been found in mixed pine stands on the higher soils near East Lake. Never very extensive on mainland Dare in historical times, not a single longleaf is known to remain. Only a few centuries earlier, however, when sea levels may have been a few meters lower, and before the extensive peat mantling that is accompanying sea level rise, longleaf pine may have been a prominent species on mineral soils of the peninsula.

WET LONGLEAF PINE FOREST AND SAVANNA

LS LONGLEAF PINE/WET SAVANNA HERBS
ln Leon sand

Community type:
___Longleaf pine/species-rich wet savanna.

There are sizeable areas of moist Leon sand on Roanoke Island, but with exception of single longleaf trees here and there, I was not able to find any remnant community tht had been maintained with fire. The associated herb layer under the original fire regime can only be guessed at by comparing that of burned examples elsewhere. All of the Leon sand at Mann's harbor, the only mainland site with longleaf soils other than those mentioned above, has been domesticated, probably since colonial times and no trace of undisturbed natural vegetation remains.

PYROPHYTIC MIXED PINE FOREST AND SAVANNA

MP MIXED LONGLEAF, POND, LOBLOLLY
jo Johns loamy sand

Community types:
___Mixed longleaf-pond pine-loblolly/diverse moist savanna herbs.
___Mixed loblolly pine-pond pine-oaks-hickories.
___Longleaf pine/mixed savanna herbs.

The loamy Johns sand occurs in flats and depressions between the wetter Leon and Icaria sands, and drier sands like the Baymeade on Roanoke Island and Mann's Harbor. Two linear lenses of this soil are also found at East Lake near the Alligator River. No burned examples were seen. All remnants with forest are now dominated by either loblolly or hardwoods. Under the

original fire regime the expected community would have been mixed longleaf, pond pine and loblolly pines, with understory composition depending upon small variations in moisture.

MARITIME FOREST AND SAND BERM VEGETATION

MF	LOBLOLLY PINE, LIVE OAK, YAUPON
du	Dunes and sand berms: wooded, shrubby, or sparsely vegetated

Community types:

___Quercus virginiana-Pinus taeda/Chasmanthium laxum.
___Mixed marsh, dune, and weedy species on frequently overwashed sand berms.
___Pinus taeda/Smilax spp./maritime forest grasses
___Quercus virginiana/Ilex vomitoria

Maritime forest. A very minor type on mainland Dare, live oak, loblolly pine and a few yaupon (*Ilex vomitoria*) are found on wooded dunes of Fripp and Ousley sands (the wooded versions of the Newhan and Corolla dune sands). These deposits occur primarily along the northern fringe of the Albemarle Sound, where waves associated with northeast storms have thrown up sand berms. In counties south of Dare there are remnant examples of maritime sites with both longleaf and live oak (Plot CA01 on Brown's Island in Carteret County). Similarly, live oak would have been a component of those loblolly and longleaf pine sites along the shoreline at Mashoes and Mann's Harbor, and around the fringes of Roanoke Island and Wanchese. These sites, which still have a few live oaks, have nearly all been used for houses and farmsteads since the early 1700s.

OAK FLATS

OF	SWAMP CHESTNUT OAK, WATER OAK, BEECH
cf	Cape Fear loam
OF	SWAMP CHESTNUT OAK, WATER OAK, BEECH
hy	Hyde loam

Community types.

___Quercus pagoda-Q. michauxii.
___Quercus pagoda-Q. michauxii-beech.
___Quercus laurifolia-Q. michauxii-beech/Leucothoe axillaris.

I saw no good remnants of oak flats in mainland Dare but they were to have been expected on these moist, fine-textured mineral soils. This is especially true of the Cape Fear loam where it occupies those sites most sheltered from fire toward the west side of the peninsula.

Some old maps have a site called beech landing on a mineral soil at the edge of a tributary of the Alligator River. This name has been altered to beach landing on some modern maps.

PINE FLATS and GUM FLATS

PF	LOBLOLLY PINE, SWEETGUM
hy	Hyde loam
PF	LOBLOLLY PINE, SWEETGUM
jo	Johns loamy sand

Community types:
___Loblolly pine/Chasmanthium laxum.
___Loblolly pine-pond pine/Myrica cerifera/marsh & swamp herbs.
___Loblolly pine-red cedar/Sabal minor/brackish marsh herbs (margins of brackish marsh).
___Canebrake fringe pyrophytic loblolly pine flats.

POND PINE/POCOSIN

PO	POND PINE/LOW, MEDIUM, OR HIGH POCOSIN
bh	Belhaven muck
PO	POND PINE/MEDIUM OR HIGH POCOSIN
cf	Cape Fear loam
PO	POND PINE/MEDIUM OR HIGH POCOSIN
hy	Hyde loam
PO	POND PINE/MEDIUM OR HIGH POCOSIN
po	Ponzer muck
PO	POND PINE/LOW, MEDIUM OR HIGH POCOSIN
pu	Pungo muck
PO	POND PINE/MEDIUM OR HIGH POCOSIN
rp	Roper muck

Community types:
___Pitcher plant bog.
___Low pocosin.
___Medium pocosin.
___High pocosin.
___Pond pine-Gordonia/medium pocosin.
___Pond pine-Gordonia/high pocosin.
___Pond pine-Gordonia forest.

Pocosin. Of nearly as great an extent as canebrake, pocosin comprised the next vegetation band just inland. There is, however, probably much more pocosin now than in the original peatlands. Pocosin has increased at the expense of canebrake because of reduction in fire frequency, and at the expense of pond pine forest and white cedar because of logging and fire exclusion. While

there appears to be no true ombrotrophic low pocosin in the county, in the original situation fire frequency was high enough that some of the area on the eastern side and on the deeper mucks would have been maintained as pyrophytic low pocosin. In the vicinity of Stumpy Point Bay two large overlapping ovals of vegetation are conspicuous on color infrared aerial photos. These are half marsh, half low pocosin, with the low stature apparently maintained in part by extreme wetness. Both of these features will probably be added to Stumpy Point Bay as sea level continues to rise. A number of interesting species like *Chamaedaphne calyculata* var. *angustifolia* are abundant. Other pocosin remnants, however, are mostly high pocosin. This whole peatland peninsula may have been somewhat more fertile than the ombrotrophic peat domes of the Croatan National Forest or the interior of Pamlico County because of the likelihood of aerosol input of nutrients from the sea. From the center of mainland Dare tall pocosin quickly grades into the peatland forest mosaic of white cedar, pond pine forest, red maple forest, swamp black gum forest and pond cypress forest.

POND PINE FOREST AND WET SAVANNA

PP POND PINE & POND PINE/CANE
ic Icaria loamy fine sand

Community types:
___Pond pine forest.
___Pond pine/diverse wet savanna herbs.
___Mixed pond pine, longleaf pine, loblolly pine/wet savanna herbs.

Pond pine forest. Frequently burned canebrakes have scattered individual trees and stands of pond pine, interspersed with large areas with nothing but cane. Pond pine-canebrake dynamics are complicated. A fairly dense pond pine forest with cane understory may be maintained through a number of light fires, but a crown fire can create a patch of nearly pure canebrake. Crown fires in flat lands usually require high winds (Anon. 1981). Wind events sufficient to drive a crown fire may only coincide with an actual fire at intervals of several to many years. Crown fires, interspersed with understory fires probably account for most of the patchiness in peatland communities. Cane is replaced with pond pine pocosin where fire frequency is reduced to the 13-25 year fire-return interval, and with a mosaic of pond pine forest, *Nyssa biflora* forest, red maple forest, bay forest and pond cypress forest when the frequency was even lower (see Chapter 3, Table 3.2). Such variation occurred across the extended fire-tension zone between the

rarely burned white cedar stands along the Alligator River and the frequently burned marshes and canebrakes of the eastern fringe of the peninsula.

ESTUARINE PINE MARSH, PINE SWAMP

PS PM LOBLOLLY PINE, POND PINE
bh bh Belhaven muck
PM LOBLOLLY PINE, POND PINE
ic Icaria loamy fine sand
PS PM LOBLOLLY PINE, POND PINE
pu pu Pungo muck
PS PM LOBLOLLY PINE, POND PINE
rp rp Roper muck

Community types:
___Loblolly pine/Chasmanthium laxum.
___Loblolly pine/Carex hyalinolepis.
___Loblolly pine-pond pine/Myrica cerifera/marsh & swamp herbs.
___Loblolly pine-red cedar/Sabal minor/brackish marsh herbs.
___Canebrake fringe pyrophytic loblolly pine flats.

Loblolly pine swamp. Not a recognized forest type, loblolly pine swamp nevertheless occurs as nearly pure stands as an oligohaline swamp type on saturated muck soils at sea level. Its persistence in these stressful sites in place of other species appears to be related to its remarkable combination of tolerance to the triple stressors of standing water, salinity and occasional fire. Typical stands may be seen along the fringes of Durant's Island, which, since losing its marsh connection to the mainland in the last few centuries, is now isolated from fire. Live oak cannot tolerate as much wetness and baldcypress is less tolerant of salinity. On more saline sites loblolly is replaced simply by marsh and estuarine shrubs and graminoids, and on freshwater muck soils by typical tidal cypress-gum swamp.

SWAMP FOREST (Cypress-gum Forest)

SW BALDCYPRESS, POND CYPRESS, NYSSA BIFLORA
bh Belhaven muck
SW NYSSA BIFLORA, RED MAPLE, BOTTOMLAND OAKS
cf Cape Fear loam
SW NYSSA BIFLORA, RED MAPLE, LOBLOLLY PINE
hy Hyde loam
SW BALDCYPRESS, NYSSA BIFLORA, RED MAPLE
pu Pungo muck

SW NYSSA BIFLORA, RED MAPLE, BAY FOREST
rp Roper muck

Community types:
___Baldcypress-Nyssa biflora-Fraxinus pennsylvanica.
___Baldcypress-Nyssa biflora-Quercus laurifolia/Sabal minor.
___Baldcypress-tulip poplar-pine-gum fire-disturbance community.

Swamp forest. Along the margins of the Alligator River and in a few other fire-protected locations, true cypress-gum forest may be found. In presettlement times, the extent of well-developed swamp forest was limited because of the absence of significant firebreaks over much of the Dare peninsula. Within 50 to 100 meters of the Alligator River shoreline, tidal cypress-gum swamp is replaced by white cedar and other fire-regenerated communities of the pyrophytic patch mosaic (see Chapter 3, Figure 3.9). In the absence of landscape-scale fire, cypress-gum swamp forest can be expected to expand and take over the habitat now and formerly occupied by the fire-dependent white cedar.

Pond Cypress. Small patches of small but old cypress remain in the patch mosaic of fire communities near the Alligator River. These appear to have originated in pockets where peat burnouts during times of low water table later pooled shallow water. The trees have ascendent foliage with appressed leaflets, more characteristic of pond cypress than baldcypress. Trees up to 330 years old were cored in Plot DA01.

Swamp black gum (Nyssa biflora). This species occurs as an element of the Alligator River interior patch mosaic as well as one of the dominant species in true swamp forest along the river.

ATLANTIC WHITE CEDAR PATCH MOSAIC

WC WHITE CEDAR
bh Belhaven muck
WC WHITE CEDAR
cf Cape Fear loam
WC WHITE CEDAR
hy Hyde loam
WC WHITE CEDAR
rp Roper muck
WC WHITE CEDAR
pu Pungo muck

Community type:
___Atlantic White Cedar

Atlantic White Cedar. Remnants of huge stands of old-growth white cedar on the Alligator River side are indicators of a much lower fire frequency, in the 100-300 year range. The stands along the Alligator River originally rivaled those of the Dismal Swamp--the largest known stand in the range of the species. See Chapter 3 for an aerial photograph of overlapping fire patterns in the white cedar/pond cypress/*Nyssa biflora* fire mosaic that comprised the original vegetation of almost the whole of the western half of the peninsula.

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CASE STUDY 3

PRESETTLEMENT VEGETATION OF THE CROATAN NATIONAL FOREST

ABSTRACT

The purpose of this project was to create a new map of the vegetation of the Croatan National Forest for guidance in managing and restoring portions of longleaf pine, pocosin and other natural ecosystems originally present. Rather than mapping existing vegetation, the intent was to produce the best approximation of the natural vegetation that existed at time of first European settlement. This is the vegetation that dominated the landscape in the late 1600s and for around 6,000 years before. About 95% of original vegetation of the Croatan was in some way structured by fire. About 75% of rare native plants in the South are in some way dependent upon fire to create or maintain their habitat. The Croatan contains a large number of these species. It also contains some of the best remaining fire communities in the South, including the best examples of pond pine communities in the U.S. A new mapping method was used to reconstruct presettlement fire frequency and presettlement vegetation. This involved field sampling of the best remnant vegetation on each of the 51 soil series of the Croatan; compilation of historical information relating to vegetation; characterizing fire effects in each kind of vegetation on each soil series; and identification of fire-frequency indicator species and fire-frequency indicator plant communities. Soil series from recently completed soil maps were then used to put boundaries on vegetation types. Much of the field data were collected over a period of 12 years prior to this study. Approximately 90 days were spent in the field in the Croatan, and several times this amount in surrounding counties. There were 14 major vegetation types in the presettlement Croatan. The Croatan has 51 soil series, some of which supported more than one type of vegetation, resulting in 99 mapping units (combinations of soil series and vegetation type). Using the pyrographic method, descriptions were prepared of the original vegetation types of the Croatan. The resulting fire-frequency map and map of presettlement vegetation were the first produced for a national forest in the South. The Croatan has begun an exemplary program of management for natural forest types, and for restoring

natural processes such as fire. Using this first approximation map as a guide for habitat restoration, the Croatan could become the first national forest in the South to establish management policies that will meet its multiple-use objectives while restoring natural fire regimes and maintaining examples of the full range of rich natural communities that it first encompassed.

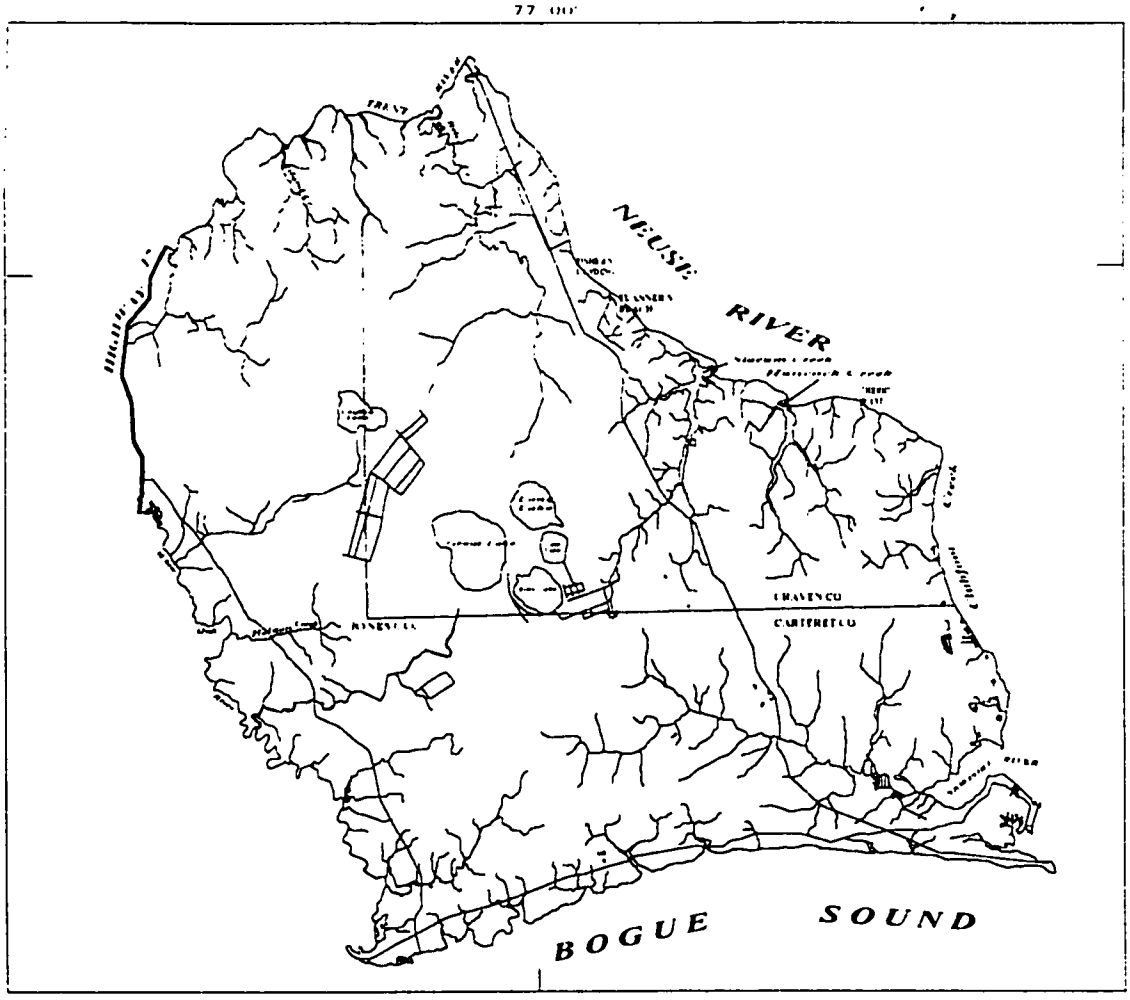
INTRODUCTION

In the southeastern U.S. it is possible to reconstruct original vegetation and natural fire regimes, even where human land use practices dating to the Colonial Era have radically transformed upland vegetation. As demonstrated in Case Study 4, this is feasible even without witness tree records from early surveys, because of the pervasiveness of fire in the presettlement southeastern landscape and the predictability of fire in shaping vegetation (see Chapters 3,4,5 and 6). Given modern soil maps as a basis for examination of vegetation, and any available historical background, a close approximation of original forest and other vegetation types can be obtained.

The landscape now occupied by the Croatan National Forest is pedologically complex but has lost some of the associated complex natural vegetation and species diversity as the result of human disturbance and twentieth century fire suppression. Still there are enough historic materials, native species and high quality community remnants on the site, as well as information from natural vegetation on similar soils beyond the National Forest boundaries, to substantially reconstruct original vegetation.

In a long-disturbed landscape, reconstructing original vegetation requires synthesis of every shred of available physical, vegetational and historic information. In the southeast this also requires interpretation of the role of fire using pyrographic methods. The overall region of which the Croatan National Forest is a part originally experienced a 1-3 year fire frequency on upland sand ridges, upland flats, and over much of the pocosin areas. But despite frequent fire on the more fire-exposed portions of the landscape, topographic complexity, particularly in peripheral areas near the White Oak River, Trent River, Newport River, Neuse estuary and Bogue Sound, permitted the coexistence of frequent fire types like longleaf pine/wiregrass on uplands, along with certain highly

Figure C3.1 The Croatan study area..


NEUSE
RIVER
CRAVEN CO
CARTERET CO
BOGUE
SOUND

fire-intolerant hardwood communities like beech on naturally fire-protected sites (slopes and ravines), sometimes within the space of a few hundred meters. A number of unusual forest communities occupied the fire-tension zones between these extremes. The objectives of this study were:

1. Determine the community types and species composition of original vegetation types and their soil, topographic and fire relations.
2. Reconstruct the generalized presettlement fire regime for the National Forest and region.
3. Create a presettlement natural vegetation map at the resolution of the soil series.

The original vegetation map is suitable for transfer to GIS, as a layer for use in planning, in future studies, and in restoration and management of natural forest communities and wildlife habitats. This prior conditions document and map can also be used to help delimit habitat for endangered and threatened animals and plants. The project also constitutes a demonstration of the pyrographic method for reconstruction of presettlement vegetation and fire frequency regime, and illustrates the applicability of this new method for public lands, natural areas and preserves throughout the southeastern U.S. Figure C3.1 outlines the primary study area, and additional insight was gained from work in the surrounding region. See Phillips (1995) for background on Quaternary Geology, Indians and physical landscape changes.

Historical Records of Croatan Vegetation

Early in the twentieth century, H.H. Brimley published an article describing the lands around Lake Ellis Simon and Little Lake. The story, serialized in four parts in Forest and Stream, was mostly about hunting adventures and life in camp at what is now Camp Bryan on Lake Ellis Simon (Brimley 1910). Brimley was a competent naturalist, however, and enough can be gleaned from his daily accounts and the accompanying photographs to substantially reconstruct local vegetation and make some inferences about fire history.

Brimley usually took the train from Raleigh to "the little way station" along what is now the Seaboard Coast Line, northwest of Havelock, where someone would pick him up. This line,

Figure C3.2. Before construction of the Intra-Coastal Waterway and several major highways, essentially all of the Croatan and Carteret peninsula comprised one single 300 square mile fire compartment without any natural firebreaks. This Landsat image shows the 20th century isolation of natural vegetation to just a few landscape-scale remnants in the Albemarle-Pamlico region, primarily in the Croatan, the Alligator River NWR, and the Great Dismal Swamp. Note also that the peripheral regions around the Croatan have few areas displaying natural vegetation signatures. Vegetation around the margins has been long transformed from the presettlement types to agriculture, disturbance vegetation and fire-suppressed successional forest.


ALBEMARLE-PAMLICO
ESTUARINE STUDY

originally the Atlantic Railroad, is one of the oldest in the state. Emmons (1860) mentions that it crossed savanna lands in the Dover Swamp in 1852. From the railroad stop it was about 6 miles drive to camp, and Brimley commented on the "open pocosin" along the way. This would have been on the last half of the drive which follows deepening organic soils beginning with Rains, Pantego, Torhunta and Croatan, until arriving at the narrow lens of Leon sand along the eastern lake shore. On several days he went along the south shore to a favorite hunting area in low pocosin on the Croatan series (Terric Medisaprists). The height of low pocosin vegetation there in 1910 can be calculated from a photo of Brimley on a short ladder which he said put him 5 ft above the ground. Assuming that he was 6 ft tall, and measuring his height in relation to the amount of ladder exposed above the pocosin, gives a height of 2-4 feet for the pocosin shrubs.

Of the low pocosin Brimley stated "The pocosins spoken of above are large stretches of low, open country, more or less swampy, with a thick growth of low gallberry bushes well and strongly laced together with bamboo brier (greenbrier or smilax)." He described the pond pine cover as "scattering small pines". "These are the light, or low pocosins, but others show a much higher growth, often over a mans's head, and they are then practically impenetrable to anything but game or dogs. There is a saying here that a deer leaps over the obstructions in a pocosin, a bear plows through them, but it is hell on men and dogs--and the saying falls rather short of the real truth. But a path had been bushed out [from the Ellis Simon lake shore] through the high pocosin next to the woods, and one could, with care and time, make his way slowly through the low growth beyond." The stature of the low pocosin can be further inferred from his descriptions of deer "loping easily and comfortably over the low bushes and tangle of tough vines....I saw a second buck covering the gallberry bushes in long, graceful leaps."

Piecing together a transect through the vegetation on the south side of Lake Ellis Simon from Brimley's accounts gives: first the low pocosin to the south, increasing in stature to high pocosin in the vicinity of the lake rim woods. This is the portion through which "a path had been bushed out" for hunting access. Next came a zone of large hardwood forest. There is a photo of the forest but Brimley unfortunately does not mention the tree species. Single trees he mentioned here and there in the woods of the lake margin included tulip poplar, sweet gum, black gum and pine. The hardwoods were extensive enough to support a flock of wild turkeys, and the lack of understory

shrubs and saplings seen of the photograph indicates relatively frequent, light surface fire. Islands of hardwoods on moist mineral soils, surrounded by frequent-fire wetland vegetation like pocosin or canebrake were not uncommon in the presettlement landscape (see Case Study 1). It is likely that the forest there today is very much the same as that seen by Brimley, and the lack of fire control in 1910 makes it likely that this forest was then little different from presettlement vegetation. On the lake side, vegetation was again thicker than in the woods: "...two of us broke through the thickets bordering the lake and out into and beyond the scattering pines (loblolly?) on to the open marsh. At this point the marsh made out fully half a mile from the woods and was only wet near the shore...being fairly dry and firm further out." This was during a time of extended fall drought.

On a day trip to Little Lake, Brimley found pocosin vegetation down to near the lake edge in places, and black gum forest in others. While attempting to stalk bear, he came upon a small patch of dead canebrake in a wooded area near the lake shore: "...as that had been the driest season on record, the ground was pretty dry, and the reed brakes had all been killed out by the high water of the previous year. These dead and prostrate reeds made the noisiest going imaginable. They lay on the ground in all directions, were very dry, as brittle as glass, and it was practically impossible to move among them with any degree of quiet." The soils around Little Lake are mostly the black Torhunta and Croatan, both potential soils for canebrake when they occur where fertility is a little higher than in pocosins, such as on lake shores. *Arundinaria* is particularly intolerant of flooding, explaining the stem kill in a wetter year.

On another day Brimley crossed Lake Ellis Simon by way of the shallow ditch through the center of the lake, which was apparently installed sometime long before 1910. This ditch is still readily visible on aerial photographs. There were several alligator holes, all in the ditch line, suggesting the possibility that the ditching had succeeded in lowering the lake level enough to confine the alligators to the deeper water in the ditch, which was only about a foot deeper than the general lake level. Water was so shallow that he had to wade the last mile and a half, first on firm ground and then on black peaty mud toward the western shore. Brimley had expressed the opinion earlier that the tract of large timber between this and Great Lake was virgin forest. On arriving he wrote: "It was sunrise, and the woods were beautiful. There were some immense trees there, veritable forest giants, cypress and sweet gum, holly and black gum, pine and maple, and it is one of

the most alluring tracts of primeval forest I know of." The soils of this swamp forest between the lakes are mapped Dorovan, and they may be wetter than the surrounding pocosin because of ponding or subsurface flow of water from one lake to the other. The forest also occurs in an unusually fire-sheltered position in an otherwise fire-exposed landscape, being protected on the northwest and southeast by the two lakes.

There are few other historical descriptions of the central Croatan region. Two other writers, however, investigated peatlands in the general region in the 1850s. In April 1852, Ebenezer Emmons came to investigate commercial possibilities of wetlands in the region for the Board of Education (Emmons 1860). According to his estimate there were 2 million a. of "swamp lands" in NC, of which the State owned 1.5 million, not counting marshes. The Legislature had decreed that these lands would be exploited or sold and the monies used to support the school system. It appears he only visited Open Grounds, and possibly the White Oak River headwaters, but his descriptions are valuable for making inferences about vegetation and historical fire frequency in the region.

Emmons treated the central belt of wetlands, from the Open Ground peninsula of Carteret County and the Croatan, across to what is now Hoffman Forest, as a single tract: "South of the Neuse, and lying in Carteret and Jones Counties, there is another immense tract of swamp land, 80,000 acres of which is known as the open prairie of Carteret." "In nearly a continued belt this swamp is 75 miles long from east to west, but its width is less than the Mattamuskeet swamp. It is not by any means perfectly continuous. It admits the passage of roads, but it lies nearly upon one plane, and the slight inequalities scarcely serve to divide it into separate sections." Hoffman Forest, along with the poorly-drained headwater wetlands of the White Oak and Trent Rivers, formed a vast interior wetland complex, including some of the Jones County portion of the Croatan at the northwestern end of his area of interest: "Onslow and Jones Counties contain a part of the great Carteret tract. This tract, at its western extremity, gives origin to the White Oak creek." "The Onslow and Jones swamp, which appear to be connected with the great Carteret open ground prairie and swamp, has an area of over one hundred square miles." "Upon the branches of the White Oak the timber is large, consisting of poplar, cypress, black and white gum and red maple. Other parts are covered with reeds which furnish subsistence to stock during the winter." The reeds referred to are bottomland and small peatland canebrakes. Hughes (1966) estimated the original acreage of

canebrake in North Carolina at around 5 million acres, of which only about 1-3% remain today. Ashe (1894) also reported a number of stands of white cedar in Onslow County, and that it: "...forms the growth of a "bay" of considerable size near the source of the White Oak river" [probably part of Hoffman Forest].

In his investigation of the Carteret peatlands, Emmons' primary interest was Open Grounds but, as he claimed to be describing 200 square miles of land, it may be that his comments also apply to the eastern arm of the Croatan. He seems to have had a poor opinion of the Carteret County peatlands: "It is rare indeed, that we can justly say of this or that piece of land, that it is good for nothing. These remarks are applicable to the tract which we propose now to consider. We shall confine our remarks to that part of this district which is included in Carteret County."

He arrived at the Open Grounds prairie in April, 1852, noting along the road from Beaufort, longleaf pine, loblolly, water oak, baldcypress and black gum. "The great tract in Carteret, generally known as the open prairie, is a marsh or swamp [he seemed not to have been familiar with the term pocosin, and, because of the nearly annual fires Open Grounds seems to have been closer to what Ashe called "grassy pocosins", more a wet prairie or bog than a shrubland], mostly destitute of trees; and hence, the area which is exposed to view is more than ten miles in length and breadth. But the entire tract, has an area of more than two hundred square miles. In this tract, there is a continuity of swamp, ranging somewhat in condition, depth of mud, and solidity of surface, but it is all swamp in reality. It furnishes a growth of coarse grasses [likely dwarf *Arundinaria*, which, in a few places, still formed dense stands less than a meter tall during my field work in the early 1980s, and *Andropogon glomeratus*] over its whole surface, or that part which is open to the sun. This tract is surrounded by a piney ridge which has a sandy soil and bears moderately large, long leaved pines. But the immediate border is so thickly overgrown with briers, reeds [*Arundinaria*], bamboos [*Smilax laurifolia*], and other ugly bushes, that it is at the expense of a man's coat, pantaloons and shirt, if he forces his way through them. This outside hedge is twenty rods wide in many places, and even wider in others. Since improvements, however, on a small scale have been undertaken by means of ditching, the access to the open grounds is easy and safe." "The prairie was filled with water and the facilities for getting over it were only clumps of grassy knowles which stood above the water. It was soft and yielding to the foot every where else, and was easily penetrated to a depth of between five

or ten feet."

Emmons was one of the first to describe radial drainage, noting that the pocosin lands were higher in the center and that is why all streams flow outward. His soil analysis found only 52.7% organic matter in the open ground peat, so he concluded it could be drained and farmed. A test section was ditched to provide drainage and there was a test planting of corn, beans and potatoes in June. As a consequence, he was also one of the first to describe peat subsidence after drainage. A drainage ditch 4 ft deep had been run in a mile and he reported that: "....the ground has settled about 18 inches over an area of about half a square mile."

The noted Virginia agriculturist Edmund Ruffin examined the same area four years later, visiting Open Grounds on July 3, 1856: "Until recently, it has been generally saturated with water, and in wet seasons mostly so covered, that in walking on any part, every step on the spongy surface would sink deep, and every foot-print made would be immediately filled with water." "Nearly the whole of this great savanna, except some pine-covered ground in narrow strips on the margins, is destitute of trees, and nearly so of bushes, and of any shrubs of as much as two feet high" (Ruffin 1861). A square mile block had been ditched in 1855, apparently an expansion of the test drainage initiated by Emmons, draining into Ward's Creek. The weather had been very dry and Ruffin remarked that: "If fire had been then applied, I am confident that the whole upper layer of soil, for some inches at least, would have been burnt off." "...after the ditching and before much drying of the land had yet been caused, a fire that burnt over the dead or dry growth also burnt up much of the banks of the shallower ditches, and in some cases spread some ten feet off, consuming from four to eight inches depth of the original soil."

Ruffin found the surface covered with Sphagnum. In the 1930s, Dr. Lewis Anderson found the surface similarly covered with Sphagnum and the fire-following moss *Funaria hygrometrica*. This species commonly appears in abundance on wet soils the year after a fire, and, according to Dr. Anderson, fire frequency was still every two or three years in the 1930s (Anderson, pers. comm.).

Ruffin saw "...not one grazing animal on all the immense savanna. I did not notice a single tuft of any apparently good grass. Yet there is enough growth of some other kinds to render the

whole surface one impassable thicket, if the fires could be kept off for but two successive summers. The present living plants, except their roots, are all the growth of the present season, produced since the last fires killed everything above ground."

Ruffin's complaint that "if the fires could be kept off but two successive summers" implies annual fires in the 1850s, and the site had burned the year before his visit. The absence of even pond pine, which thrives on the peripheral portions of this tract now, may be due to the combination of extreme fire frequency and the seasonal standing water that Emmons and Ruffin both commented upon. Plant species he reported included some small ericad, and other dwarf shrubs, *Smilax laurifolia*, "the bunched-topped (or wet-land) broom grass" (*Andropogon glomeratus*), *Sarracenia flava*, "and some of the kindred pitcher plant" (*Sarracenia purpurea*?), "and other flowers and weeds of wet and sour savanna lands." *Sarracenia flava* is a frequent-fire indicator species, now disappeared from much of its former range. As Ruffin viewed the area in 1856: "The whole broad surface of the "Open Ground" presents a singular and remarkable scene of desolation and solitude. There was no appearance that any human being had gone as far into the ground as the remoter ditches, since they had been finished."

The Croatan region attracted the attention of foresters beginning shortly after the Civil War (Wah between the States). Sargent (1884) prepared a map of major pine stands of the region, which he divided into three types in the area: longleaf dominant stands, loblolly dominant but mixed with longleaf, and former pine lands from which merchantable pine had already been removed. A band of longleaf running down the Minnesott Ridge in nearby Pamlico County can be clearly discerned. Sargent did not distinguish pond pine from loblolly pine except where found in its stunted pocosin form (which Ashe [1894] called "savanna pine"), so many of the areas mapped mixed loblolly and longleaf were actually mixed stands of pond pine, loblolly and longleaf.

W.W. Ashe, one of the first trained graduates of the Biltmore School of Forestry in Asheville, provided the most reliable descriptions of 19th century vegetation of the region. Fifty years before beginning of effective fire control in the region, and at a time when there were still a few stands of virgin forest remaining, many of Ashe's observations are essentially descriptions of presettlement vegetation. He provides a number of specific references to community types for the

Croatan counties, and some inferences can be made about fire regimes.

Longleaf pine. The dynamics of the various species of pines in relation to fire and fire suppression are complicated. On sandy soils of the Croatan, in fire exposed places, pure longleaf was dominant, with any loblolly and shortleaf being confined to swamp fringes or areas near estuarine shorelines. Pond pine was excluded to adjacent peatlands or wet clayey soils like the Leaf, and loblolly was common along maritime shorelines. With reduction in fire frequency, any of the other three pines could move up into the savannas to form mixtures with longleaf. Around the periphery of the Croatan, however, in fire-tension zones between the pure longleaf savannas and partially fire-protected sites, natural mixtures of two, three or even four pines occurred. Ashe (1915) described four combinations of pines in mixed pine savanna.

Ashe noted that most virgin longleaf had been removed in the Croatan by 1894 and most of the region was coming back in second growth. He commented that: "From Carteret southward there was some uniformity as to its manner of occurrence. It occupied a belt from two to twenty miles wide immediately on the coast...." "In southern Carteret, near the coasts, there are 20,000,000 board feet of long-leaf pine, all consisting of timber in abandoned [turpentine] orchards." Most of the Kureb area along highway 24 had recently been logged in 1897: "Along the great sand hills just within the sounds, the long-leaf pine occurs in open forests of small trees, now largely removed (Pinchot and Ashe (1897). Of the rate of sawmilling of longleaf pine in 1894 Ashe commented: "At this rate of decrease [2 billion bd ft cut in North Carolina in 13 years] in less than 20 years [1914] the long-leaf forests will be a thing of the past."

As with Ruffin's description of fire frequency on the Open Grounds peninsula, Ashe implied nearly annual fires on the longleaf uplands. An ardent advocate of fire suppression, Ashe lobbied for establishing fire wardens, stronger fire laws and more severe penalties. Like some other foresters of the time, he considered fire the ultimate enemy of longleaf pine and was one of the voices most responsible for the strong anti-fire attitude developed later by the Forest Service. He believed that the conspicuous failure of longleaf regeneration was "...due largely to the fires which in many places pass over the land **every year** [emphasis mine] consuming the dead herbage, the wire grass and the leaves of the scrub oaks, and destroying the slow-growing young pines..." He

also had an idea that one of the important ways fire was harmful was that it would destroy the natural humus that would hold moisture and support the growing longleaf. In my study plots at various successional stages, the accumulation of a humus layer is lethal to longleaf seedling establishment.

Longleaf pine and the naval stores industry. During the Colonial Era, New Bern shipped large quantities of tar, pitch and crude turpentine to New york and Philadelphia, where it was reshipped for England, and there the crude turpentine was distilled. Ashe witnessed the decline of the industry in the New Bern area: "By 1855 about one-half of the spirits of turpentine shipped from Wilmington was distilled inland. The shipments from Washington and New Bern had already begun to decline..." "By 1860 the orchards from which Washington drew its supply approached exhaustion and production soon ceased. Newbern being farther south, the industry continued there for several years longer, but after 1870, the decline in production became rapid and practically ceased during the past decade. There is now no distillery in full operation within thirty miles of Newbern" (Ashe 1894).

Early lumber production. Ashe reported that: "As early as 1830 both Newbern and Washington had large trades in long-leaf pine lumber with foreign ports, mostly in the West Indies. By 1860, however, owing to the exhaustion of the long-leaf pine in these sections, their trade had ceased, and since that time these points have become centers for the production of loblolly pine lumber." He also reported that as of December, 1893, only 400 acres of virgin, unboxed longleaf pine remained standing in Jones County. Craven had 5,000 acres of young, second-growth longleaf. The output of lumber in 1893 from the three Croatan counties was:

CARTERET	6.7 million bd ft.	3 sawmills
CRAVEN	46.7 " "	16 sawmills
JONES	2.2 " "	5 sawmills

Replacement of longleaf by loblolly. In Craven much of the former longleaf lands had been cut over in the early to mid-1800s and had come back in loblolly pine: "Although extensive lumbering has been carried on in this county for over half a century it has large tracts of second growth of

loblolly forest which have never been cut into. The long-leaf pine was first removed and was rapidly replaced by the loblolly pine, except on the high sandy lands lying north of the Neuse river [near Bridgeton]. Most of the lumber now manufactured in the county is from this latter pine, although for some mills the savanna pine [pond pine] furnishes a great many logs" (Ashe 1894).

Pinchot & Ashe (1897) summarized the replacement of longleaf by loblolly, which was eventually to be completed over most of the original landscape: 1 "There are large areas, particularly to the south of the Neuse River, on which the two trees occur side by side forming about equal proportions of the woods, but in such places the loblolly pine is in process of supplanting the long-leaf pine, and such woodland will be considered from a sylvicultural point of view, as being more suitable for the growth and development of the loblolly than the long-leaf pine." "The loblolly pine, resisting successfully the fires and uninjured by cattle, has colonized either by solitary specimens or more frequently by groups of a few trees which have already reached maturity, or by thickets of younger ones, wherever openings in the cover have enabled it to secure a foothold. In sections long-settled, where the long-leaf pine has been culled, and in long-abandoned turpentine orchards the loblolly has replaced a great part of the long-leaf pine." "This tree, once dominant over such an extensive area, is surely failing to reproduce itself, and it is fortunate that a tree as valuable as the loblolly pine is supplanting it on these soils [they were commenting on the moister, level soils]." The greater part of the compact loblolly growth to the south of the Tar River has in this manner gradually extended by occupying the lands from which the progeny of its closest competitor [longleaf] has thus been excluded by the influence of human agencies." "Under existing conditions it is impossible for the long-leaf pine to ever again succeed naturally in forming a growth on the lands which the loblolly pine has thus possessed. The shade of the loblolly pine with that formed by the accompanying undergrowth of broad-leaf trees is too deep for the growth of the long-leaf pine seedling beneath them, even where there are long-leaf pines standing near that might produce the necessary seed." In the succeeding 100 years since Ashe's observations, where former longleaf lands have not been converted to agricultural or urban uses, loblolly and hardwoods have consolidated their beachheads. This is especially true in the long settled lands outside the Croatan. Longleaf has been so long excluded from much of its former range that the present owners of the land often have no memory of its ever having occurred there.

Loblolly pine. On frequently-burned, wet, black, mineral soils like the Pantego and Torhunta, transitional between peatlands and uplands, pure pond pine stands extended over many thousand acres, continuing into wet clayey flats of Leaf soils. Where partially fire-sheltered, pond pine and loblolly coexisted on these soils. With fire suppression the extent and percent of loblolly has increased.

Ashe (1894) recorded the original extent of loblolly pine in the region and described some of the successional changes that had already occurred by the late 19th century : "Loblolly pine was originally confined to the lower and moister land, especially where it was loamy or slightly clayey, over the entire coastal plain region and westward beyond it for a distance of about forty miles. While its limits have not materially changed, it has increased its acreage, occupying now some of the higher and more sandy land, especially tracts which have once been under cultivation and much of the moister soil once completely or partially occupied by the long-leaf pine." As regards, the clayey lands (soils like Leaf and Lenoir), by 1915 Ashe had come to distinguish that much of what he originally called loblolly land was actual mixed loblolly and tall, straight pond pine. From past usage, he somewhat loosely uses the term loblolly pine lands when referring to the natural mixed pine stands. He sometimes also includes second growth loblolly on former longleaf pine sites in the "loblolly pine lands", but mentions that some of these lands were covered with "the old-field pine (up to 2 1/2 feet diameter)". Many of these old field stands had already been logged.

While supplies of longleaf continued, loblolly was considered relatively worthless as a timber tree. Ashe observed the change in attitudes in the mid-19th century: "As the supply of long-leaf pine became exhausted north of the Neuse River other pines were used in its place, the short-leaf pine being the next used and then the loblolly." "It is only within the past thirty years [1864-1894], however, that the loblolly pine has entered the general market in the form of lumber, being debarred, previous to that time, because of the fact that so large a proportion of it is sap wood" (Ashe 1894). It was the introduction of drying kilns that ultimately made loblolly pine marketable.

By 1915 Ashe reported that: "The loblolly or North Carolina pine is by far the most important tree now being cut for lumber in North Carolina. While distributed over only the eastern half of the state, yet this tree furnishes more than half of the annual lumber cut of the whole state.

Most of the lands which many years ago were denuded of longleaf pine by the turpentine operators and the lumbermen and then devastated by fires and hogs, later came up to loblolly pine and now 50 to 100 years later are furnishing another and a more remunerative crop of timber (Ashe 1915)."

Pond pine. Over the years between his three major publications (1894, 1897, 1915), Ashe took more pains to distinguish pond pine from loblolly in stands he investigated. *Pinus serotina* did not generally come to be called pond pine, a rather inappropriate name, until the 20th century. "Savanna pine (*P. serotina* Michx.) is also called short-leaf and other names for it are old-field pine, bastard short-leaf, swamp and pocosin pine. This pine is seldom recognized as distinct from the loblolly. Its most frequent designation where so distinguished is *pocosin pine*, from its growing in flat marshy [swampy/boggy] land; the flat, undrained lands, usually at the head of streams, being called 'pocosins'. These pocosins are covered with a low growth of gums, this pine, and an undergrowth of gallberry bushes, huckleberries and andromedas [*Zenobia*], while in places there is more or less coarse, densely stooled grasses and sedges."

While lumbermen usually did not distinguish tall, straight pond pine from loblolly, and Ashe himself probably often failed to notice it in mixed stands in his early explorations of what he called the loblolly pine lands. By 1915 he took care to describe habitats with mixtures of tall pond pine and loblolly. Besides the similarity of pond pine and loblolly growing on moist mineral soils, the issue may have been further confused by the common name loblolly, which means a wet or boggy place, and both species were largely confined by fire to wet soils until human intervention allowed loblolly to escape onto uplands.

While being one of the early crusaders against fire, Ashe (1915) acknowledged its role in maintaining open savannas on wet mineral soils: "The frequent fires on the heavy sod on the longleaf pine flat land [low, moist mineral soils like Leon, Rains and Lenoir] and the pocoson pine savannas are responsible to a large extent for the open stands on such lands." "The same is true of the grassy peaty lands." As mentioned above, the "grassy peaty lands included very frequently burned areas like Open Grounds, and possibly the boggy, wet centers of the largest low pocosins on the Croatan, when they were frequently burned.

While beyond the boundaries of the Croatan, Ashe's description of pond pine savanna in Craven County's Dover Swamp paints a very different picture from modern vegetation: "There are nearly 200,000 acres of swamp in the county, the Dover swamp, lying in the south-western section, having an area of over 120,000 acres. This swamp is sandy, and in the interior is covered with an open growth of the savanna pine and occasional cane brakes."

The original extent of pond pine forests has been largely overlooked. Where pond pine grew tall and straight, as on flats of a number of the extensive wet mineral soils like Leaf, Rains, Torhunta and Pantego, lumbermen, as noted by Ashe, seldom distinguished it from loblolly. By 1897 Ashe had a better view of the extent of pond pine, when he wrote: "In a few limited districts a considerable part of the saw-logs are from this species. It is chiefly of importance on account of the large areas in the State on which it occurs as the only timber tree." He noted that: "There are possibly 300,000,000 board feet of the *savanna pine* in pocosins and around the edges of swamps...." Craven and Jones were mentioned as two of the six counties having the most pond pine (Pinchot & Ashe 1897).

Outside the Croatan, pond pine has disappeared from much of its former range. Where it occurred in tall stands of commercial density, it was a s valuable as loblolly, and has long since been removed. Since it is dependent upon fire to keep its habitat open enough for regeneration and maintenance, sites logged and fire suppressed succeeded to red maple, other hardwoods, bay forest or loblolly.

Shortleaf pine. Although it occurs in several places, there are few clear historical references to shortleaf pine (*Pinus echinata*) in the Croatan. Ashe (1894) stated that it had largely been removed by the time of his investigations: "South of the Neuse River it was a rare tree, being found in small clumps interspersed among the long-leaf pines where the soil was inclined to be a dry or gravelly loam."

Both loblolly and pond pine were sometimes called shortleaf where they co-occurred with longleaf. Edmund Ruffin (1861) who did recognize *Pinus echinata*, commented that, while it may have been never abundant on the coastal plain, it appeared to be declining from a somewhat greater

extent in the early 1800s. Pinchot and Ashe (1897) commented that "shortleaf pine has as thoroughly disappeared as longleaf." Its principal habitats in the Croatan appear to have been in the peripheral mixed pine savannas on sandy soils like the Wando and Seabrook in fire-tension zones transitional between interior longleaf and peripheral maritime forest. Scattered trees and small stands still can be found along the Bogue Sound fringe, in sandy woods near the White Oak River, and on soils like the Norfolk sand along the Trent River. It may also have been a significant component of mixed pine savanna and pyrophytic woodland on certain fine-textured upland soils like the Nahunta and Lenoir where it occurred intermixed with other pines and post oak.

Cypress. Most cypress appears to have been logged before the end of the 19th century. A respondent to P.M. Hale's 1882 timber questionnaire, said of Carteret County: "Our swamps abound with oaks and cypress" (Hale 1883). Ashe, however stated that "there is now found in Carteret county scarcely any cypress suitable for mill purposes (Ashe 1894). In Craven he found that "the supply of cypress and ash in the river swamps is nearly exhausted, Swift creek and Trent river being now the principal sources of supply." In the small stream swamps, Ashe observed that cypress seemed not to be regenerating after logging: "the thickets of water and sweet gums growing beneath them have rapidly pushed upward to take the place of the cypress on its removal." The closure of the *Nyssa aquatica* and *N. biflora* canopy after removal of the towering, emergent, primeval cypress seems to have been a universal phenomenon throughout the south, and a century later there seems to have been little recovery of cypress.

Wet Hardwoods. Wet oak forests occurred on the slightly higher swamp microsites and on low-lying wet flats such as in the White Oak Swamp region in the headwaters of the White Oak and Trent rivers. While *Quercus alba* was common on slopes along both the White Oak and Neuse shorelines, the white oak referred to may most often have been swamp chestnut oak. Ashe seems to have used the terms swamp white oak and swamp chestnut oak interchangeably. White Oak swamp was "...fringed with a broad band of swamp white oak [Quercus michauxii?] and water oak flats [Quercus nigra]" (Ashe 1894). In another place Ashe says the Craven County swamps "...are fringed with swamp chestnut oak or water oak flats, which have never been cut into (Ashe 1894). Pinchot and Ashe (1897) remarked that Jones was one of the few counties where white oak had not yet been severely culled. They also expressed the opinion that "white oak" had been widely

replaced by water oak after logging. In my own experience, water oak seems to occur most commonly as a seral species on moist mineral soils, especially where sandy.

Upland hardwoods. There is little mention of upland oaks and hickories anywhere in the region, except in relation to slopes or fire-suppressed areas. In Hale's timber survey for Carteret County it was only mentioned that there were "...various kinds of oaks, the most abundant kinds being the red and black-jack varieties. We have some hickory, but of smaller size" (Hale 1883). The red oak referred to, probably *Quercus falcata*, should have been common, as it is today, on the steeper slopes of the sandy Autryville, Marvyn and Wando series along streams and shorelines. In the Carolinas, "black-jack" usually referred to *Quercus laevis* in the 19th century, the term turkey oak not having come into general usage until the 20th century. Large *Carya tomentosa* and *Carya glabra* can be found on the steep, fire protected slopes of Autryville and Suffolk soils near shorelines and these, as well as *Carya cordiformis*, are frequently found as components of pyrophytic woodland.

One of the most fire-intolerant of trees, beech (*Fagus grandifolia)* nevertheless thrives in several kinds of natural fire refugia in the Croatan. W.W. Ashe, while he made immensely valuable contributions as the first professional forester to write about forests of the Coastal Plain, had no grasp or appreciation of the role of fire in structuring forest communities. He believed that beech was scarce in the Croatan region because of a need for humidity! "In a few places in the vicinity of the coast, or near large bodies of water where the air is especially humid, there is a considerable intermixture of beech with the oaks (Pinchot and Ashe 1897)." While all of the beech sites in the Croatan are cooler and moister than the general upland climate, this is mostly a coincidence of topography. One thing that is clear upon reconstructing presettlement vegetation and fire regimes is that in frequent-fire landscapes, fire-sensitive species like beech were strictly confined to the few fire refugia. Ware observed that in long fire-suppressed and un-logged sites, beech has escaped from its fire-protected bottomlands and slopes, onto the uplands (Ware 1978, Ware et al. 1993).

In the Croatan beech is found in three topographic situations. First are the steep slopes on soils like the Suffolk series in deeply-cut small stream drainages truncated by the Neuse River estuary. These are probably the most fire-protected habitats in the Croatan, and contain a large

number of other fire-refugial species like *Magnolia tripetlala*, *Aesculus pavia* and *Storax grandifolia*. Second are ravines like those at Island Creek, and slopes along deeply cut small swamp drainages like those on Marvyn soils in the interior of the Croatan. Finally are the stands on wet mineral soils along swamps, where gently sloping soils lead down from upland fire communities. Good examples can be found in the Brice Creek watershed.

The overall historical picture demonstrates that there were significant components of hardwood forest, swamp forests, and loblolly pine, but the strong indication is that pond pine and longleaf were the two dominant tree species in presettlement forests of the Croatan. The best and most extensive remaining examples of the tall forms of pond pine communities occur in the Croatan. As such these stands are a valuable, and until recent years, overlooked component of the natural diversity of the Forest. I know of no place within its range where management plans include perpetuation of the diversity of pond pine savanna, pond pine canebrake or pond pine forest communities.

METHODS

General methods for reconstructing presettlement vegetation were outlined in Chapters 5 and 6. The methods used for the Croatan included vegetation analysis in the field, historical records, historical photos and the use of soils to put boundaries on vegetation. Only a few relevant historical photos were found, mostly those by H.H. Brimley of the North Carolina Museum of Natural History. The difficulty with using historical photographs is that, in the Croatan vicinity, as in most of the rest of the South, any landmarks that could be used to place the locality of the photograph are hidden by the trees. The few exceptions are those photos taken by Brimley around the interior lakes in the early part of the century (Brimley 1910 and Bryan Family Papers, UNC Library, North Carolina Collection).

In this application of the pyrographic or landscape fire ecology method for developing maps of presettlement vegetation, six major steps led to production of the final map:

1. Field work approximating presettlement community types. Over a 10 yr period I sampled numerous examples of natural vegetation in the three counties. Most of the work was done between 1982 and 1990. Fifty-seven 1/10-hectare plots were used to sample plant communities in and around the Croatan, and 61 more were done in surrounding counties. There were 28 in Carteret County, 14 in Craven and 15 in Jones; about half these were outside the boundaries of the Croatan. A less intensive survey method was used at other sites. The recently completed county soil maps on aerial photos were used to locate remnant natural vegetation on all of the soils of each county (Barnhill 1991, Goodwin 1987, 1989. Complete species lists were compiled for each soil series at each site examined. Dominant plant species were recorded by stratum and a variety of fire history information was taken. Trees were cored and shrubs were examined to determine time since last fire. Successional trends under fire suppression were observed on each soil series here and in other counties, and extrapolated into the past to get an estimation of previous vegetation. A first approximation species list and description of presettlement plant communities was prepared for each soil series.

2. First approximation vegetation map. As tentative or predicted presettlement community types were built up for each soil series during field work, additional sites were visited to check the predictions, and the community descriptions were periodically refined as needed. A preliminary map was then constructed using all of the 51 soil series of the Croatan and vegetation types were assigned to each series.

3. Fire frequency map. The first vegetation approximation, along with information from study plots in 18 other counties in the region, was used to help construct a generalized presettlement fire frequency map. In turn, the fire frequency map was used to further refine the vegetation map. Another round of field work was then required to provide answers to unresolved questions. In particular, it became obvious that, for all but a few soils, there was often more than one community type on the same soil series, and it was necessary to visit and document each of these.

4. Second approximation vegetation map. With these questions addressed, revised vegetation descriptions were prepared for each soil series. These were not necessarily descriptions of existing vegetation but were refined estimates of presettlement vegetation. Many kinds of evidence were

weighed, including remnant fire-frequency indicator species mentioned above, and fire-frequency indicator communities like canebrake. Successional status of vegetation on each series, in various stages of fire suppression, was also considered, as was evidence from tree cores, including fire scars and other evidence of cyclic wildfires such as even-aged stem classes. Decisions were also influenced by evidence from remnant fire communities on the same soil series in nearby counties.

5. Final vegetation map. The final map was produced by making adjustments to mapping units based on the additional historical information.

Mapping Unit Example

Mapping units used are the individual soil pedons, exactly as they appear on the county soil maps. Map unit codes consist of couplets with the uppercase letters indicating vegetation type and lowercase indicating the soil series, usually the same code as used on the county soil maps. For example MB/lf is the code for brackish marsh on Lafitte muck (see descriptions below and key on enclosed vegetation map supplement).

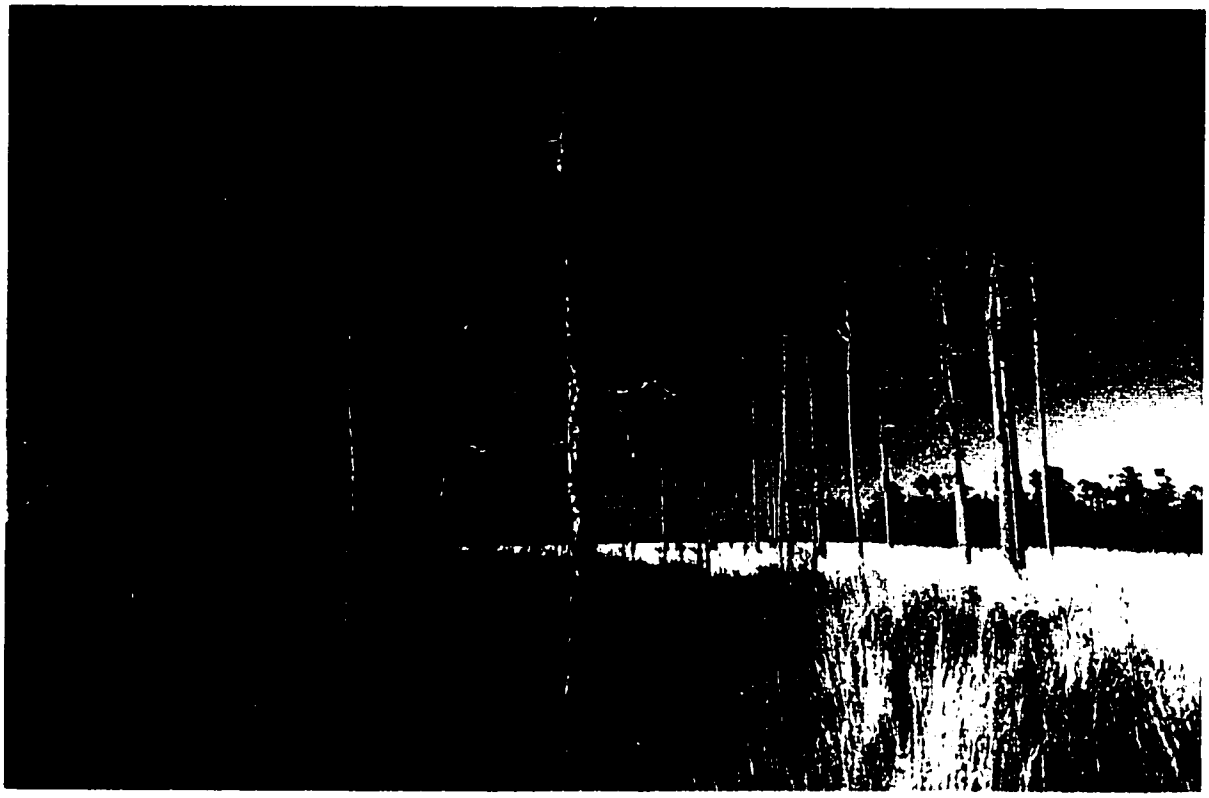
There is not room to go into all of the evidence and rationale for each mapping unit, but it may be useful to discuss one unit as an example. LS/ln is the coding for wet longleaf pine savanna on Leon sand. These moist sands occur in a number of topographic situations such as the ridge and swale system between Nine Foot Road and Hibbs Road, and also as low sand lenses in the great peatlands. Many of the latter appear to be the partly peat-mantled sand rims of buried Carolina Bays. Many good examples of vegetation on the Leon occur in the Croatan, while others have become shrubby or densely wooded because of reduced fire frequency. The presettlement vegetation type is described below as species-rich, frequently-burned, longleaf pine wet savanna. The preliminary fire frequency map indicated the presettlement fire frequency for the sandy parts of the Croatan as 1-2 years, the highest fire frequency class. As one of the principles of landscape fire ecology discussed earlier, in ridge and swale systems it is considered likely that a long body of sand with high fuel-continuity types like longleaf pine litter and wiregrass, could burn at a higher frequency than adjacent types because it could be ignited by local fires in adjacent pocosin anywhere along its length. These fires

could then carry along the more flammable savanna for some distance, so these soils would be expected to have a higher fire frequency than those of the adjacent pocosins, which are estimated to have burned at a slightly lower frequency, perhaps every 3 yrs on average. Vegetation on small lenses of Leon sand isolated in the great pocosins would burn at the same frequency as the surrounding pocosin. A large number of typical southeastern savanna herbs were found in this area, including a number of rare species and several near the northern limit of their range. Many Leon savanna remnants have been long fire-suppressed, so all stages of fire-suppressed succession are available for study. Typically, on such fire-suppressed sites the oldest trees on the sites examined sites were longleaf, but the understory had filled in with young pond pine, Nyssa biflora, Gordonia, and dense shrubs, mostly species of the adjacent pocosins. These woody pocosin species are ordinarily kept reduced to fire-dwarfed forms in regularly burned Leon savannas. The herb layer was shaded, litter-buried and very depauperate in many areas. In several interior savannas surrounded by pocosin, Venus's flytrap was found, an obligate pyrophyte, and an indicator species for the highest fire-frequency class. Another frequent-fire indicator species on Leon sand, Lysimachia asperulaefolia, is a federal endangered species, believed to be endangered primarily because of fire suppression and its dependence upon frequent fire (Frantz 1994). Venus's flytrap is listed as a Special Concern species in North Carolina and is declining as a result of habitat loss and fire suppression (Boyer 1994). Over much or their former range the two species are barely surviving, having been extirpated or excluded from their original habitats to small sunny patches where logging roads and hunting trails cut through the heavy shrub cover on the Leon sand.

None of the savanna species found on the Leon are weedy or known to be rapid colonizers. The entire assemblage on the Leon sand seemed clearly indicative of fire-suppressed remnants of a once extensive, much more open, frequently-burned, species-rich longleaf pine savanna system. In reaching this conclusion, both plot data and casual observations of vegetation on some 40 examples of Leon sand were considered. Fire-indicator species, species composition, vegetation structure, plant succession, fire history, fire compartment size, fire compartment shape, and site position in the landscape all contributed to the classification.

Equally involved rationale supports conclusions about each of the approximately 100 other mapping units. These are grouped into the 14 broad vegetation associations or alliances described below.

Figure C3.3. A virgin stand of longleaf pine on an isolated sand lens, part of a peat-buried Carolina Bay sand rim, southeast of Millis Road savanna. Some of the trees are over 200 years old. This is one of the most important sites on the Croatan, one of the few examples of virgin plant communities left in North Carolina. The Savanna exhibits the classic bilayered structure, with pure longleaf pine canopy and a wiregrass-dominated herb layer. It also demonstrates a striking phenomenon of frequently burned wetland-upland contacts in the South. In such wet ecotones, pond pine comes up to within a meter or two of the mineral soil, and longleaf comes down to within a few meters of the organic soil, but there is a treeless zone between the pond pine and the longleaf. Several rare species occur in the wetter portion of this treeless, fire-maintained ecotone. In the photo, wiregrass is flowering and the site had been burned by a wildfire in the preceding season (photo taken around 1993).



The descriptions focus on community dominants, but complete lists of all species found, by vegetation layer are available to support the classification. One or more specific community types are also given for each group mapped. These individual community types are not described further here but complete species lists and cover values for the sample plots can be found in the appendices.

Vegetation Descriptions

There were some 14 major presettlement vegetation associations of the Croatan, of which three were not mappable: canebrake because of its disappearance over substantial areas; bottomland hardwoods because the sites are small and are included in areas just mapped as swamp; and bay forest because of its tendency to occur as narrow zones which do not correspond well to particular soil series. The major communities were distributed over the 51 soil series, which, in various combinations produced a little over 100 mapping units listed below (see enclosed map supplement). Ordinarily, mapping units would not correspond strictly with soil series. There can be more mapping units than soil series, since, for example, more than one plant community was found on some of the organic soils in large peatlands. Also, in some cases, it would make sense to combine pairs of very similar soils with nearly identical vegetation into one mapping unit, especially where there is too much fine detail for the map scale. However, to facilitate transferring presettlement vegetation to GIS, all soil series boundaries were retained on the accompanying map.

Transfer to GIS. Where the same soil series has fire vegetation in the center of the Croatan and non-fire vegetation in some of the partially fire-protected peripheral areas, it will be necessary to label individual polygons (soil pedons) as they appear on the accompanying hand-drawn map. Also, in preparing output maps from GIS, it may be desirable to shade similar vegetation types, e.g. all those listed under Mixed Pine Savanna as the same color or shading pattern. This would make the map much more readable for the major associations.

Table C3.1. Master list of the 51 soil series in the Croatan National Forest. Two-letter county codes (Ca, Cr, Jo) indicate the counties (Carteret, Craven, Jones) in which each of the soil series occurs. For vegetation mapping, each soil series was also given a two-letter code. In most cases these match the soil series codes on the county soil maps, but in four instances, different codes were used for the same soil series on the original maps for the three counties, so a uniform symbol was chosen. In these cases the original code is shown in parentheses. An asterisk after the two letter soil code indicates one or more (up to five) intensive tenth hectare plots were surveyed to document vegetation on that soil. For the rest, species lists and several other kinds of information were obtained.

Table C3.1. MASTER LIST OF SOIL SERIES

(N=51) SERIES	COUNTIES	MAP CODE	TAXONOMY
Alpin	Jo	an*	Typic Quartzipsamments (fine sand)
Altavista	Ca, Cr	aa*	Aquic Hapludults (fine sandy loam, loamy fine sand)
Arapahoe	Ca	ap*	Typic Humaquepts (fine sandy loam)
Augusta	Ca, Cr	ag*	Aeric Ochraquults, (fine sandy loam, loamy fine saand
Autryville	Ca, Cr, Jo	au*	Arenic Paleudults, (loamy sand, loamy fine sand)
Bayboro	Cr, Jo	ba	Umbric paleaquults, clayey (mucky loam)
Baymeade	Ca	by*	Arenic Hapludults (fine sand)
Carteret, high	Ca	ch*	Typic Psammaquents (sand, high phase)
Carteret, low	Ca	cl*	Typic Psammaquents (sand, low phase)
Conetoe	Ca, Cr	cn*	Arenic Hapludults (loamy sand)
Craven	Ca, Cr, Jo	cr*	Aquic Hapludults, clayey (loam, silt loam)
Croatan	Ca, Cr, Jo	ct*	Terric Medisaprists, loamy, siliceous dysic (muck)
Dare	Ca, Cr	da*	Typic Medisaprists (muck)
Deloss	Ca, Cr	de*	Typic Umbraquults (fine sandy loam)
Dorovan	Ca, Cr, Jo	do*	Typic Medisaprists (muck)
Exum	Cr, Jo	ex*	Aquic Paleudults (silt loam)
Goldsboro	Ca, Cr, Jo	go*	Aquic Paleudults (loamy fine sand)
Grantham	Cr, Jo	gr	Typic Paleaquults (silty loam)
Hobonny	Jo	ho	Typic Medisaprists, euic (muck)
Hobucken	Ca	hb*	Typic Hydraquents, nonacid (muck)
Johns	Jo	jo	Aquic Hapludults (fine sandy loam)
Kalmia	Jo	ka	Typic Hapludults (loamy sand)
Kenansville	Jo	ke*	Arenic Hapludults (loamy fine sand)
Kureb	Ca, Cr	ku*	Spodic Quartzipsamments (sand)
Lafitte	Ca, Cr	lf*	Typic Medisaprists (muck)
Leaf	Cr, Jo	la*	Typic Albaquults, clayey (silt loam)
Lenoir	Cr, Jo	le*	Aeric Paleaquults, clayey (silt loam)
Leon	Ca, Cr, Jo	ln*	Aeric Haplaquods (sand)
Lynchburg	Ca, Cr, Jo	ly*	Aeric Paleaquults (fine sandy loam)
Mandarin	Ca	mn*	Typic Haplohumods (sand)
Marvyn	Jo	mv (Ma)	Typic Hapluduults (loamy sand)
Masontown	Ca	ma*	Cumulic Humaquepts, siliceous, nonacid (mucky loam)
Masontown	Cr	mm*	Cumulic Humaquepts, siliceous, nonacid (mucky fine sandy loam) and Muckalee: Typic Fluvaquents, nonacid (sandy loam)
Meggett	Cr, Jo	me	Typic albaqualfs (sandy loam)
Muckalee	Jo	mk	Typic Fluvaquents, nonacid (sandy loam)
Murville	Ca, Cr, Jo	mu*	Typic Haplaquods (mucky sand, mucky loamy sand)
Nahunta	Jo	na*	Aeric Paleaquults, fine-silty (loam)
Norfolk	Ca, Cr, Jo	no*	Typic Paleudults (loamy fine sand)
Onslow	Ca, Cr, Jo	on*	Spodic Paleudults (loamy sand)

Pactolus	Jo	pc* (Pa)	Aquic Quartzipsamments (loamy fine sand)
Pantego	Ca, Cr	pa* (Pn)	Umbric Paleaquults, (fine sandy loam)
Rains	Ca, Cr, Jo	ra*	Typic Paleaquults (fine sandy loam)
Roanoke	Ca, Cr	ro*	Typic Ochraquults, clayey (loam, fine sandy loam)
Seabrook	Ca, Cr	se*	Aquic Udipsamments (fine sand, fine loamy sand)
Stallings	Jo	sg (St)	Aeric Paleaquults (loamy fine sand)
State	Ca, Cr	st*	Typic Hapludults (loamy fine sand, loamy sand)
Stockade	Jo	sx	Typic Umbraqualfs (fine sandy loam)
Suffolk	Cr	su	Typic Hapludults (loamy sand)
Tarboro	Cr	ta	Typic Udipsamments (sand)
Tomotley	Ca, Cr	tm*	Typic Ochraquults (fine sandy loam)
Torhunta	Ca, Cr, Jo	to*	Typic Humaquepts (mucky fine sandy loam, and fine sandy loam)
Wando	Ca	wa	Typic Udipsamments (fine sand)
Woodington	Jo	wo	Typic Paleaquults (fine sandy loam)

Table C3.2 VEGETATION AND SOILS OF THE CROATAN NATIONAL FOREST RANKED APPROXIMATELY FROM DRIEST TO WETTEST

	SOIL SUBGROUP	SOIL SERIES
1	Spodic Quartzipsamments	Kureb□
2	Typic Quartzipsamments	Alpin□
3	Typic Udipsamments	Tarboro□, Wando□■*
4	Arenic Paleuduults	Autryville●*
5	Typic Paleudults	Norfolk□*
6	Arenic Hapludults	Baymeade□, Conetoe□, Kenansville□*
7	Typic Hapludults	Kalmia□, Marvyn●*, State□, Suffolk●
8	Aquic Quartzipsamments	Pactolus□
9	Aquic Udipsamments	Seabrook■●#
10	Aquic Paleudults	Exum□#, Goldsboro□
11	Spodic Paleudults	Onslow□
12	Aquic Hapludults	Altavista■●*, Craven□, Johns#
13	Typic Haplohumods	Mandarin□
14	Aeric Paleaquults	Lenoir○#, Lynchburg□, Nahunta#, Stallings□*
15	Typic Paleaquults	Grantham○, Rains□○, Woodington□○
16	Aeric Ochraquults	Augusta●
17	Typic Ochraquults	Roanoke●, Tomotley●
18	Typic Albaqualfs	Meggett●*
19	Typic Albaquults	Leaf○*
20	Aeric Haplaquods	Leon□
21	Typic Umbraqualfs	Stockade●*
22	Typic Humaquepts	Arapahoe○#, Torhunta○
23	Umbric Paleaquults	Bayboro○, Pantego○
24	Typic Umbraquults	Deloss○
25	Typic Haplaquods	Murville○
26	Typic Fluvaquents	Muckalee●
27	Cumulic Humaquepts	Masontown●

28	Terric Medisaprists	Croatan○
29	Typic Medisaprists	Dare○, Dorovan●
30	Typic Hydraquents and Typic Medisaprists	Hobucken muck, Hobonny muck and Lafitte muck
31	Typic Psammaquents	Carteret m

□ Longleaf dominant stands.

○ Pond pine dominant or a significant component.

Mixed pine savanna or pyrophytic woodland.

* Loblolly pine significant, usually with other pines or hardwoods.

● Hardwoods dominant (includes uplands and swamp hardwood stands).

■ Maritime forest.

m Marsh.

Characters following each series indicate the most typical dominant species. Variations are discussed in the appendix summarizing vegetation by soil series. Groups 21 to 24 are soils transitional from uplands to wetter areas and have conspicuous black organic layers over mineral soil. Groups 25 to 31 are mostly muck soils underlying peatlands, marshes and swamps (except the sandy Carteret). Moisture classes are based on soil taxonomy (Natural Resources Conservation Service).

Community types. Numerous specific community types were distinguished, but mapping is not necessarily by community type, which would be too fine-textured for this map scale, and many of these were fire-suppression artifacts. Some mapping units, especially on uplands, do correspond to a single community type but most include two or three.

Vegetation Types. The vegetation types described below are mostly major vegetation groups at something like the plant Association or Alliance level. Most are obviously broader than specific community types such, as might be found in a specific stand. They are also slightly broader than the groupings that would be expected in a numerical classification, since some large groups like hardwoods or longleaf uplands are not broken down into smaller groups. No attempt has yet been made to fit these into existing classification systems since many of these communities do not agree well with current classifications, which are based in large part on fire-suppressed replacement communities. In this approximation I have tried to let the evidence define the presettlement, pyrophytic community groupings rather than to tease them into an existing classification. Correlation with Schafale and Weakley (1993), or more general systems could now be done.

Vegetation types are arranged below in alphabetical order according to their two-letter vegetation type code as used on the accompanying map. A few presettlement types are included here that do not appear on the map because they were either too small, too dispersed, or too long displaced by succession or disturbance to adequately map:

CANEBRAKE-POND PINE FOREST MOSAIC (not mapped)

MPOC=medium pocosin, HPOC=high pocosin

CA	MPOC, HPOC, POND PINE/CANEBRAKE
ct	Croatan muck
CA	MPOC, HPOC, POND PINE/CANEBRAKE
de	Deloss fine sandy loam
CA	POND PINE/CANEBRAKE, HPOC
pa	Pantego loam
CA	POND PINE/CANEBRAKE, HPOC
to	Torhunta fine sandy loan

Community types:

___Canebrake (*Arundinaria gigantea*), trees lacking.

___Pond pine/canebrake, with highly variable pond pine cover--pines in patches or relatively evenly scattered.

___Mixed pine/canebrake (longleaf, pond pine, loblolly)

___Bottomland hardwoods/canebrake.

Being dependent upon frequent fires, canebrake has been one of the communities most affected by reduction in fire frequency on the Croatan. While canebrake reaches its best development on organic soils around a meter deep, it can sometimes be found on mineral soils with high organic content, as well as on peat two meters deep where nutrient status is not severely limited. In the central Croatan, however, soils underlying the great pocosins are apparently too oligotrophic for cane (see canebrake and pocosin vegetation in the peatland tables of Chapter 3. On the periphery, however, where organic soils are less than 1 meter deep and feather out onto mineral soils, there are still areas where cane forms a dominant understory after fire, and there were surely substantial zones of canebrake and pond pine/canebrake in presettlement communities. While the cane rhizome mats may have died out in some places, the response of cane after the great Fish Day Fire of May 21 to Thanksgiving, 1994 gives some indication of its original extent.

Canebrake, once one of the principal and most extensive vegetation types of presettlement coastal peatlands and fluvial bottomlands, has largely vanished, as pocosin, red maple and bay forest have replaced the cane rhizome mats waiting vainly for the next fire. The great canebrakes of the South, recorded in numerous historical accounts, were centered in Cells 10 and 18, in the peatland tables (Chapter 3). Average fire frequency for peatland canebrakes may have been around every 3 yrs, but canebrake thrives under a 2 year fire-return interval in some small stream bottomlands on Ft. Bragg. In addition, large portions of the peatlands having a slightly lower fire frequency, experienced a cycle of alternating canebrake and pocosin (Cells 11 and 19). In this situation, cane dominates for 3 or 4 years after fire and pocosin dominates after 7-8 years. This phenomenon, apparently widespread in original peatlands, has only recently been described (Frost 1995). The site has the appearance of pure canebrake in the years immediately following fire. In the big peatlands, pond

pine is usually the only tree to survive canebrake fire. Pocosin shrubs resprout after fire but are suppressed by the dense cane, which may reach 2 meters tall in the first full growing season. The shrubs, however, are very slow to regain their pre-burn stature. Eventually, toward the end of the fire cycle, shrubs overtop and suppress the cane, and the community aspect becomes that of pond pine pocosin, although cane stems are common upon closer inspection. The next fire resets the process. Under a 1, 2, or 3 year fire regime, shrubs may be almost entirely lacking.

Canebrake remnants occur across the Neuse River in Pamlico County and wildfire still periodically rejuvenates substantial portions of canebrake in mainland Dare County. In Pamlico County I compared burned and unburned plots in Northwest Pocosin. In this pair of 1/10 ha plots on either side of a fire line, the plot burned in the preceding year had 567,200 cane stems per ha, while the side which had grown for 8 years since last fire had 67,200 stems per ha, or about a tenth as many. The immediate dominance of cane seen after a burn suggests that only 10% of the potential stem density still has the ability to maintain the entire rhizome mat until the next burn. With further reduction in fire frequency, succession proceeds to tall pocosin and various kinds of forest communities. Cane is almost entirely eliminated by around 25 years.

Hughes (1966) estimated originally around 5 million acres of canebrake in North Carolina coastal peatlands. Today I estimate that less than 1% remains of the original extent in the State. The disappearance of southeastern canebrakes has gone largely unremarked, and I know of no place in the South on public or private lands where management plans specifically include burning to maintain canebrake.

While cane is a common dominant in the understory in many places, I have not seen good examples of canebrake on the Croatan. In the Little Deep Creek pocosin vicinity, light patches resembling canebrake occurred on color infrared aerial photos after past fires. Some shallow peats and mineral soils with thin organic layers in the Brice Creek headwaters also appear to be likely candidates. If manageable remnants can be found, it would be a valuable contribution to maintain some canebrake on the Croatan by perpetuation of the natural 2-5 year fire regime.

HARDWOOD FOREST

HF	MIXED WET-MESOPHYTIC HARDWOODS-LOBLOLLY
aa	Altavista fine sandy loam
HF	MIXED MESOPHYTIC HARDWOODS
ag	Augusta loamy fine sand
HF	SOUTHERN RED OAK-MIXED DRY-MESOPHYTIC HARDWOODS
an	Alpin fine sand
HF	MIXED DRY-MESOPHYTIC HARDWOODS
au	Autryville loamy sand
HF	MIXED DRY-MESOPHYTIC HARDWOODS
cn	Conetoe loamy sand
HF	MIXED MESOPHYTIC HARDWOODS
go	Goldsboro loamy fine sand
HF	MIXED MESOPHYTIC HARDWOODS
jo	Johns fine sandy loam
HF	MIXED MESOPHYTIC HARDWOODS
ka	Kalmia loamy sand
HF	MIXED MESOPHYTIC HARDWOODS
ke	Kenansville loamy fine sand
HF	MIXED WET-MESOPHYTIC HARDWOODS
ln	Leon sand
HF	MIXED WET-MESOPHYTIC HARDWOODS
me	Meggett sandy loam
HF	MIXED DRY-MESOPHYTIC HARDWOODS
no	Norfolk sand
HF	MIXED MESOPHYTIC HARDWOODS
pa	Pactolus loamy fine sand
HF	MIXED MESOPHYTIC HARDWOODS
ro	Roanoke loam
HF	WATER OAK-LOBLOLLY PINE
se	Seabrook fine sand

HF	MIXED MESOPHYTIC HARDWOODS
st	State loamy fine sand

HF	TULIP POPLAR, OAKS, OTHER HARDWOODS
tm	Tomotley fine sandy loam

Community types:

___*Quercus falcata\Gaylussaccia frondosa*-mixed dry-mesic shrubs

___Mixed mesophytic oaks-hickories.

___Oak-hickory-beech/mixed mesophytic subcanopy trees/mixed mesophytic shrubs/mixed mesophytic hardwood slope shrubs.

___*Quercus alba-Liriodendron tulipifera-Fagus grandifolia*/mixed mesophytic subcanopy trees/mixed mesophytic shrubs/mixed mesophytic hardwood slope shrubs.

___*Fagus grandifolia*.

In presettlement forests, hardwoods in the Croatan were conspicuously distributed according to a fire-effects gradient. In theory, nearly all of the upland soils would be dominated by longleaf pine if they occurred in fire-exposed parts of the landscape, and if the same soils were completely protected from fire, all would be dominated by beech. The actual distribution of communities depended upon the frequency and intensity of fires, and the landscape position of the soils. Fire effects were most extreme in the central, most fire-exposed parts of the landscape, where fire probably occurred every 1-2 years. Mesophytic hardwoods like white oak are lacking, and under the original fire regime even the scrub oaks would have been excluded from the most frequently burned savannas. Scrub oaks appeared in longleaf pine communities with slightly lower fire frequency, and fire-tolerant hardwoods like post oak could be found in mixed pine savannas on some of the fine-textured soils like the Nahunta. Mesophytic oaks and hickories began to appear in pyrophytic woodlands of mixed hardwoods and pines, where fire frequency fell between 7-12 years. These woodlands were found in fire-tension zones between the frequently burned longleaf pine uplands, and nonpyrophytic shoreline and swamp communities. Hardwood-dominant stands occurred in rolling areas near rivers and streams, on steep slopes, at wet toes of gentle slopes, on peninsulas, and on bodies of upland soils surrounded by swamps. Present forests of the Croatan still display this distribution of hardwoods according to the fire-effects gradient. The net change resulting from reduction in fire

Figure C3.4. Beech forest on Goldsboro series on west side of Brice Creek. Beech and other non-pyrophytic hardwood forest occurred in several naturally fire-protected landscape situations in what was originally a frequent-fire landscape. Beech and longleaf pine occupy opposite extremes on a gradient of fire tolerance. In this case beech occurs on a soil series for which longleaf pine is more typical, but landscape factors create an atypically fire-sheltered situation. This site is bounded on one side by Brice Creek swamp which lies nearly at sea level at this point and so never dries out. In addition, the wet cypress-gum swamp has no understory vegetation to carry fire. Fire can only approach the beech flats and toe slopes by moving downslope, something that fire does not do well. So fire moving through the mixed pond pine-loblolly-longleaf forest on the wet, clayey Leaf series on adjacent uplands must decrease in intensity and become a creeping surface fire in order to reach the zone of beech. Beech can survive light surface fires, and beech litter, which mats down to only about 1 cm thick during the winter, will scarcely carry a fire during the growing season. Beech and beech-magnolia communities also can be found on the steep fire-sheltered slopes of the Suffolk series, and, in some fire-sheltered sites, on the steeper slopes of the Marvyn, Craven, Norfolk and Autryville. Pure hardwood stands can also be found on a few islands of high ground surrounded by swamps, near the Trent River in Jones County. Photo January 1996.

frequency, has been a general increase in proportion of hardwoods to pines, across all soils and landscape positions.

Xeric and dry-mesic sites. After fire effects, the most prominent master gradients affecting distribution of hardwood species are moisture and soil texture. There are four common oaks and hickories on mesic and dry sites around the Croatan periphery: white oak (*Quercus alba*) and southern red oak (*Quercus falcata*), Pignut hickory (*Carya glabra*) and mockernut hickory (*Carya tomentosa* [*alba*]). *Carya pallida* may occasionally be found on sands, and *Carya cordiformis* sometimes appears on the fringes of longleaf pine savannas near the White Oak River. In general, white oak occurs in greater numbers where soils are mesic and medium textured, while southern red oak may dominate on dry, fire-infrequent sands. Southern red oak and loblolly pine are the conspicuous successional dominants upon removal of fire from longleaf pine dry savannas on Baymeade, Tarboro, Conetoe and the other dry sands.

Mesic sites. The term mesic does not mean wet or moist, but rather refers to the optimally-drained habitat in the landscape for plant growth, neither too dry nor too wet. Most mesic oak-hickory sites in the original Croatan were on slopes (see the Hardwood Slope category below), the mesic upland sites being almost entirely occupied by longleaf pine. Some naturally fire-protected mesic hardwood sites occurred along the Trent River, where patches of Autryville, Norfolk, Kalmia, Kenansville, Johns and Pactolus soils appear on peninsulas and "islands" surrounded by swamp.

Wet-mesic sites. Moist refugia for hardwoods occurred in at least two distinct situations. The first was along the toes of gentle slopes between upland fire vegetation and streams or swamps. These occurred on a variety of soils, the topographic position being more important than the soil type. In the second case natural habitats for hardwoods were found on flats of certain fine-textured soils where the combination of soil type and vegetation produced some inherent resistance to fire. Soils like the Augusta, Roanoke and Tomotley tend to occur in partially fire-sheltered sites in the landscape, and vegetation on these moist soils also seems to have some built-in fire resistance. Fires in such communities tend to die down, perhaps due in part to the fact that clayey soils are resistant to spread of rhizomatous shrubs which could create a flammable layer, and in part to the tendency of some species like beech to produce thin leaves that lie flat upon the ground, soak up moisture during

the winter, to form a litter layer that, by the time fire season arrives, will not carry a fire. These soils are of limited extent in the Croatan, being found mostly in the Brice Creek watershed and in peripheral areas near Clubfoot Creek.

Wet-mesic and hydric sites: bottomland hardwoods. Since bottomland hardwoods in the Croatan cannot be separated from swamp forests on the basis of the county soil maps, they are discussed with swamps below.

HARDWOOD SLOPES

HS	DRY-MESOPHYTIC OAKS-HICKORIES
au	Autryville loamy sand
HS	MESOPHYTIC OAKS-HICKORIES-BEECH
cr	Craven silt loam
HS	MESOPHYTIC OAKS-HICKORIES-BEECH
mv	Marvyn loamy sand
HS	DRY-MESOPHYTIC OAKS-HICKORIES-LOBLOLLY
no	Norfolk loamy fine sand
HS	WATER OAK-LOBLOLLY PINE
se	Seabrook fine sand
HS	OAKS-HICKORIES-BEECH-MAGNOLIA
su	Suffolk loamy sand
HS	MESOPHYTIC OAKS-HICKORIES
Wa	Wando fine sand

Community types:

___Mixed dry-mesophytic oaks-hickories/*Gaylussaccia frondosa*

___Mixed mesophytic oaks-hickories

___Mixed oak-hickory-beech/*Magnolia tripetala*-mixed mesophytic subcanopy hardwoods.

___Mixed oaks-longleaf pine/mixed subcanopy hardwood trees and shrubs (Wando)

___*Quercus alba-Liriodendron tulipifera-Fagus grandifolia*/mixed mesophytic subcanopy trees/mixed mesophytic shrubs/mixed mesophytic hardwood slope shrubs

___Beech forest (Island Creek).

TABLE C3.3. HARDWOOD HABITATS AND SLOPE CLASSES OF CROATAN SOILS

Of the 51 Croatan soil series, only 17 have any slope class modifiers. The other 34 are mostly flat. Of the 17 with noticeable slopes only two series, the Craven and the Norfolk, have more than 1 slope class mapped. Of the 50 series, only the Alpin, Autryville, Baymeade, Craven, Kureb, Marvyn, Norfolk, Suffolk, Tarboro and Wando have areas with slope classes greater than 5% that are large enough to map. Several others, however, have locally steeper areas along streams, too small or too narrow to appear on the soil maps. Where these occur, the modest degree of fire protection offered by the slopes leads to small stands of non-pyrophytic hardwoods (oak, hickories, tulip poplar, beech) atypical of the fire-influenced flatland vegetation usually found on that series. Series indicated with an asterisk are those with a significant hardwood slope component on the steeper slopes. Note that soil surveyors may assign slightly different ranges for the B slope class in different counties—see slopes in parentheses in Jones County.

SOIL SERIES		SLOPE CLASS	COUNTIES WHERE FOUND		
AaA	Altavista	0-2%	Ca	Cr	
AnB*	Alpin	0-6%			Jo
AuB*	Autryville	0-6%	Ca	Cr	Jo (0-4%)
ByB	Baymeade	1-6%	Ca		
CnB	Conetoe	0-5%	Ca		
CrB	Craven	1-4%	Ca		Jo
CrC*	Craven	4-8%			Jo
ExA	Exum	0-2%		Cr	Jo
GoA	Goldsboro	0-2%	Ca	Cr	Jo
KaA	Kalmia	0-3%			Jo
KeA	Kenansville	0-3%			Jo
KuB	Kureb	0-6%	Ca	Cr	
MaC*(Mv)	Marvyn	6-15%			Jo
NoA	Norfolk	0-2%	Ca	Cr	
NoB*	Norfolk	2-6%	Ca	Cr	Jo (1-4%)
StA	State	0-2%	Ca	Cr	
SuD*	Suffolk	10-30%		Cr	
TaB*	Tarboro	0-6%		Cr	
WaB*	Wando	0-6%	Ca		

In presettlement forests, there were virtually no areas of natural mesophytic upland hardwoods in the Croatan except for ravines like Island Creek, a few uplands isolated by swamps, and narrow bands of rolling slopes along streams. Good examples still occur on the sandy Suffolk series on slopes where small drainages are truncated by the receding Neuse/Pamlico shoreline. One study plot done on this series near Flanner Beach had beech and *Magnolia tripetala* as significant components. Along the White Oak river examples can be found where the adjacent uplands are high enough to create steep slope refugia for hardwoods and mesophytic shrub species lie *Storax grandifolia* and *Aesculus pavia*. One such site was sampled on the Autryville sand slopes at Hadnot Creek.

Typical species are white oak, mockernut hickory, pignut hickory, swamp white oak, cherrybark oak and a few beech. Beech are scarce in the Croatan, the original landscape too prone to fire to permit its establishment except in the few truly fire-protected places in the landscape.

In the slightly less fire-prone and long fire-suppressed areas along the Trent River, and in some lands inland from the Neuse/Pamlico shoreline hardwoods can be found on uplands which are undergoing succession from pine-dominated fire communities in the long absence of fire. Some of these sites originally had natural mixed stands of longleaf pine, loblolly, some shortleaf and hardwoods in woodlands.

LONGLEAF PINE FOREST AND SAVANNA (XERIC, DRY & MESIC)

LL	LONGLEAF PINE/XERIC SAVANNA
ku	Kureb sand
LL	LONGLEAF PINE/DRY-MESIC SAVANNA
an	Alpin sand
LL	LONGLEAF PINE/DRY-MESIC SAVANNA
ta	Tarboro sand
LL	LONGLEAF PINE/DRY-MESIC SAVANNA
au	Autryville loamy sand
LL	LONGLEAF PINE/DRY-MESIC SAVANNA
no	Norfolk loamy fine sand
LL	LONGLEAF PINE/DRY-MESIC SAVANNA
by	Baymeade sand

LL	LONGLEAF PINE/DRY-MESIC SAVANNA
cn	Conetoe loamy sand
LL	LONGLEAF PINE/MESIC SAVANNA
ke	Kenansville loamy fine sand
LL	LONGLEAF PINE/MESIC SAVANNA
mv	Marvyn loamy sand
LL	LONGLEAF PINE/MESIC SAVANNA
ka	Kalmia loamy sand
LL	LONGLEAF PINE/MESIC SAVANNA
st	State loamy sand
LL	LONGLEAF PINE/MESIC SAVANNA
go	Goldsboro loamy fine sand
LL	LONGLEAF PINE/MESIC SAVANNA
ex	Exum silt loam
LL	LONGLEAF PINE/MESIC SAVANNA
on	Onslow loamy fine sand
LL	LONGLEAF PINE/MESIC SAVANNA
cr	Craven loam
LL	LONGLEAF PINE/MESIC SAVANNA
aa	Altavista loamy fine sand
LL	LONGLEAF PINE/MESIC SAVANNA
mn	Mandarin sand
LL	LONGLEAF PINE/MESIC SAVANNA
ly	Lynchburg fine sandy loam
LL	LONGLEAF PINE/MESIC SAVANNA
sg	Stallings loamy fine sand

Community types:

___Longleaf pine/wiregrass-dry savanna herbs.

___Longleaf pine/turkey oak/wiregrass-dry savanna herbs.

___Longleaf pine/bluejack oak/wiregrass.

___Longleaf pine/wiregrass-bluestem-diverse mesophytic savanna herbs.

___Longleaf pine/wiregrass-*Vaccinium crassifolium*.

___Longleaf pine/wiregrass-*Gaultheria procumbens*.

All of this group of soil series were clearly dominated by classic longleaf pine forest and savanna. The definition of savanna here follows Frost, Walker and Peet (1986), in which, for southeastern fire communities the term savanna applies to any fire-maintained bilayered community, in which the two layers are a tree layer with up to 50% cover, over a continuous, usually grassy herb layer. Woody understory was sparse under the original fire regime. The eleven series are listed approximately from dry to moist. Wiregrass was an herb layer dominant in all of these originally, although it has been reduced to remnants in many places. With fire suppression, a deep pine needle buildup smothers the herb layer and in extreme cases hardly any herbs can be found.

Even with a group of soil series all dominated by longleaf pine, separate mapping units were retained for each soil series where possible. This will permit more precise future mapping of individual areas because specific communities and character species can be defined for most of these. For instance, turkey oak is most abundant on the Kureb; bluejack oak (Quercus incana) is an almost certain indicator species for the Baymeade sand, and teaberry (Gaultheria) reaches its best development on the Onslow loamy sand and Goldsboro loamy fine sand. In the category below, Venus's flytrap is almost exclusively limited to the wet Leon sand.

LONGLEAF PINE WET SAVANNA

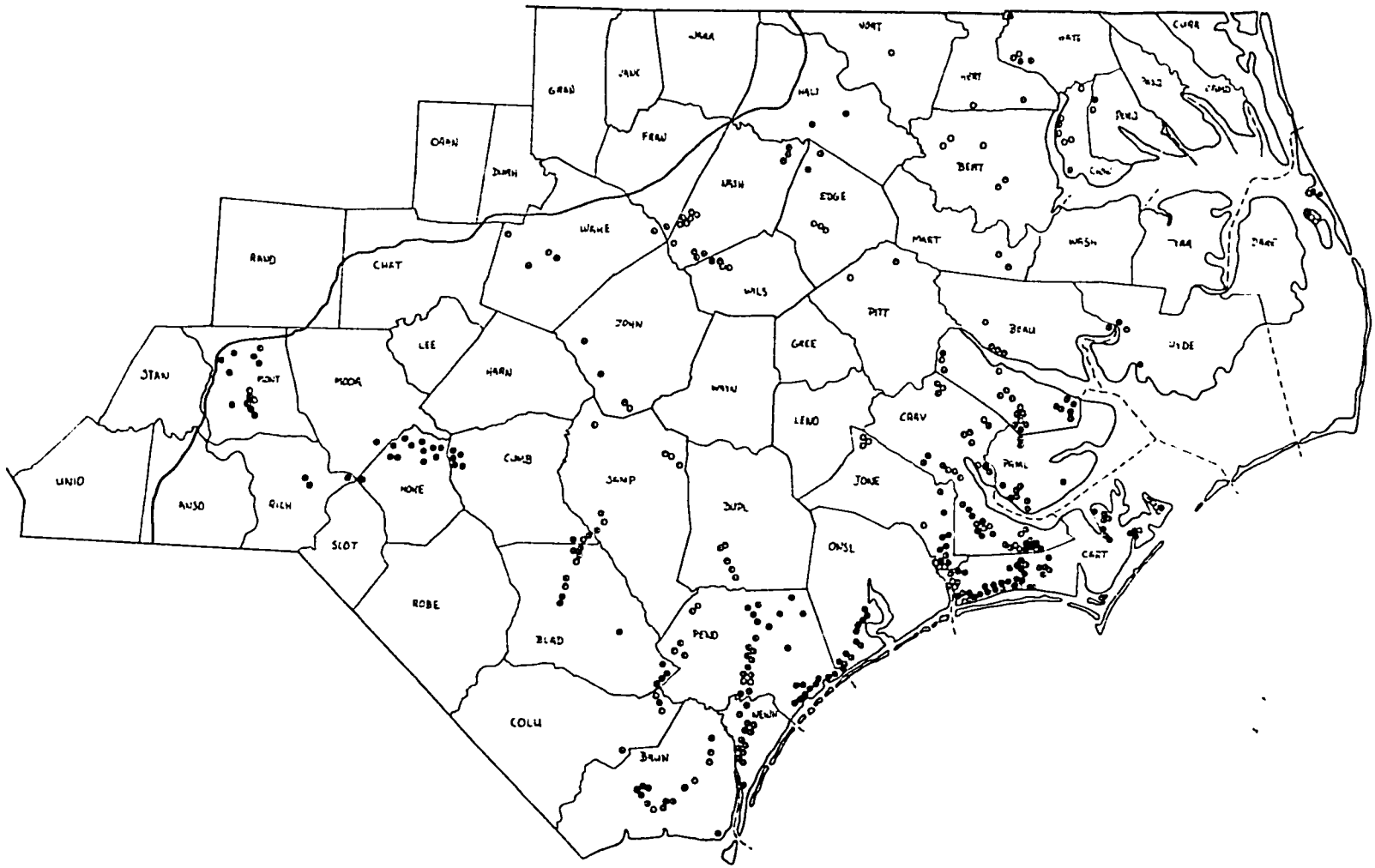
LS	LONGLEAF PINE/WET SAVANNA HERBS
ln	Leon sand
LS	LONGLEAF PINE/WET SAVANNA HERBS
ra	Rains fine sandy loam (mineral phase)
LS	LONGLEAF PINE/WET SAVANNA HERBS
wo	Woodington fine sandy loam

Community type:

___Longleaf pine/species-rich wet savanna.

___Longleaf pine/*Arundinaria gigantea*-diverse wet savanna herbs.

Figure C3.5. Stand conditions and fire in 352 longleaf pine stands in North Carolina. Open circles indicate sites where the last longleaf was extirpated only in the last two or three decades. Circles with dots are localities with only 1 to 10 individual trees persisting in woods that have succeeded to loblolly pine and hardwoods. Half circles are fire-suppressed longleaf dominant stands having a dense understory of hardwoods and loblolly pine. Such stands are not likely to regenerate longleaf in the future. Solid circles indicate some of the few high-quality, fire-maintained longleaf communities. While not at all complete, this map of somewhat randomly-selected stands shows the near extirpation of longleaf pine from the northern 200 kilometers of its range and from most of the agricultural regions of the rest of the coastal plain. The solid line on left is the edge of the historical range.


GRAN
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ORAN
WAKE
EDGE
MART
WASH
TYRR
DARE
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CHAT
WILS
PITT
BEAU
HYDE
LEE
JOHN
GREE
STAN
MOOR
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WAYN
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CRAV
PAML
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ANSO
RICH
MONT
CUMB
SAMP
JONE
CART
SCOT
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ROBE
BLAD
PEND
NEWH
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BRUN

Figure C3.6. Tenth hectare study plot on Baymeade sand, Millis Road Savanna. This site had been burned several times at around 3-5 years apart when this photo was taken. Note the clear dominance of longleaf pine and wiregrass, with virtually no hardwood understory or shrubs. June 20, 1983. Compare with fire-suppressed vegetation succession on the same soil in the next figure.

Figure C3.7. Study plot also on Baymeade sand, but with fire excluded for 30 years. While the canopy is still dominated by longleaf, a multilayered subcanopy has developed, with southern red oak, loblolly pine, turkey oak and bluejack oak. A dense pine needle and oak leaf litter has accumulated, up to 1 foot deep, completely eliminating the herb layer. Only a few sprigs of wiregrass could be found. Without fire, this stand will be permanently converted to loblolly pine and hardwoods when the longleaf is logged. Even so, fire-suppressed succession on this somewhat sterile sand is much slower than on more loamy soils (see Figures 17 and 18 where an even greater degree of succession may occur in only about 10 years). Stand is on private land in Carteret County near the Craven County line, just outside the Croatan National Forest boundary. Photo June 23, 1983.

Figure C3.8. Lynchburg series July 13, 1983, six months after a spring burn, and previously burned three years before that. Species diversity is highest on wet mineral soils, which require frequent fire to maintain the open savanna condition. At this frequently burned site there were around 90 species per 1/10 hectare, among the highest to be found in the Croatan vicinity. The wet-mesic Lynchburg (Paleaquults) is slightly wetter than the mesic Craven series (Hapludults). With exclusion of fire, succession proceeds most rapidly of all on the moist mineral soils. Longleaf pine was the only tree in the plot, but the herb layer contained seedlings of pond pine and hardwoods, ready to emerge should fire frequency be reduced. Savanna south of Hunter's Creek.

Figure C3.9. Nutrient shadow created by decomposition of a fallen longleaf. This site is on one of the isolated sand lenses in the vast oligotrophic peatlands north of Catfish Lake. Soils are so poor that decomposer microbes may tie up all available nutrients for decades, until the wood is consumed. This site, the same sand lens as in Figure 14, is near the center of the Croatan peninsula. Adjacent pocosin vegetation structure, like nearby Sheep Ridge low pocosin, species composition and low species diversity, indicate an apparent fertility gradient from the nutrient poor, ombrotrophic center of the Croatan, outward to the more fertile perimeter. Photo October 7, 1985.

Good examples of moist, species-rich longleaf pine savanna persist as part of the Mandarin (mesic), Leon (wet-mesic), Murville (hydric) mosaic of low sands around the edges of peatlands. These moist soils, when kept free of litter and overtopping vegetation by frequent fire, have some of the greatest species diversity, including many species essentially limited to wet soils with frequent fire. The Croatan is near the northern limit for the federally endangered Lysimachia asperulaefolia (whorled loosestrife), as well as Lysimachia loomisii, Dionaea muscipula (Venus's flytrap), Fothergilla gardenii, Asclepias pedicellata, Carex elliottii, Carex striata, Pterocaulon virgatum, Spiranthes brevilabris var. floridana, Rhynchospora ciliaris, Rhynchospora baldwinii, Rhynchospora plumosa, Carphephorus paniculatus and Rhexia lutea. A large number of other wet savanna species are also present. Many of these moist communities, which were truly open savanna under the original fire regime, have become shrubby or densely wooded as a result of fire suppression

SALT MARSH, BRACKISH MARSH and OLIGOHALINE MARSH

MB		BRACKISH MARSH
hb		Hobucken muck (shallow muck)
MB	MO	BRACKISH MARSH, OLIGOHALINE M.
lf	lf	Lafitte muck (deep muck)
MO		OLIGOHALINE M.
ho		Hobonny muck (deep muck)
MS		SALT MARSH
ch		Carteret (high phase)
MS		SALT MARSH
cl		Carteret (low phase)

Community types observed:

___*Juncus roemerianus.*

___*Juncus roemerianus-Distichlis spicata.*

___*Spartina patens-Distichlis spicata.*

___*Spartina alterniflora.*

___*Spartina cynosuroides.*

___*Cladium jamaicense.*

___*Typha latifolia.*

___*Typha angustifolia.*

___*Panicum hemitomon* (Lake Ellis Simon)

___Brackish mud flats with *Lilaeopsis chinense*-mixed brackish marsh herbs (Hadnot Creek).

___Red cedar/brackish marsh herbs in marsh-upland transition zones.

While brackish marshes, including the vast Piney Point and Cedar Island Marshes, fringe the northeastern end of Carteret County, a smaller but more diverse assemblage are included along the fringes and within the boundaries of the Croatan National Forest. Most interesting of these are the series of salt, brackish and oligohaline marshes scattered along the White Oak River. Most of the community types listed above can be seen along the long-attenuated salinity gradient that begins near Bogue Inlet and ends upstream in Jones County near the mouth of Holston Creek.

The Carteret series are found only at the lower end of the White Oak River, at the mouths of the small drowned creeks along Bogue sound (such as Gales Creek) and in the lower Newport River estuary. It is divided into a low and a high phase. The Carteret Low is adjacent to the water and is flooded deeply twice daily by the tides. It is most typically a wet greenish sand, sometimes with a light colored silty component. The common dominant species is salt marsh cordgrass (Spartina alterniflora), and one 1/10 hectare plot had no other species. Along the barrier islands this phase often also has halophytes like Salicornia spp., Borrichia frutescens, Distichlis spicata and Aster tenuifolius. The Carteret High is between the Carteret Low marsh and adjacent uplands and is less deeply flooded by the tides. It is wet sand with varying amounts of organic matter, most commonly in a peaty layer on the surface, and usually heavily dominated by black needle-rush (Juncus roemerianus), sometimes with patches of Distichlis in the Juncus matrix.

The Carteret salt marshes grade quickly upstream into brackish marsh on Hobucken muck. The Hobucken covers a broad range of salinity, with black needle rush being the most common dominant. See Table C3.4 below for salinity ranges of marsh types. Other marsh species appear in the headwaters of small streams like Pettiford Creek. Salinity decreases upstream and species diversity increases. In the brackish marshes of Hadnot Creek, generally dominated by Juncus, an unusual community dominated by patches of the tiny Lilaeopsis chinense was found along shaded

shorelines.

Table C3.4. SALINITY RANGES FOR MARSH TYPES

SALINITY RANGES:	Salt Marsh 3-4%	30-40 PPT
	Brackish Marsh	5-30 PPT
	Oligohaline	0.5-5 PPT
	Fresh Marsh	0-0.5 PPT

At the uppermost reaches of marsh along the White Oak River, oligohaline marshes on Hobonny muck soils appear. Marsh diversity of the Croatan is highest here and numerous species occur. See Frost (unpub), and the data set for this dissertation for a list of 305 marsh species of the region ranked according to salinity preference. Most of these occur in the Croatan marshes.

Along the Neuse River estuary where shorelines are higher, wave action has carved bluffs into adjacent uplands, relegating marshes to small patches near the mouths of streams and small swamp drainages. On the Craven County soil map all marshes are assigned to only one soil series, the Lafitte. This is a deep muck, typically around 80 inches thick and is the most extensive mapping unit for brackish marshes all around the Pamlico Sound. Smaller patches of other marsh soils are included within the areas mapped Lafitte. In the Cedar Island area the Lafitte is dominated by black needle-rush where unburned. In one such plot on Lafitte there were only 8 species found, and cover of *Juncus roemerianus* was over 98%. In a burned plot on the same series, 23 species, or about three times as many as in the fire-suppressed plot, were found. On the Neuse, the salinity gradient is attenuated upstream, as in the White Oak River, and marshes in the Trent River estuary at New Bern fall into the oligohaline range. Here they are dominated by Spartina cynosuroides (big cordgrass) in dense stands, sometimes with interiors of sawgrass at the marsh-upland interface.

No examples of true freshwater marsh were seen in the streams or estuaries around the Croatan, but several types occur in shallow waters around shorelines of the lakes, particularly Lake Ellis Simon, where cattail (Typha latifolia) marsh can be found along the shoreline, and maiden cane (Panicum

hemitomon) occurs in shallow water.

With exception of a few marshes which lie in naturally fire-protected areas, most of the marshes of the region would have originally experienced frequent fires, which originated in flammable upland vegetation. Most have been long fire-suppressed and consequently may have lost some species diversity. It would be good if some examples of marsh could be included when controlled burning is planned for adjacent uplands.

Marsh-upland transition zones. These are some of the most interesting areas in terms of unusual species, and form distinctive communities. The salinity gradient may be quite steep in brackish marshes, and in most places the zone of transition between tidal brackish marsh and the interior fresh groundwater pool is too narrow to show on the vegetation map. Typical marsh-upland transitions may have an intermixture of herbs native to brackish marshes, fresh marshes and freshwater swamps. Much of the local species diversity occurs in these zones, and where fire suppressed, they are filling in with cedar, loblolly pine, wax myrtle, Baccharis and other shrubs, to the detriment of the herb layer. The marshes of the Croatan deserve further study.

MARITIME FOREST

MF	LOBLOLLY PINE-LIVE OAK-YAUPON
aa	Altavista loamy fine sand
MF	LOBLOLLY PINE
ap	Arapahoe loamy fine sand
MF	LIVE OAK-LOBLOLLY PINE-YAUPON
se	Seabrook fine sand
MF	LIVE OAK-LOBLOLLY PINE-YAUPON
wa	Wando fine sand

Community types:

___Mixed marsh, dune, and weedy species on frequently overwashed sand berms (especially on the Pamlico shoreline near Cedar Island.

___*Pinus taeda/Smilax* spp./maritime forest grasses.

___*Quercus virginiana-Pinus/Ilex vomitoria.*

___*Pinus palustris-Quercus virginiana-Quercus laurifolia*/maritime forest grasses (*Aristida stricta, Chasmanthium laxum*).

A zone of maritime forest is found on uplands fringing salt or brackish waters all around the periphery of the Croatan. Exceptions include the high, receding shorelines along the Neuse estuary, where erosion has formed an active scarp. Here estuarine wave action is cutting directly into interior upland forest communities, and recession is too rapid to permit formation of maritime forest. The estuarine wave action is cutting directly into upland forest communities.

Characteristic maritime forest species are live oak, loblolly pine, sometimes longleaf, and yaupon (Ilex vomitoria). Few good examples remain, however, these stands having experienced nearly three centuries of human exploitation and disturbance, and it is necessary to go well outside the Croatan to see natural stands. This type occurred on several soils, all sandy. On the Cedar Island peninsula I sampled a stand with longleaf pine, small live oak, clumps of yaupon and a well-developed savanna herb layer on Mandarin sand. On Brown's Island (plot CA21, just west of Harker's Island) there was some longleaf, also on Mandarin sand, interspersed with pockets on live oak and laurel oak in depressions. The herb layer was sparse wiregrass. Just south of Wilmington, on the peninsula leading to Fort Fisher, there are some stands of mixed longleaf and live oak, and on Currituck Banks there are some stands on the sound side, of live oak with a burned, open, grassy layer of Chasmanthium laxum. Live oak seems to tolerate fire with no ill effects in all of these situations, and it may require fire for regeneration in stands away from the immediate coastal fringe. Most mainland maritime forest communities seem to have experienced frequent fire that spread from interior fire communities. All the live oak in the region was sought out and removed for ship timbers during the 18th and 19th centuries (Wood 1981). Most of the sites which still have some of the second growth live oak have been used for houses and farmsteads since the early 1700s. There may be some restorable remnants around the periphery of the Croatan. The distribution and diversity of maritime forests are described in Wentworth et al. 1992.

MIXED PINE SAVANNA AND PYROPHYTIC WOODLAND

MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
aa	Altavista loamy fine sand

MP	PURE OR MIXED POND PINE-LOBLOLLY-LONGLEAF
ag	Augusta loamy fine sand
MP	QUERCUS FALCATA-MIXED PINES
an	Alpin sand
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
ap	Arapahoe loamy fine sand
MP	LONGLEAF-LOBLOLLY-HARDWOODS
au	Augusta loamy fine sand
MP	LONGLEAF-LOBLOLLY-HARDWOODS
cn	Conetoe loamy sand
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
cr	Craven silt loam
MP	MIXED LONGLEAF-LOBLOLLY-HARDWOODS
ex	Exum silt loam
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
go	Goldsboro loamy fine sand
MP	MIXED LONGLEAF-OTHER PINES-POST OAK
gr	Grantham silt loam
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
jo	Johns loamy sand
MP	MIXED LONGLEAF-LOBLOLLY-HARDWOODS
ka	Kalmia loamy sand
MP	MIXED POND PINE-LOBLOLLY
la	Leaf silt loam
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY-SHORTLEAF
le	Lenoir silt loam
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
ln	Leon sand
MP	MIXED LONGLEAF-POND PINE-HARDWOODS
ly	Lynchburg sand
MP	LONGLEAF-POND PINE-LOBLOLLY-POST OAK
na	Nahunta silt loam

MP	MIXED LONGLEAF-LOBLOLLY-OAK-HICKORY
no	Norfolk sand
MP	MIXED LONGLEAF-LOBLOLLY-OAK-HICKORY
on	Onslow loamy sand
MP	MIXED LONGLEAF-POND PINE-LOBLOLLY
ra	Rains fine sandy loam
MP	LONGLEAF-LOBLOLLY-HARDWOODS
se	Seabrook fine sand
MP	LONGLEAF-LOBLOLLY-HARDWOODS
st	State loamy sand
MP	LONGLEAF-LOBLOLLY-HARDWOODS
ta	Tarboro sand
MP	MIXED PINES-OAKS-HICKORY
tm	Tomotley fine sandy loam
MP	LONGLEAF-LOBLOLLY-SHORTLEAF-HARDWOODS
wa	Wando fine sand

Community types, mixed pine savanna.

___Mixed pond pine-loblolly pine forest.

___Mixed longleaf-pond pine/diverse mesic savanna herbs.

___Mixed longleaf-loblolly-shortleaf.

___Mixed longleaf-pond pine-loblolly/diverse wet savanna herbs.

___Mixed longleaf-loblolly-shortleaf-pond pine.

Community types, pyrophytic woodland.

___Pyrophytic woodlands occurred with varying mixtures of Longleaf pine, shortleaf pine, loblolly pine, pond pine, mixed oaks and hickories (*Quercus falcata*, *Q. stellata*, *Q. margaretta*, *Q. marylandica*, *Carya tomentosa*, *C. cordiformis*, *C. pallida* and *C. glabra*).

___Mixed loblolly pine-pond pine-oaks-hickories.

___Post oak-mixed pines.

Figure C3.10. A community of natural mixed pond pine and longleaf, with an understory of *Arundinaria* and wet-mesophytic peatland herbs, on the more organic phase of the Rains series (Typic Paleaquults). The Rains is the wettest loam soil that can still support longleaf pine. On its slightly drier, more mineral phase, examples of pure longleaf can be found. This site, the wetter, more organic phase of the Rains, demonstrates some of the fire-frequency/soil wetness dynamics that permit the existence of mixed species pine stands. At this site, going into the Croatan from the east along Catfish Lake Road, the 2-species pine mixture is maintained because the site is just dry enough to permit some longleaf pine to persist, while fire frequency is just high enough to prevent dominance by pond pine. While loblolly pine has expanded into the Croatan from its natural peripheral communities, fire frequency in this area has still been too high to permit its establishment. Photo January 1996.

Figure C3.11. A rare remnant of mixed pine savanna on Craven loam. Virtually every patch of loamy soil in the South was cleared for agriculture by the Civil War, and those not farmed succeeded to loblolly pine and hardwoods after fire laws were passed in the late 19th century. The canopy here is mixed longleaf and pond pine. The stand demonstrates the characteristic bilayered structure of frequent-fire communities. Hardwoods and shrubs are lacking. The herb layer is dominated by a mixture of wiregrass, *Andropogons*, other grasses, and a species-rich assortment of other savanna herbs. Ashe (1884) described such mixed-species pine savannas in the region 100 years ago. The photo was taken July 18, 1984, about the time that this site, along with the adjacent large pocosins, was designated wilderness under RARE II. The site had burned 1.5 years before the photo (in spring 1983), and again 4 years before that (1979). Presettlement fire frequency was around 1-3 years.

Figure C3.12. The same site as Figure 11 above, unburned for 10 years (last fire was spring of 1983, this photo taken 1993). Succession in the absence of fire proceeds much more rapidly on good soils. Compare the degree of succession in 10 years on the Craven loam with the similar degree in 30 years on the dry, somewhat infertile Baymeade sand between Figures 6 and 7. In the early stages of wilderness management, the wilderness designation made it impossible or much more difficult to obtain permission to carry out controlled burns, while the mandate still held for putting out or otherwise controlling all wildfires, even natural fires resulting from lightning. The consequence on soils most susceptible to woody succession has been loss of species diversity, fire-dependent rare species, and radical alteration of vegetation structure and woody species composition.

Were enough fire-maintained samples available, a numerical analysis would probably segregate mixed pine savannas and pyrophytic woodlands into separate groupings. In reality, they fall along the fire frequency/fire effects continuum which ranges from pure longleaf pine, to mixed pine savanna, to pyrophytic woodland, to non-pyrophytic hardwood forest. Mixed pine savanna could include any of the four pine species of the Croatan. It would have experienced fire at only slightly lower frequency than longleaf pine, and still would have been a two-layered community, with trees over grass.

The existence and role of mixed pine savannas in presettlement vegetation is little appreciated, since only small remnants persist, and are readily confused with fire-suppressed former longleaf pine communities that have been logged and invaded by other pine species. Of those that occurred on the better soils (finer textured sands and loams), most were converted to agriculture 100 to 200 years ago. The stands on moist mineral flats too wet to farm were logged, fire suppressed, and grew up in loblolly pine. Ashe (1915) described the following various mixtures of loblolly, longleaf, pond pine and shortleaf pine in original mixed pine forest and savanna in the Croatan region.

> "Only in a few localities are all four pines found growing together. Near the coast the loblolly, pocoson, and longleaf pines are sometimes associated on sandy hummocks; the wettest places, however, are as a rule occupied by the pocoson pine; the pocoson and the loblolly pines are associated on savannas and slightly drier knolls; on better drained soils the longleaf replaces the pocoson pine in the mixture and on thoroughly drained soils only the longleaf pine is found."

The best examples in the Croatan were found in peripheral areas, often in transition areas between pure longleaf pine on uplands, and more fire-protected communities in bottomlands. In the past, many of these sites were pronounced loblolly sites, and fire-suppressed or actually converted to loblolly.

Pyrophytic woodland differs from mixed pine savanna in being a little farther from the pure longleaf pine area, and experienced fire at intervals long enough or irregular enough to permit occasional establishment of an oak or hickory stem, which could avoid being killed by fire long enough to escape into the canopy and become large enough to resist fire. Under this fire regime and

topographic situation, pines and hardwoods could coexist. Partial shading by the hardwoods may have been a factor in reducing fire intensity. These stands, in turn, graded into pure hardwoods in fire-sheltered sites.

ESTUARINE FRINGE LOBLOLLY PINE FOREST, PINE MARSH (not mapped)

PF	LOBLOLLY PINE-POND PINE
ap	Arapahoe loamy fine sand
PF	LOBLOLLY PINE-POND PINE
ho	Hobonny muck (mineral soil inclusions)
PF	LOBLOLLY PINE-POND PINE
hb	Hobucken muck (mineral soil inclusions)

Community types:

___Loblolly pine/Chasmanthium laxum.

___Loblolly pine-pond pine/Myrica cerifera/marsh & swamp herbs.

This is one of the truly natural habitats for loblolly pine. Loblolly pine marsh (pine savanna, pine meadow, pine swamp) occurs as nearly pure stands of pine on wet, dark clayey muck and sandy soils in marshes or in the interface between marsh and uplands. In the Croatan vicinity the occurrences are too small to appear on soil maps. The best examples known occur at Jones Island, in Pamlico County, a private preserve that has been burned occasionally, and at Knott's Island. When burned, there is a true fire-maintained bilayered community with only two strata, the pine canopy and a grassy herb layer. While no burned examples were seen around the Croatan, this type probably occurred where fires burned down into some of the marshes under the original fire regime. Small examples probably occur in or around the fringes of marshes but have developed thick understories because of fire suppression.

POND PINE/POCOSIN (PEATLAND VEGETATION)

Abbreviations: LPOC - Low Pocosin,

MPOC - Medium Pocosin, HPOC - High pocosin

PO	POND PINE-GORDONIA/MPOC,HPOC
ba	Bayboro mucky loam
PO	MPOC, POND PINE/CANEBRAKE
ct	Croatan muck
PO	LPOC, MPOC, HPOC
da	Dare muck
PO	LPOC, MPOC, HPOC
de	Deloss fine sandy loam (don't have any mapped yet-do)
PO	LPOC & OPEN BOG, MPOC
mu	Murville mucky loamy sand
PO	POND PINE/MPOC,HPOC
pa	Pantego fine sandy loam
PO	POND PINE/MPOC,HPOC
to	Torhunta fine sandy loam

Community types:

___Pitcher plant bog.

___Low pocosin.

___Medium pocosin.

___High pocosin.

___Pond pine-Gordonia/medium pocosin.

___Pond pine-Gordonia/high pocosin.

___Bay forest

___Pond pine forest

___Pond pine-Gordonia forest.

Pocosin represents one of the three largest natural community groups in the Croatan (longleaf pine, pond pine forest, pocosin). Some of it, however, probably represents succession from canebrake

Figure C3.13. Evidence for frequent fires in peatlands. The photo shows evidence of at least four pocosin fires over the preceding two decades, despite active fire suppression in the region. Patches of small trees, mostly red maple (light dots), probably date to a widespread fire about 20 years before the photo was taken. They survived a fire, which burned most of the interior 5-10 years before the photo. A third wildfire, which began in upper right corner, cut an expanding swath toward lower left about 2-5 years before the photo. This fire path was crossed a year later by another fire beginning in top center and proceeding to right center. Both fires are flanked by fire plow lines that confined them to their paths. Since some blackened ground is still visible, the most recent fire appears to have occurred within the year before the photo was taken. The site is in a pocosin near Harlowe, just east of the Croatan boundaries. North is to the right. Color infrared aerial photo taken around 1982 for the National Wetlands Inventory.

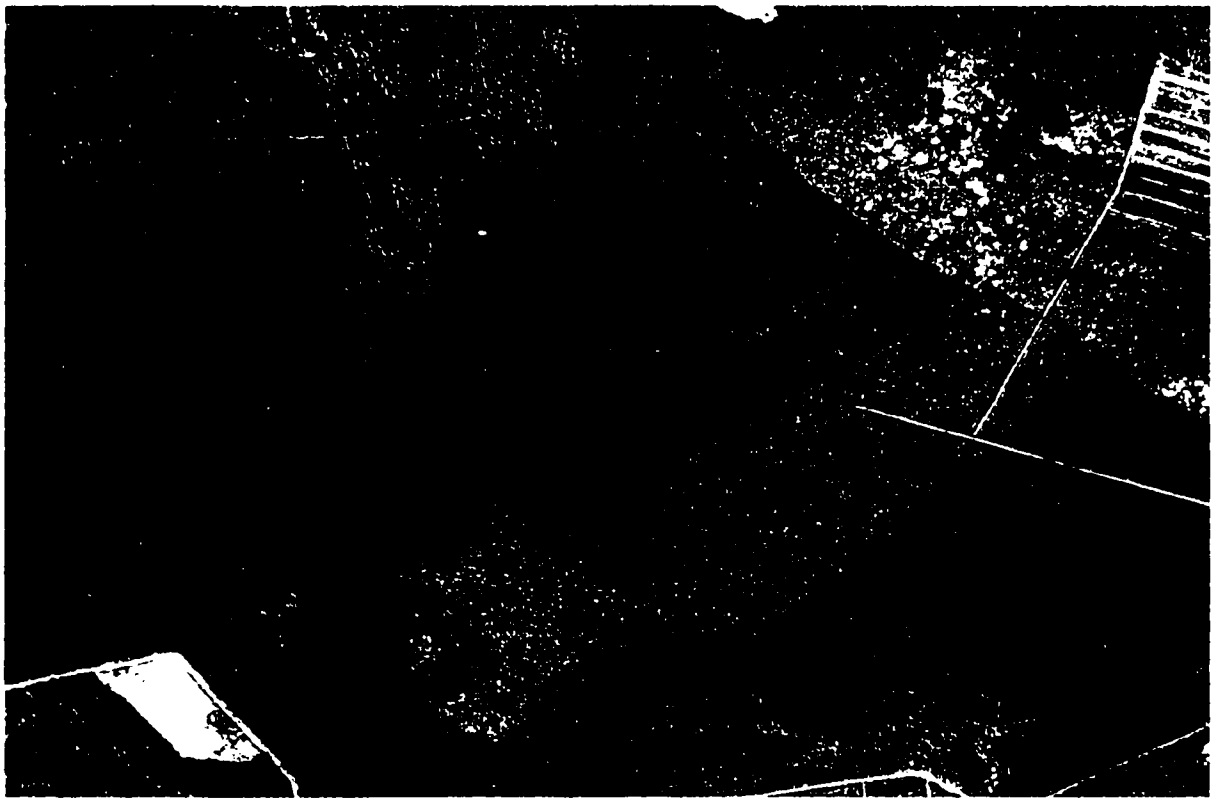

Figure C3.14. Ecotones are the most valuable parts of the landscape in terms of species diversity. Many rare species have their primary habitat in transitional areas where wet peat feathers out onto mineral soil. In this portion of the Carteret County soil map, curving sand rims of peat-drowned Carolina Bays are mapped Leon sand. The black lines outlining the soil bodies are a good representation of the linear ecotones which constitute the most significant rare plant habitat in the Croatan. These are also the parts of the landscape most vulnerable to damage from fire plows. The species that depend upon the ecotones for habitat were probably not rare, in the past when thousands of miles of such habitat in the South were maintained by landscape-scale fires that disregarded upland/wetland boundaries.


Mn
KuB

Figure C3.15. Placement of fire plow lines in the ecotone around the edge of savannas in order to burn the upland but keep fire out of the wetlands was standard practice in most of the South for many years. At Millis Road savanna, where the pocosin-savanna boundary was plowed before each prescribed burn, at least four separate plow lines can be seen along the side of the savanna away from Millis Road. The first plow line, the most distant in photo, was placed in what was at that time the original margin of the pocosin. Since the pocosin was not burned, tall shrubs grew up along the fire plow line. Some fire plow operators have a tendency to place each succeeding line further upslope to keep fire away from the tall shrubs. Since the whole ecotone (about 20 meters wide at this point) is moist, shrubs again move up to the line, causing the operator to place the next line further inland into the savanna, and so on. Eventually the entire ecotone is converted to dense pocosin, eliminating the numerous herb species whose primary habitat is the open moist ecotone. The remedy is to try to include lands with such ecotones within burn compartments rather than using the wetland/upland boundary as a boundary. Where it is not practical to burn across the ecotone there may be other ways to use fire to keep it open without igniting the pocosin. At Shoestring Savanna in the Green Swamp, and in Apalachicola National Forest, Florida, fire managers routinely burn against pocosin under wind and moisture conditions that allow fire to burn into the ecotone, keeping critical habitat open, while not actually burning the pocosin (photo Millis Road Savanna, 11 weeks after April 25, 1985 wildfire).

Figure C3.16. Longleaf pine, on a lens of Leon sand surrounded by pocosin, killed by a wildfire in 1982 or early 1983 (photo taken 1983). Dead trees on another such sand lens can be seen in the distance on the right. This would seem to be a case of fire suppression leading to mortality of otherwise highly fire-resistant trees. The longleaf were up to 200 years old, and historical records and other evidence suggest that these trees arose and survived under a frequent-fire regime for at least the first 150 years of their life span. In its early years as a national forest, wildfires were suppressed in the Croatan. Later, when control burning was instigated, plow lines were put between the pine savannas, which were burned, and the pocosins, which were not. The most likely explanation for demise of large, fire-resistant longleaf, which may have survived 50 fires in the past, is that fire suppression led to accumulation of enough dead and live fuel in the form of tall shrubs and saplings, that when a wildfire did occur, it was hot enough to kill even the longleaf.

Figure C3.17. Possibly the most nutrient-limited site in the Southeast, Sheep Ridge Low Pocosin was still only waist high after more than 27 years of fire exclusion at time of photo on July 10, 1984. The site was so sterile that it still had not formed a dense enough woody cover to exclude orchids, a few pitcher plans, and a number of graminoids. The pocosin, which finally burned in the Fish Day Fire of May 21, 1994, may have experienced fire as frequently as every 3 years under the presettlement fire regime. Because of the slow regrowth of shrubs on this sterile site, a very frequent fire regime may have maintained some of the low pocosins as open herbaceous bogs, what Ashe (1915) called "the grassy peaty lands." Trees are dwarfed pond pine (Table 6, Cell 61). Walbridge (1986) has shown phosphorus to be the limiting nutrient.

and, in a few limited areas, from white cedar, now all gone but for an occasional tree or patch. Some of the areas mapped here as pocosin originally included zones of canebrake, especially peripheral areas with shallower organics. true pocosins include most of the deep peats and the more sterile sites on shallow organics, as well as more fertile soils in fire-tension zones where fire frequency was too low to support canebrake. The Croatan contains perhaps the best examples of pocosin vegetation remaining in the U.S.

In general, most of the Croatan pocosins were probably kept to low or medium pocosin stature by frequent fire, under presettlement conditions. Where peat sites were partially fire protected, such as around the lakes, high pocosin, bay forest and pond pine forest could develop.

There is considerable evidence that some of the low pocosins once burned often enough to maintain them in a more open, bog-like condition, with grasses and pitcher plants and orchids in addition to the dwarfed shrubs. Both Emmons (1860) and Ruffin (1861) described the Open Grounds peninsula as such open bog in the early to mid 1800s. While there are soil differences between this peninsula and, say, Sheep Ridge low pocosin, before the construction of the Intracoastal Waterway, much of the Croatan and the Open Grounds-Cedar Island peninsula consisted of a single 300 square mile fire compartment, with no natural firebreaks other than the lakes. Both Emmons and Ruffin said that Open Grounds burned nearly every year. Without any firebreaks, there is no reason to expect that the croatan peatlands burned at much lower rate. Pocosins can burn frequently. The blackened sticks left by killed but unburned green shrub stems, form part of the fuel for the next burn. Color infrared aerial photos taken for the National Wetlands Inventory in 1982, show two crisscrossing fires that seemed to have occurred in two successive years in a pocosin near Harlowe, just east of Little Deep Creek Pocosin. Similar overlapping fires can be seen in the same CIR photos of the Dare County peatlands. Dr. Lewis Anderson of Duke explored the Open Grounds Pocosin in the 1930s and said that they still burned every two or three years at that time. The vast peatland was covered in fire-adapted mosses like Funaria hygrometrica, pitcher plants and grasses. Ruffin and Emmons described these as Sarracenia flava, Sarracenia purpurea and Andropogon glomeratus.

It seems likely that some of the more nutrient-limited pocosins also would have been kept in an open boggy condition under the original fire regime. Reducing shrub dominance would permit

insectivorous plants and many members of peatland Orchidaceae and Liliaceae to flourish. In Sheep Ridge and pocosins around Millis Road it is common to find suppressed, vegetative orchids and members of the lily family that do not flower under the shade until a fire temporarily opens the shrub cover. A number of rare species seem to require frequent fire in wet peatlands.

POND PINE FOREST AND SAVANNA

PP	POND PINE
ap	Arapahoe fine sandy loam
PP	POND PINE
ba	Bayboro mucky loam
PP	POND PINE
de	Deloss fine sandy loam
PP	POND PINE
gr	Grantham silt loam
PP	POND PINE
la	Leaf silt loam
PP	POND PINE
pa	Pantego fine sandy loam
PP	POND PINE
ra	Rains fine sandy loam
PP	POND PINE
to	Torhunta fine sandy loam

Community types:

___Pond pine forest.

___Pond pine/diverse wet savanna herbs.

___Pond pine/cane-wet savanna herbs.

The pond pine complex originally comprised a distinctive group of forest and wet savanna communities. Because succession is rapid on these moist soils, most have gone through succession to dense forest with thick midstory and shrubs, in response to reduction in fire frequency.

Pond pine forest on organic soils occurred in partially fire-protected sites in peatlands as discussed under pocosins above. True pond pine forest also seems to have occurred primarily on a certain class wet mineral soils, just downslope on the moisture gradient from wet longleaf pine sites. Because of their dependence upon frequent growing season fire, good examples are now very rare, but can still be seen in portions of Fort Bragg and Holly Shelter which have been burned about ever 2-3 years.

Pond pine savannas were described in the Croatan region by W.W. Ashe (1894). In the original situation the pond pine forest/savanna burned nearly as frequently as the longleaf forest with which it intergrades, and the original understory flora of these stands is virtually unknown. A number of rare plant species are native to these communities. Most descriptions fit well with the remnants mentioned above. These were very open, sunny stands, the canopy was almost pure pond pine and the density varied from almost treeless to nearly closed. The understory was free of hardwoods and shrubs and there was a well-developed grassy layer with a large number of species, comparable to the most diverse wet longleaf pine savannas. All remaining stands have been fire suppressed to varying degrees. Those that have experienced occasional wildfires have not burned often enough to prevent development of a thick understory. There are extensive areas of these soils on the Croatan and it should be possible to restore an example of pond pine savanna just by summer burning. See the appendices for recommendations.

. Pond pine may have been originally the most abundant pine in the Croatan, and there were probably a dozen different pond pine-dominated communities that experienced fire at 1-3 year frequencies. For many years on the Croatan there have been no pond pine sites that have burned at anything near this frequency. Following are some examples of the consequences of reduced fire frequency on communities with pond pine in the canopy:

___On wet, fine-textured mineral soils like the Leaf: expansion of mixed loblolly-pond pine stands toward the center of the Croatan, into areas formerly dominated by pure pond pine forest.

___In low pocosin: decrease in pocosin herbs like pitcher plants and sedges, loss of open bog habitats.

___On shallow organic soils, like parts of the Pantego, Torhunta and Croatan: conversion of canebrake to pocosin.

___On moist mineral soils like the Leon: conversion of pond pine savanna to pond pine pocosin, conversion of longleaf pine savanna to longleaf pine-pond pine/dense pocosin shrubs.

SWAMP FOREST AND BOTTOMLAND HARDWOODS

SW	NYSSA BIFLORA-BALDCYPRESS-BOTTOMLAND HARDWOODS
ba	Bayboro mucky loam
SW	NYSSA BIFLORA-BALDCYPRESS
ct	croatan muck
SW	NYSSA BIFLORA-BALDCYPRESS
do	Dorovan muck
SW	BALDCYPRESS-NYSSA SPP.-RED MAPLE
ma	Masontown mucky fine sandy loam
SW	MIXED GUM-POPLAR-CYPRESS-WETLAND OAKS
me	Meggett sandy loam
SW	BALDCYPRESS-NYSSA-FRAXINUS-BOTTOMLAND OAKS
mm	Masontown mucky fine sandy loam and Muckalee sandy loam
SW	BALDCYPRESS-NYSSA BIFLORA-BOTTOMLAND OAKS
mk	Muckalee sandy loam
SW	LOBLOLLY-TULIP POPLAR-BALDCYPRESS
sx	Stockade fine sandy loam

Community types:

___Baldcypress-*Nyssa aquatica*

___Baldcypress-*Nyssa biflora-Fraxinus pennsylvanica.*

___Baldcypress-*Nyssa biflora-Acer rubrum*/small stream swamp shrubs/*Woodwardia areolata.*

___*Pinus taeda-Nyssa biflora-Acer rubrum*/small stream swamp shrubs/*Woodwardia areolata.*

___Pyrophytic *Nyssa biflora*/pocosin shrubs.

___Baldcypress-mixed bottomland hardwoods

___*Quercus michauxii.*

Linear swamps. There are no large fluvial swamps in the Croatan, those of the Neuse River having

terminated where the river empties into the estuary upstream in Craven County. Linear small stream swamps occurs in several parts of the Croatan. The longest are Brice Creek, the two prongs of the upper Newport River, and Hunters Creek, the linear swamp drains Great Lake, and forms the western boundary between Carteret and Craven County. Smaller swamps occur in the headwaters of the short, drowned creek valleys draining the broad interior upland pocosins and flats into the Neuse River, Trent River, White Oak River and Bogue Sound. Typically the lower half of these valleys are occupied by short tidal streams bordered by brackish marshes. These terminate abruptly upstream, heading in marsh-swamp transition vegetation. The marshes and upland flats are joined by short, narrow connector swamps, often with a fairly steep elevational gradient. Some of these are less than a kilometer long. Baldcypress, Quercus laurifolia, Nyssa biflora and Fraxinus spp. are common dominants.

Pyrophytic Nyssa in Peatland Swamp Drains. In fire-tension zones in a places around the periphery of the large peatlands, there are remnant examples of fire-resistant Nyssa biflora baldcypress forest. These often originate at the edges of upland pocosins, such as that at Millis Road Savanna. They begin as a single row of fire-scarred Nyssa where a drain leads out of the upland pocosin. The swamp widens downslope, leading eventually into nonpyrophytic cypress-gum swamp in the stream bottomlands.

Cypress ponds. Cypress can be found in depressions in what was originally extensive fire communities on the south side of Brice Creek, but were not investigated for this project. There are a number of cypress fire communities and these may be related to the pyrophytic stands (which appear to be pond cypress) in the Dare County peatlands.

Bottomland Hardwoods. The swamps of the Croatan, mapped simply Masontown or Masontown-Muckalee, contain a mosaic of bottomland communities. More soil types occur than are mapped in the linear small stream swamps, but are too small and complex to appear on the soil maps. There are at least two principal phases of bottomland forest. The first, dominated by a mixture of cypress, loblolly pine, tulip poplar, swamp black gum and occasional semi-evergreen bottomland oaks, is found on slightly higher black loam soils adjacent to the wetter Masontown cypress-gum swamps. This type sometimes forms a band of forest next to the adjacent uplands. Second are swamp

chestnut oak flats. These occur primarily on the drier phase of the Muckalee and similar silty soils in the swamp bottomlands. These communities appear to have never been much influenced by fire. Good examples can be seen in the upper Brice Creek watershed. While too small to map, these would likely appear as distinct communities in a numerical classification.

On slightly drier soils, wet-mesophytic trees like water oak, tulip poplar and sweetgum may dominate the canopy, with a diverse assortment of subcanopy trees and shrubs. Patches of evergreen Leucothoe axillaris can sometimes be found. Herbs density can vary from very sparse to nearly continuous cover. Gum (sweetgum and *Nyssa biflora*),-tulip poplar communities can occur as transitional communities in the fire tension zones between flammable pocosin or canebrake and non-pyrophytic oak flats or small stream swamp forest.

ud	Udorthents (man-made/disturbed)
W	Water

ATLANTIC WHITE CEDAR

WC	ATLANTIC WHITE CEDAR
ct	Croatan muck

Community type:

___Chamaecyparis thyoides.

Other than a few small clumps of trees around the periphery of some of the lakes, there are no substantial stands of white cedar remaining in the Croatan. It is likely that there may have been a little more in presettlement times, white cedar having been logged and replaced by pocosin, red maple or other forest types over 99% of its original range (Frost 1987). In nearby Pamlico County there is no white cedar remaining, other than a few trees, but a hundred years ago Ashe (1894) discovered about 3,000 acres in Eastern Gum Swamp.

Around the south rim of Catfish Lake, white cedar may be present in part because it occurs in the fire shadow of the lake, and partly because the site is wetter than nearby pocosin. Where fires might move unobstructed across peatlands, they are blocked by bodies of water. Since pocosin fires

do not move well against the wind, vegetation on the downwind side of the lake would often burn less intensively, or escape until a later fire approached from another direction. The net effect would be a lower fire frequency in vegetation all around lakes, with the effect most noticeable on the side away from the most frequent fire-driving winds. White cedar in such situations is very slow to recover after logging since removal of white cedar often leaves pocosin-like vegetation which is more likely to burn than the original cedar forest.

OTHER TYPES TOO LIMITED TO MAP:

BAY FOREST(not mapped)

BF	BAY FOREST
ct	Croatan muck (and several other organic soils)

Community types.

___*Persea palustris-Magnolia virginiana-Gordonia lasianthus*/high pocosin shrubs.

Small patches of bay forest occur on the Croatan, and they occur on a variety of soils, but are not extensive enough to map. Bay forest occurs as an element of the patch mosaic in infrequently-burned wetlands like those of the western half of the Alligator River National Wildlife Refuge. In the Croatan, bay forest is only found as narrow bands transitional between pocosins and swamp forest. They were probably of very limited extent in presettlement plant communities, but have increased in acreage as high pocosin develops into forest with reduced fire frequency.

The final vegetation map illustrates two of the main points of pyrographic vegetation mapping: on uplands or wetlands with mineral soil, and given a known historic fire regime, it was possible to assign a narrowly-defined vegetation type to each soil series. On upland soil series little variation in vegetation was found which could not be explained by evident differences in logging history or other past land use, or by variation in the degree of natural fire exposure or fire protection in the landscape. On the other hand, in the centers and peripheries of large peatlands there were usually more than one potential community type on the same series. This last phenomenon appears to be related to nutrient status and the degree of exposure to fire (see peatland tables, Chapter 3).

Something like 95% of the original vegetation of the Croatan appears to have been either distinctive fire communities or vegetation whose structure and species composition was influenced by light ground fire. The only notable exceptions were some of the freshwater marshes in the lakes, and naturally fire-protected beech and other mesophytic hardwoods in ravines and steep, moist slopes.

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APPENDIX 1: SUMMARY OF PRESETTLEMENT VEGETATION BY SOIL SERIES

SERIES	COUNTIES	MAP CODE	TAXONOMY

(N=51)(an asterisk following the map soil code indicates that one or more 1/10 hectare data plots exist for the series)

Alpin	Jo	an*	Typic Quartzipsamments (fine sand)

Areas of Alpin soils, while sizeable, are limited to the northwestern section of the Croatan near the Trent River. Virgin longleaf was removed in the late 19th century. Most of this region has experienced reduced fire frequency and has consequently gone through various stages of non-pyrophytic succession. This deep sand is similar to the Kureb but lacks a spodic horizon. Original vegetation would have been distributed along a gradient according to degree of natural fire protection in the landscape. Most of the Alpin appears to have been dominated by longleaf, but graded into mixed pine savanna, pyrophytic woodland and forest close to the Trent River, a natural fire barrier. Near the confluence of Muddy Cove and Island Creek, narrow swamps create islands of several small tracts containing Alpin and Kenansville soils. On these, fires would have been limited to the rare instances when lightning or Indians started fires within these compartments, or to severe fire weather when firebrands could be carried across the swamps. The original vegetation on these "islands" was probably hardwood forest dominated by white oak, southern red oak, water oak and hickories (*Carya tomentosa* and *C. glabra*).

Altavista	Ca, Cr	aa*	Aquic Hapludults (fine sandy loam, loamy fine sand)

The Altavista sands are in low places in the landscape, usually on flats and slopes on the edges of the larger streams. Because some such sites are approachable by fire, while others are almost completely fire-protected, vegetation on the Altavista soils ranged along the entire fire-frequency

gradient from frequently-burned longleaf pine to non-pyrophytic hardwood forest. Most of the Altavista in the Croatan is found along Brice Creek. I have not seen burned remnant natural vegetation on this soil on the National Forest. Vegetation of the Brice Creek watershed is complex and deserves considerable further exploration.

Arapahoe Ca ap* Typic Humaquepts (fine sandy loam)
The typical natural vegetation on the Arapaho is tall, straight pond pine forest, but forest composition may include longleaf dominant stands on the slightly dryer phase, to patchy mixed longleaf and pond pine, to pure pond pine. Loblolly occurs where fire frequency is lower. Original stands had open, grassy understories where frequently burned, to shrubby understories dominated by *Lyonia lucida*, in partially fire-protected sites.

Augusta Ca, Cr ag* Aeric Ochraquults, (fine sandy loam, loamy fine sand
Like the drier Altavista, the Augusta soils occur on the edges of streams. Because of the readily available moisture and the wide variation in degree of protection from fire, the Augusta soils have perhaps the widest range of possible vegetation types in the region. In the region, sites can be found with pure dominant longleaf pine or with dominant beech where nearly completely protected from fire. Good examples of moist longleaf pine savanna on Augusta soils can still be seen at Goose Creek Game Land near the Beaufort/Pamlico county line.

Autryville Ca, Cr, Jo au* Arenic Paleudults, (loamy sand, loamy fine sand)
Vegetation on Autryville soils ranges broadly depending upon landscape position and degree of slope. On rolling sands on the northwestern part of the Croatan, the Autryville originally had pure longleaf and mixed pine stands. Along the White Oak River near Hadnot Creek, on more steeply sloping sites, partially protected from fire by slope and bodies of water, the Autryville has hardwood slope forest with mixed oaks, hickories, and distinctly non-pyrophytic species like *Magnolia tripetala*, *Storax grandifolia* and *Aesculus pavia*.

Bayboro Cr, Jo ba Umbric paleaquults, clayey (mucky loam)
There are three distinct phases to vegetation on soils mapped Bayboro. First are the wide bands of Bayboro soils around the periphery of the large peatlands. Under the original fire regime, the naturally high fire frequency probably maintained most of these soils in pyrophytic low or medium pocosin, with varying amounts of pond pine cover. Vegetation grades into tall pocosin and pond

pine forest in the slightly more fertile situations where this series is bordered by mineral soils. Today, medium or high pocosin is the most typical vegetation.

Second are small sloughs and wet depressions in poorly-drained pine flats on slightly higher soils like the Leaf series. Under the original fire regime, where fire provided more available light, vegetation of most of these sloughs was probably more shrubby, ranging from medium pocosin to pond pine forest to wet hardwood forest depending upon depth of the slough and length of ponding. Most such sloughs today have shifted toward the swamp hardwood end of the fire-frequency gradient. Typical species are *Nyssa biflora*, sweetgum, pond pine and loblolly pine, with an occasional bottomland oak. The understory includes red maple, red bay (*Persea*) and sweet bay (*Magnolia virginiana*) and remnant pocosin shrubs like *Ilex coriacea*, *Ilex glabra* and *Cyrilla*.

The third mapping phase involves a few narrow swampy drains leading from upland flats, downslope to bottomland swamp. The variation in vegetation is similar to the second phase above. Similarly, some of the sloughs shallow enough for fires to pass through probably once supported pocosin, while the deeper sloughs tended to pine and wet hardwoods. Most today have swamp forest composed of the same species found in the sloughs above.

Baymeade Ca by* Arenic Hapludults (fine sand)

Virtually all of the Baymeade soils were originally vegetated with longleaf pine dry savanna. Bluejack oak (*Quercus incana*) is a character species confined almost exclusively to the Baymeade in the Croatan. The only other Arenic Hapludults (Conetoe series), occur both in the most fire-exposed parts of the landscape, and in partially fire-sheltered sites close to the Trent River. The typical community on Baymeade is longleaf pine/wiregrass with little understory other than the scattered bluejacks. The Baymeade is rather sterile and species diversity in the herb layer is usually low. *Cnidoscolus stimulosus*, several *Andropogon* species and members of the aster family can usually be found.

Belhaven Ca bh* Terric Medisaprists (muck)

The peaty Belhaven series elsewhere is a classic white cedar substrate. In most of the Croatan the original fire frequency may have been too high, and fire-protected sites on peat soils too few for white cedar, leading instead to tall pocosin, bay forest or pond pine forest. I have not seen white cedar on the Belhaven in the Croatan. Given that nearly 99% of presettlement white cedar has been

replaced by pocosin, bay forest and various kinds of swamp forest (Frost 1987), it seems likely that there was some on this series in the original forests. Existing vegetation on Belhaven in the area is mostly medium and tall pocosin.

Carteret, high phase Ca ch* Typic Psammaquents (sand)

Black needle-rush (*Juncus roemerianus*) is the strong dominant on almost all examples of the Carteret high phase, with saltgrass (*Distichlis spicata*) the only other common species. The Carteret soils are of very limited extent, occurring only along the Bogue Sound shoreline and at the mouth of the White Oak estuary where tidal influx of salt water (salinity between 5 and 30 PPT) limits vegetation to true salt marsh species. The Carteret high phase commonly has an organic layer of marsh peat overlying the sand. This layer, lacking in the Carteret low, is composed almost entirely of living and dead Juncus rhizomes and trapped sediment.

Carteret, low phase Ca cl* Typic Psammaquents (sand)

Carteret low phase is flooded with salt water (salinity > 3%) twice daily by the tides. Few vascular plants can tolerate such an extreme combination of salinity and flooding, so species diversity is limited. On the wettest sites occur pure stands of saltmarsh cordgrass (*Spartina alterniflora*) with no other species. On slightly higher sands may be found patches of salt flat vegetation with species like saltwort (*Salicornia* spp.), saltgrass (*Distichlis spicata*) and *Borrichia frutescens*.

Conetoe Ca, Cr cn* Arenic Hapludults (loamy sand)

Where exposed to fire, the Conetoe is a classic longleaf pine soil. In the Croatan, however, much of this series lies in partially fire-sheltered sites near the Trent River and original cover would have ranged from pure longleaf to dry mixed pine savanna and forest. Canopy dominants were longleaf pine, with loblolly and southern red oak added in a fringe along the river.

Craven Ca, Cr, Jo cr* Aquic Hapludults, clayey (loam, silt loam)

The Craven and Norfolk soils are the only series which have 2 separate slope classes mapped. The steeper phases occur in narrow bands of slopes along streams and narrow drains. Since the two classes can have substantially different vegetation, they are kept separate for vegetation mapping. The flat to gently rolling CrB Craven soils were originally dominated by longleaf pine in the most open, fire-exposed sites and by mixed pine savanna with longleaf and pond pine in slightly less frequent-fire sites. Good fire-maintained examples are now very rare, the more fertile soils having

long ago been cleared for agriculture, or converted to loblolly pine. The loam soils are also the most prone to undergo rapid succession from longleaf pine to pond pine, loblolly pine and hardwoods with reduction in fire frequency.

The phase mapped CrC on the county soil map is more sloping, and being most often found along the upper slopes of swamps and streams, had mixed pine forest with Longleaf, loblolly and hardwoods, or where more fire-sheltered, pure hardwood forests with white oak, post oak, southern red oak and hickories.

Croatan Ca, Cr, Jo ct* Terric Medisaprists, loamy, siliceous, dysic (muck)
The Croatan soils are now uniformly covered with pocosin, with stature ranging from low to medium or tall pocosin depending upon landscape position with respect to the center of the large peat formations. Most of the acreage of Croatan muck was probably low or medium pocosin. In smaller peatlands and slightly more fertile situations with high fire frequency (1-3 and 4-6 year fire-return intervals), some of the Croatan soils originally supported canebrake. There are examples of large canebrakes in Pamlico County in Northwest Pocosin, and formerly in Light Ground Pocosin. If the rhizome mat has not completely died out under fire suppression, former canebrake may reveal itself when rejuvenated by wildfire. A number of rare species, including pocosin lily (*Lilium iridollae*), Swainson's warbler, and the butterfly, St. Francis satyr reach their best development in and around canebrakes. Canebrake seems to be primary habitat for many other uncommon species like the chat. The eastern part of the Croatan being a little less infertile than the central portion, it is likely that canebrake once occurred on some of the Croatan soils west of Harlowe. Before reduction in fire frequency it is also likely that canebrake occurred on some of the Croatan soils in the headwaters of Reedy Creek. The creek name may indeed be a clue: in colonial times the term canebrake was unknown in North Carolina, with *Arundinaria gigantea* usually just called "reeds". There are many reedy creeks and a Reedy Pocosin in a nearby county which surely referred to canebrake. Any remaining canebrake discovered on the Croatan National Forest that can be maintained with fire would be a valuable addition to its esthetic and biodiversity.

Dare Ca, Cr da* Typic Medisaprists (muck)
The Dare series are the classic pocosin soils, with stature under the original fire regime mostly limited to low pocosin by the combination of extreme infertility and fire. Some of the less infertile

sites have succeeded to medium or high pocosin under fire suppression. Small stands of white cedar, Gordonia and tall pocosin occur on Dare peat in the fire shadow of Catfish Lake and the other lakes.

Deloss Ca, Cr de* Typic Umbraquults (fine sandy loam)

Original vegetation on the Deloss was primarily a mosaic of pocosin and canebrake, with the cane occurring in peripheral areas where soil fertility was slightly higher than in the large peatlands, or where soil pH was not as strongly acid. Reduction in fire frequency has led to replacement of cane with tall pocosin, pond pine forest or wetland hardwoods. In fire-protected sites on a phase of the Deloss with higher mineral content, forested variants include gum-tulip poplar flats, and various mixtures of sweet gum, loblolly pine, swamp black gum, and bottomland oaks like *Quercus laurifolia* and *Q. michauxii*. Partially fire protected sites with this soil series also constitute one of the original habitats for loblolly pine on the Croatan. On almost completely fire-protected sites common species include white oak, southern red oak, water oak, swamp black gum, sweet gum, tulip poplar and hickory (*Carya glabra*), with an understory of mesophytic subcanopy trees such as dogwood and sourwood.

Dorovan Ca, Cr, Jo do* Typic Medisaprists (muck)

The Dorovan soils support a variety of swamp forest types, with various mixtures of baldcypress, swamp black gum (*Nyssa biflora*), and various species of ash. Dorovan muck is typically found along swampy streams, but in the center of the Croatan there is swamp forest on Dorovan soils in the fire shadow created by the close proximity of several lakes. A fire shadow is an area on the downwind side of a lake, where fire is less frequent than in the surrounding vegetation because the lake acts as a natural firebreak. Such sites are usually not fire-free since fires can approach from directions other than that of the prevailing winds, but fire frequency is lower than in completely exposed peatlands. Examples can be seen around the peripheries of all the Croatan lakes, but especially between Lake Simon Ellis and Great Lake. This is not an artifact of recent fire suppression, but a natural phenomenon described early in this century, before the beginnings of fire suppression in the region (Brimley 1910).

Exum Cr, Jo ex* Aquic Paleudults (silt loam)

Being fine-textured and in a slightly lower landscape position than the surrounding longleaf pine lands, the Exum soils originally supported mixed pine savanna (longleaf, pond pine and loblolly) over most of their area. More fire-protected sites had pyrophytic woodland with species like post

oak, white oak and loblolly pine on moister sites in sloughs or slightly concave areas. Pure longleaf stands only occurred in small stands on a slightly higher sandy phase.

Goldsboro Ca, Cr, Jo go* Aquic Paleudults (loamy fine sand)
Frequently burned Goldsboro sands had some of the highest species diversity seen on the Croatan. Typical vegetation on the Goldsboro was pure longleaf savanna with a species-rich herb layer dominated by wiregrass. Being relatively fertile and moist, Goldsboro soils undergo rapid succession and loss of species diversity when fire frequency is reduced.

Grantham Cr, Jo gr Typic Paleaquults (silty loam). Original vegetation on the wet Grantham loam was mostly tall, straight pond pine forest. Where frequently burned, canopy was patchy and openings supported grasses and wet savanna herbs like pine barrens gentian (*Gentiana autumnalis*). No good fire-maintained remnants were seen in the Croatan.

Hobonny Jo ho Typic Medisaprists, euic (muck)
The Hobonny occurs near the upper extent of salt influence in the White Oak and Trent Rivers. Vegetation fresh to oligohaline marsh. This mapping unit is used only in Jones County. As described under Hobucken below, marshes grade upstream along the White Oak River and Trent Rivers, from brackish (salinity between 5 and 30 PPT) to oligohaline (salinity between 0.5 and 5 PPT). Good examples of oligohaline marsh occur from Haywood Landing, downstream for 2 or 3 miles. Upstream, as the river becomes strictly freshwater, marshes are quickly replaced by swamp forest. Fire originating on the uplands probably helped maintain high species diversity in oligohaline marshes by periodically knocking back the tall dominant species, and clearing out the dead thatch that builds up in marshes. The marsh communities of the Croatan have not been fully explored, but probably contain from 200 to 300 plant species.

Hobucken Ca hb* Typic Hydraquents, nonacid (muck)
The marsh soil complex mapped Hobucken occurs only along the Carteret County portion of the lower White Oak River. These are brackish marshes (salinity between 5 and 30 PPT), and include a variety of marsh community types, of which the most extensive is Juncus marsh (black needle-rush, *Juncus roemerianus*). Upstream salinity grades from brackish to oligohaline (salinity between 0.5

and 5 PPT), and the mapping unit name changes rather arbitrarily at the Jones County line to the less saline Hobonny. Marshes are usually mapped at a much lower degree of resolution. than upland soils, and large marsh areas with several soil types are usually mapped as the most abundant series.

In addition to typical marsh, both the Hobonny and Hobucken have small amounts of woody vegetation. On pockets of fibric organic accumulation, especially in zones near upland margins where salinity is reduced by fresh groundwater input, there may be small stands of pond pine. These are also possible localities for white cedar, although I have not seen any along the rivers. Where sand lenses approach the surface beneath the muck, red cedar or loblolly pine appear. Some of these wet mineral soil flats originally supported loblolly pine marsh, a 2-layered community with a canopy of almost pure loblolly pine over an open grassy layer of marsh grasses or, in the interior, Carex. Originally most of these would have been kept very open by frequent fire spreading from the uplands or adjacent marsh. One of the few remaining fire-maintained examples occurs on Jones Island in Pamlico County. All such stands around the Croatan shoreline have now succeeded to loblolly pine with a tangled, impenetrable understory of shrubs and vines, especially Smilax rotundifolia, S. glauca, S. bona-nox, and Gelsemium. These stands are designated Estuarine Fringe Loblolly Pine Forest in Schafale and Weakley (1993).

Johns Jo jo Aquic Hapludults (fine sandy loam)

The Johns occurs on mesic sandy slopes between longleaf pine uplands and swamp bottomlands. Since the slopes are usually not steep enough to act as firebreaks, the forests are mostly fire-influenced. Most typical original vegetation was mixed pine (longleaf, shortleaf and loblolly savanna and forest with occasional stems of white oak and hickory (mostly *Carya tomentosa)*. On lower slopes with only light ground fires, were found almost pure stands of water oak (*Quercus nigra*). Of limited extend in the Jones County portion, most examples of the Johns have developed dense hardwood understories with reduction in fire frequency.

Kalmia Jo ka Typic Hapludults (loamy sand)

Of very limit extent, in the northwestern part of the Croatan in Jones County, the Kalmia sand typically supported pure stands of longleaf, grading into mixed pine where burned at about every 4-6 or 7-12 years, to hardwoods where most sheltered from fire. Most of the small remnants have now succeeded to loblolly pine and hardwoods.

Kenansville Jo ke* Arenic Hapludults (loamy fine sand)

Limited to Jones County, within the curve of the Trent River around the northwestern corner of the Croatan, the forests of the Kenansville loamy sands originally ranged from pure longleaf in the most fire-exposed parts of the landscape, to mixed pine savanna and pyrophytic woodland closer to the Trent. As with the Alpin soils, there are several naturally fire-protected "islands" of upland soils surrounded by swamps near the confluence of Muddy Cove and Island Creek, where fire was rare, leading to dominance by hardwoods.

Kureb Ca, Cr ku* Spodic Quartzipsamments (sand)

Good examples of the original longleaf pine/dry wiregrass savanna remain in the Croatan. Turkey oak has increased with reduction in fire frequency on most sites but there has been little loss of species diversity. In general the driest sites in the landscape are the most stable, as succession is very slow. There seem to be no naturally fire protected sites with Kureb soils in the Croatan. Similar sands on peninsulas or shorelines were mapped as other series like Wando. This may not be a mapping artifact: illuviation of fine ash accumulated in the soil over millennia of burning may contribute to formation of a spodic layer and other horizonation that would actually lead to different soil series on the same sandy parent material.

Lafitte Ca, Cr lf* Typic Medisaprists (muck)

The brackish Lafitte muck (salinity between 5 and 30 PPT) underlies the vast Cedar Island marsh, and all marshes of Craven County are assigned to this series. Since marsh soils change upstream along the Pamlico/Neuse/Trent River shorelines to soils more resembling Hobucken and Hobonny, this classification is rather arbitrary. In most coastal counties, brackish marshes underlain by deep marsh peat are mapped Lafitte, while shallower, less saline or sandier soils are assigned to other series. The most common dominant in the small marshes along the Pamlico/Neuse estuary is black needle-rush. Upstream, especially along the Trent River, salinity decreases to the oligohaline range. Near New Bern there are large stands of tall cordgrass (*Spartina cynosuroides*) and cattail (*Typha latifolia*).

Leaf Cr, Jo la* Typic Albaquults, clayey (silt loam)

Dominant original vegetation appears to have been tall, straight pond pine forest with the understory kept clear of woody stems by frequent fire. Variation included patches of open pond pine savanna in

slightly wetter situations, and mixed pond pine-loblolly pine near natural firebreaks like streams or wet swamps where fire frequency was slightly lower. Like the slightly dryer Lenoir series (see below), Leaf soils in the region have been almost uniformly excluded from fire and converted to loblolly pine plantation or dense, pocosin-like loblolly and pond pine stands.

Lenoir Cr, Jo le* Aeric Paleaquults, clayey (silt loam)

One of the major soils of the Croatan, the Lenoir loam is also one of the most transformed, in terms of original vegetation. The Lenoir occurs on sometimes extensive flats, along the moisture gradient between slightly drier soils like the Craven, supporting longleaf pine savanna, and slightly wetter series like the Leaf, which originally had tall, fire-maintained pond pine forest. The Craven->Lenoir->Leaf catena developed on fine-textured, almost clayey loam soils. Most existing vegetation on the Lenoir has experienced major reduction in fire frequency, the past practice in the Croatan having been to put fire plough lines at the Craven/Lenoir interface in order to burn only the longleaf pine on the Craven. The result has been to replace the original wet savanna herb layer with a dense, almost pocosin-like understory. Since the Lenoir is a moist mineral soil, extensive acreage throughout the region also has been converted to loblolly pine. I have not seen a good, fire-maintained example on the Croatan, but a small stand in Beaufort County had Longleaf pine, loblolly, pond pine and shortleaf, with scattered stems of post oak. The understory was sparse, with a well-developed grassy herb layer dominated by Andropogon species and a rich diversity of other mesic savanna herbs.

Leon Ca, Cr, Jo ln* Aeric Haplaquods (sand)

The Leon sands are a major series in the Croatan, and where frequently burned, support the largest number of rare plant species. Throughout its range, Venus's flytrap is limited to the wet, sandy Leon and a few closely related series. Under a normal fire regime, pure longleaf pine/diverse wet savanna is the typical natural vegetation. Leon soils are frequently infertile, partly because of the coarse sand texture and partly the location in the landscape. Those in the middle of large peatlands may be so sterile that species diversity is limited to longleaf pine, sparse wiregrass and a few other herbs, despite abundant light and moisture (see the narrow sand lenses north of Catfish Lake). Vegetation and species diversity on the Leon soils have particularly suffered in the past from two practices. Succession to dense woody understory is rapid in less sterile situations than those described above, and most controlled burning was carried out on drier soils. General fire suppression of wetlands led to an unnatural buildup of litter and a pocosin-like shrub layer beneath the longleaf pine on lenses of

Leon sand. When wildfire finally did occur, the fire was fueled by materials so dense that even old longleaf pines were killed. A major episode of this culminated with a fire in the early 1980's that killed about half the longleaf on Leon sand lenses south of Millis Road Savanna. Many of these were 200 year-old trees that had arisen under a frequent fire regime which kept fuel reduced to non-catastrophic levels. The second was the common practice of placing fire plow lines in the ecotone between Leon or other wet soils and dryer longleaf pine savannas. These wetland/upland transition zones, often only a few meters wide, are the primary habitat for a number of the rarest species, whorled loosestrife (*Lysimachia asperulaefolia*) for example.

Lynchburg Ca, Cr, Jo ly* Aeric Paleaquults (fine sandy loam)
Lynchburg is a typical longleaf pine savanna soil type. Characteristic vegetation is pure longleaf pine/wiregrass with diverse savanna grasses and forbs. One frequently burned site on Lynchburg in western Carteret had the second highest species diversity found in this study.

Mandarin Ca mn* Typic Haplohumods (sand)
Typical vegetation of the Mandarin sand is pure longleaf pine/moist wiregrass savanna. Where frequently burned, understory trees are absent and the only shrubs are dwarf species like *Vaccinium tenellum* and *Gaylussaccia dumosa* in the herb layer. Species diversity is moderate to high. The best example is found at Millis Road Savanna. Outside the Croatan, at Cedar Island on the south shore of North Bay, there is an example of Mandarin sand with maritime influence. This site has longleaf pine/wiregrass with yaupon (*Ilex vomitoria*)and shrubby live oak in the understory.

Marvyn Jo mv Typic Hapludults (loamy sand)
A soil of limited extent on the Croatan, confined to side slopes (6 to 15%) along small tributaries of the White Oak River and Trent River in Jones County. In flat landscapes like the Croatan region, fires on most sites could approach only from the upland flats, the bottoms being too wet to carry fire. Under such circumstances, slopes as steep as those on the Marvyn are excellent firebreaks, and fire effects are limited to creeping litter fires which kill stems in the smallest size classes (up to 1 inch diameter) on the upper slopes only. Original vegetation would have been mixed oaks and hickory, with beech on the lower half of steeper slopes. There are some wet-mesophytic trees like sweetgum, black gum, tulip poplar and loblolly pine on the toe slopes, and the upper slopes graded into mixed pine forest and savanna, and then into more fire-exposed uplands of longleaf or pond pine. (In Jones

County the symbol for Marvyn was changed from Ma, as used on the county soil map, to Mv to avoid conflict with the use of Ma to indicate Masontown soils in Carteret).

Masontown Ca ma* Cumulic Humaquepts, siliceous, nonacid (mucky loam)

The Masontown is a swamp forest soil type, with several variants in vegetation dominants. Within the swamp bottoms there are usually at least two phases of vegetation, depending upon wetness. In the wettest places the original swamp forest had a five-layer structure: 1. an open baldcypress canopy, standing some 20 to 40 feet above the closed subcanopy of; 2. *Nyssa aquatica* (in standing water) or *Nyssa biflora* (where muck soils were not actually flooded); 3. a sparse second subcanopy composed of saplings of the canopy cypress and gum plus a few red maple and *Fraxinus caroliniana*; 4. a sparse shrub layer with species like *Clethra alnifolia* and *Itea virginica*, and 5. a highly variable herb layer with *Woodwardia areolata* the most common dominant. The second major variant occurs along the outer third of the swamp bottoms. Cypress appears to have also been the original canopy dominant but loblolly pine is important in places. This appears to be one of the original natural refugia for loblolly pine in a landscape where the original fire regime was otherwise too inhospitable. Fire in the adjacent upland longleaf pine savannas kept the flanks of the bottomlands open, permitting enough light and occasion disturbance for continued loblolly pine establishment. In the bottomlands, most of the virgin cypress was removed 100 years ago, but the remains of five-foot diameter stumps in the Northwest and Southwest Prongs of the Newport River indicate the size of virgin swamp forest.

The Masontown swamps occur near sea level and grade upstream into several different series. The soil series-vegetation complex changes to Dorovan swamp forest where the soil becomes more peaty but, still being below the general peatland surface, is topographically protected from fire. Where it grades into fire-exposed pocosin the soil type changes to Croatan. Where small, narrow drains have been cut from the upland pocosins down to the Masontown bottomlands, the soil series may be mapped Pantego or Torhunta. Nyssa biflora may be the last canopy tree upstream where stringers of narrow swamp drain out of upland pocosins.

Undifferentiated Masontown/Muckalee Cr mm* Cumulic Humaquepts, siliceous, nonacid (mucky fine sandy loam) and **Muckalee**: Typic Fluvaquents, nonacid (sandy loam)

In Craven county swamp soils were mapped without attempting to distinguish the Masontown and Muckalee series. See the discussions for the component series above and below for vegetation of the Masontown-Muckalee complex.

Meggett Cr, Jo me Typic albaqualfs (sandy loam)

The Meggett soils occur in parts of the landscape that have a nonacid clayey subsurface layer. The few examples in the Croatan are atypical of the series elsewhere, where it may occur as wet flats. In the Croatan, soils mapped Meggett are found in swamp headwater sloughs transitional between mixed pine uplands and bottomland swamp. Vegetation of the Meggett is fire-influenced only at its upper end where it grades into fine textured soils like Craven and Exum. Original vegetation at this interface would have been pyrophytic woodland, but the dominant type on the Meggett in the Croatan is nonpyrophytic hardwood forest, with a variety of canopy dominants, including swamp chestnut oak, white oak, tulip poplar, sweet gum, red maple and loblolly pine. Most typical are semi-evergreen bottomland oaks like willow oak, laurel oak and water oak, and in the most fire-protected sites, beech. The understory varies widely in density and includes ironwood (*Carpinus caroliniana*), a few stems of cane and other bottomland shrubs. The Meggett is the only Alfisol with occurrences large enough to map on the Croatan. The occurrence of circumneutral soil type at Island Creek was not large enough to map.

Muckalee Jo mk Typic Fluvaquents, nonacid (sandy loam)

The Muckalee occurs as clayey depressions at the heads of small sloughs leading downstream to swamp forest, or as mineral soil flats along the edges or in the swamp bottoms themselves. The Masontown-Muckalee swamp bottomland complex is incompletely mapped in the region. In Carteret, only the Masontown is shown, although there are small pockets of the slightly dryer Muckalee, mostly too small to map. In Jones County only Muckalee is designated, although the swamp bottoms so mapped also have pockets of soils more like Masontown and Dorovan. In Craven the swamps are all designated Masontown-Muckalee. The Muckalee is less mucky than the Masontown, but the original dominant appears to also have been baldcypress. the understory included loblolly pine, *Nyssa biflora*, tulip poplar, red maple, ash and sweet gum on the wetter phase. Oak flats, dominated sometimes by almost pure stands of swamp chestnut oak (*Quercus michauxii*) can be found. Good examples of the latter occur in the headwaters of Brice Creek. Virgin stands too far upstream for timber to be floated down to sawmills probably persisted until around the turn of the century. In September, 1882 a Carteret County respondent to a timber survey questionnaire stated

"Our swamps abound in oak and cypress." (Hale 1883). The writer's address was just given as "Sander's Store".

Murville Ca, Cr, Jo mu* Typic Haplaquods (mucky sand, mucky loamy sand)
The Murville is one of the major soil series of the Croatan. It consists of a wet, black, mucky sand and vegetation is typically medium pocosin. The stature varies from low to tall pocosin and pond pine-Gordonia forest, depending upon nutrient status and fire. Since the Murville is rarely found except in the most infertile situations, the taller stands are almost invariably the result of reduced fire frequency.

Nahunta Jo na* Aeric Paleaquults, fine-silty (loam)
A little less clayey than the similar Lenoir series, the Nahunta supports mixed pine savanna (more fire) and pyrophytic woodland (less fire), depending upon degree of site exposure to fire. Pines may be various mixtures of longleaf, loblolly, pond pine and even shortleaf depending upon local seed source. Post oak, mixed with the pines, may be an important component on less frequently burned sites. Herb layer dominants include grasses such as *Chasmanthium laxum*, *Andropogon* species and low cane, along with mesic savanna forbs like *Silphium compositum* and *Polygala lutea*. Good, fire-maintained remnants are rare, most examples in the region having been converted to loblolly pine.

Norfolk Ca, Cr, Jo no* Typic Paleudults (loamy fine sand)
Norfolk sand occurs mainly around the western and northern periphery of the Croatan, and, because of the better fire control in the peripheral areas, has lost much of its original diversity through succession. Original vegetation was pure longleaf pine on the more fire-exposed sites toward the interior, and mixed pine savanna toward the edges of streams and bottomland swamps. In these mixed species fire communities, canopy species included longleaf pine, loblolly pine, pond pine and occasionally shortleaf, with an herb layer of mixed grasses and low shrubs. I have only seen one fire-maintained remnant on the Croatan, on the south side of Hunter's Creek.

Onslow Ca, Cr, Jo on* Spodic Paleudults (loamy sand)
Original vegetation was pure dominant longleaf pine/wiregrass, with very high species diversity in the herb layer. In the landscape outside the Croatan, nearly all the Onslow and other loam soils have long been farmed or converted to loblolly pine, and examples with natural vegetation maintained by fire are rare. Some small occurrences of good savanna on Onslow loam are found in the Croatan,

and, like the Craven, Goldsboro and Lenoir, are valuable reference communities for study as examples of original southeastern vegetation.

Pactolus Jo pc* Aquic Quartzipsamments (loamy fine sand)
Limited to Jones County, along the Trent River and the northwestern corner of the Croatan, the forests of the Pactolus sands originally ranged from pure longleaf in the most fire-exposed sites, to mixed pine savanna and pyrophytic woodland closer to the Trent. Most of the remnants have now succeeded to loblolly pine and hardwoods. As with the Alpin soils, there is some Pactolus on naturally fire-protected "islands" of upland soils surrounded by swamps near the confluence of Muddy Cove and Island Creek, where fire frequency was lower than the rest of the region, leading to dominance by mixed pines and hardwoods, rather than longleaf-dominant stands. (In Jones County the symbol for Pactolus was changed from Pa to Pc to avoid conflict with the use of Pa for Pantego in Carteret and Craven).

Pantego Ca, Cr pa* Umbric Paleaquults (fine sandy loam)
Vegetation of the Pantego is similar to the similar Torhunta series. Those occurrences on the edge of the large peatlands originally would have been maintained in low or medium pocosin by frequent fire. Where it extends into lows between pine savanna lands, fertility would be less nutrient-limited and tall pocosin and pond pine forest occurred. Most has now formed very dense, fire-suppressed understory in such areas. (In Jones County the symbol for Pantego was changed from Pn to Pa to agree with symbols for Pantego in Carteret and Craven).

Rains Ca, Cr, Jo ra* Typic Paleaquults (fine sandy loam)
Along with Leon and Woodington, the Rains is the wettest soil series upon which longleaf pine can be found. Vegetation varies widely on the Rains depending upon slight variation in wetness and organic versus mineral content. The original dominant on the slightly drier, slightly less organic phase was wet longleaf pine savanna. Slightly wetter, more organic sites have mixed longleaf and pond pine, often with a considerable amount of cane in the understory. Sites with slightly lower fire frequency can have mixed pine savanna with longleaf, pond pine and loblolly pine co-occurring, in greatly variable dominance by any of the three species. The herb layer in slightly drier, longleaf-dominated situations is species-rich wet savanna herbs. On slightly wetter sites diversity may be lower if the understory is dominated by cane or ferns.

Roanoke Ca, Cr ro* Typic Ochraquults, clayey (loam, fine sandy loam)
Uncommon in the Croatan, the Roanoke soils often serve as refugia for fire-intolerant species like beech. The dense, clayey soil seems to prevent shrub rhizomes from running, so understories usually lack sufficient fuel to carry anything other than light litter fires. Where such fires are frequent, beech may be excluded and the canopy is dominated by oaks, particularly white oak, sometimes with tulip poplar and occasional hickories (*Carya tomentosa* and *Carya glabra*).

Seabrook Ca, Cr se* Aquic Udipsamments (fine sand, fine loamy sand)
Vegetation is complex on the Seabrook soils, which are found primarily on rolling sands adjacent to estuaries. Canopy dominants range from water oak on lower slopes and flats, to longleaf pine on the upland and inland side. In the original landscape they were mostly accessible to fire, but because of slope and proximity to rivers and sounds, did not burn as frequently as other upland types. Three phases can be distinguished. First is mixed pine forest and savanna, which occurred on the higher and more inland sites, along the fire-frequency gradient to pure longleaf types. At various sites, longleaf, loblolly, shortleaf and pond pine can be found, and the Seabrook soils were among the principal natural habitats for loblolly and shortleaf in the original landscape. Second is pyrophytic woodland, with oaks, especially water oak, and loblolly pine, on lower slopes and moist sand flats. Fire was important for maintaining stand structure but fire effects were limited to light litter fires that kept shrubs down, and exposed soil for regeneration. Fires crept down from the uplands or swept inland from adjacent marshes. One exceptionally fire-protected site outside the Croatan, on the peninsula south of Bridgeton in Craven County, had beech, tulip poplar, loblolly pine water oak, post oak southern red oak, white ok and mockernut hickory (*Carya tomentosa*) with an light understory of shrubs. Third are maritime forests, examples of which can be found along salt-influenced shorelines. The presence of live oak and yaupon (*Ilex vomitoria*) define this phase. Most of these sites were accessible to fire and any of the four pine species above may be found along with live oak, with loblolly usually the most important (see Wentworth et al. 1992). Photographs by H.H. Brimley early in this century show a few live oak on Seabrook soils protected within the mouth of Slocum Creek. This was also probably the case with the other larger creeks, but the apparent high rate of erosion and shoreline recession along the Craven portion of the Neuse/Pamlico estuary probably prevented development of any substantial element of maritime forest. The evidence today indicates that in presettlement times, this shoreline had long been cutting directly into longleaf pine savannas.

Stallings Jo sg Aeric Paleaquults (loamy fine sand)

The Stallings series occurs only in the Jones County portion, on flats near drainageways leading into the White Oak River, and as savanna islands in the peatlands near Catfish Lake. The original type was longleaf pine/wiregrass. On the infertile, isolated "islands" species diversity is low and the understory is kept free of shrubs and saplings by frequent fire. Succession is also retarded because of sterility, so that even though original fire frequency was high, a relatively low fire-return interval is required to maintain the bilayered structure. More species diversity occurs on the flats away from peatlands. (In Jones County the symbol for Stallings was changed from St to Sg to avoid conflict with the use of St to indicate State soils in Carteret and Craven).

State Ca, Cr st* Typic Hapludults (loamy fine sand, loamy sand)
The State is another longleaf pine/wiregrass savanna soil. It is of limited extent in the Croatan.

Stockade Jo sx Typic Umbraqualfs (fine sandy loam)
There are only a few tiny occurrences of the Stockade series, all in western Jones County. Vegetation is usually swampy but may have tulip poplar. This series is also a natural habitat for loblolly pine in a landscape where fire originally excluded it from the more frequently burned uplands.

Suffolk Cr su* Typic Hapludults (loamy sand)
The Suffolk series consists of steeply rolling sandy slopes and ravines along tributaries of the Neuse River in Craven County. Because the steep, moist slopes acted as good firebreaks against fires approaching from the west, the Suffolk is clothed with rich mesic, non-pyrophytic forest. Canopy dominants are white oak, tulip poplar and several species of hickories, with an understory containing *Magnolia tripetala*, *Carpinus caroliniana*, *Storax grandifolia* and beech. Vegetation is multi-storied and there is high species diversity in the shrub and herb layers. This includes many mesophytic species like solomon seal, uncommon in the surrounding fire communities, suggesting that these moist slopes have long been nonpyrophytic refugia in a fire landscape.

Tarboro Cr ta Typic Udipsamments (sand)

Like the Conetoe, soils mapped Tarboro occur primarily along the south side of the Neuse River. As with most other soils in the vicinity, reduced fire frequency has lead to woody succession from the presettlement longleaf pine-dominated stands to loblolly and hardwoods, which were originally

confined to the relatively fire protected zone within perhaps a hundred meters of the river. The Tarboro is similar to the Wando, the only other Typic Udipsamments in the Croatan. On these dry-mesic sands, the first stage of non-pyrophytic succession leads to loblolly pine and southern red oak (*Quercus falcata*), and these are the dominants today, having replaced longleaf over much of the area. Original vegetation was dry longleaf pine savanna on more fire-exposed locations, mixed pine savanna and pyrophytic woodland on the more rolling portions, and loblolly pine and southern red oak along the river.

Tomotley Ca, Cr tm* Typic Ochraquults (fine sandy loam)
Tomotley soils support hardwood forest in sites that are almost completely fire-protected and pyrophytic woodland where accessible to fire, but at longer intervals than in the surrounding pine uplands.

Torhunta Ca, Cr, Jo to* Typic Humaquepts (mucky fine sandy loam, fine sandy loam)
The Torhunta is wetter than the Leon, Rains and Woodington, which represent the wettest soils that support longleaf pine savanna. Under the original fire regime, presettlement vegetation would have ranged from open, tall pond pine forest to pond pine savanna. The forest would have been bilayered with the understory kept clear of woody stems by frequent fire, which also maintained the herb layer. Herb layer dominants probably ranged from ferns to cane in the forested portions, to species-rich wet savanna grasses and forbs in the open savanna. With reduction in fire frequency, most examples of Torhunta have succeeded to pond pine forest with dense shrub understory, dense pocosin, or bay forest.

Wando Ca wa Typic Udipsamments (fine sand)
Soils mapped Wando occur on sands near shorelines where erosion has lead to some topographic development. Vegetation ranges from pure longleaf on the inland, more fire-exposed parts, to mixed pine savanna on the more rolling and somewhat fire-protected parts, to maritime forest with live oak and yaupon along shorelines. Most live oak was removed in the 18th and 19th centuries for shipbuilding.

Woodington Jo wo Typic Paleaquults (fine sandy loam)
This series which is similar to the Rains, occurs on the Croatan only in southwestern Jones County in

the vicinity of Black Swamp Creek and Holston Creek. Under the original fire regime, vegetation would have been longleaf pine/open wet savanna. With reduced fire frequency, a dense woody understory has developed on all sites in the Croatan. Examples of the original open savanna under a frequent-fire regime can be seen in Holly Shelter Game Land. Variation includes patches of pond pine savanna and mixed longleaf and pond

CASE STUDY 4

PRESETTLEMENT VEGETATION OF THE SAVANNAH RIVER SITE

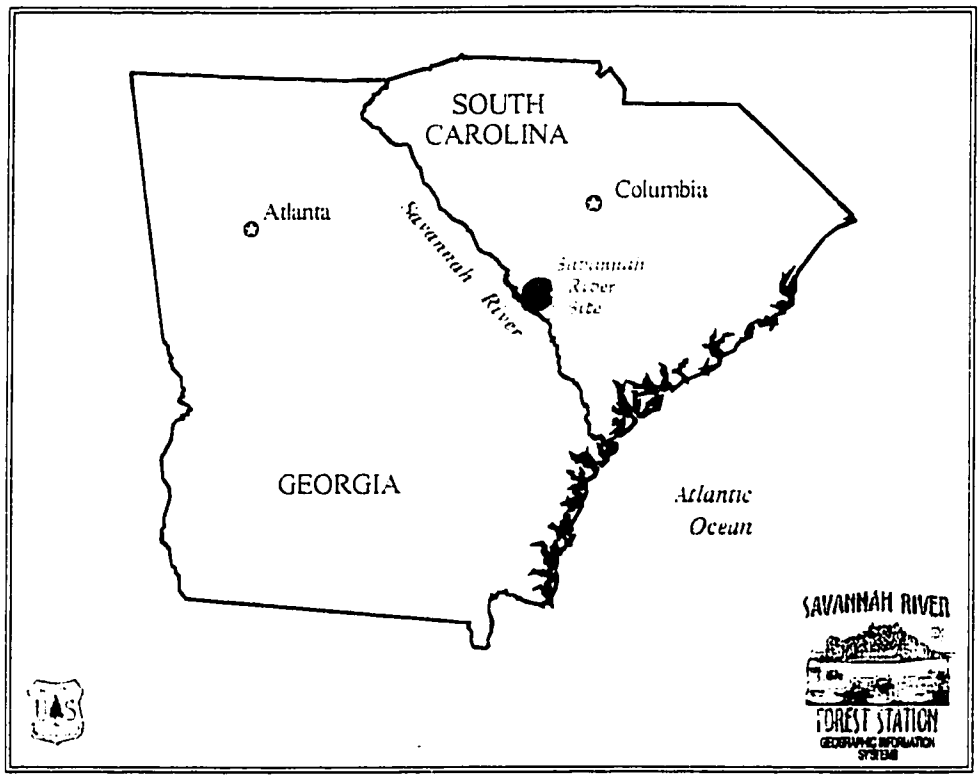
ABSTRACT

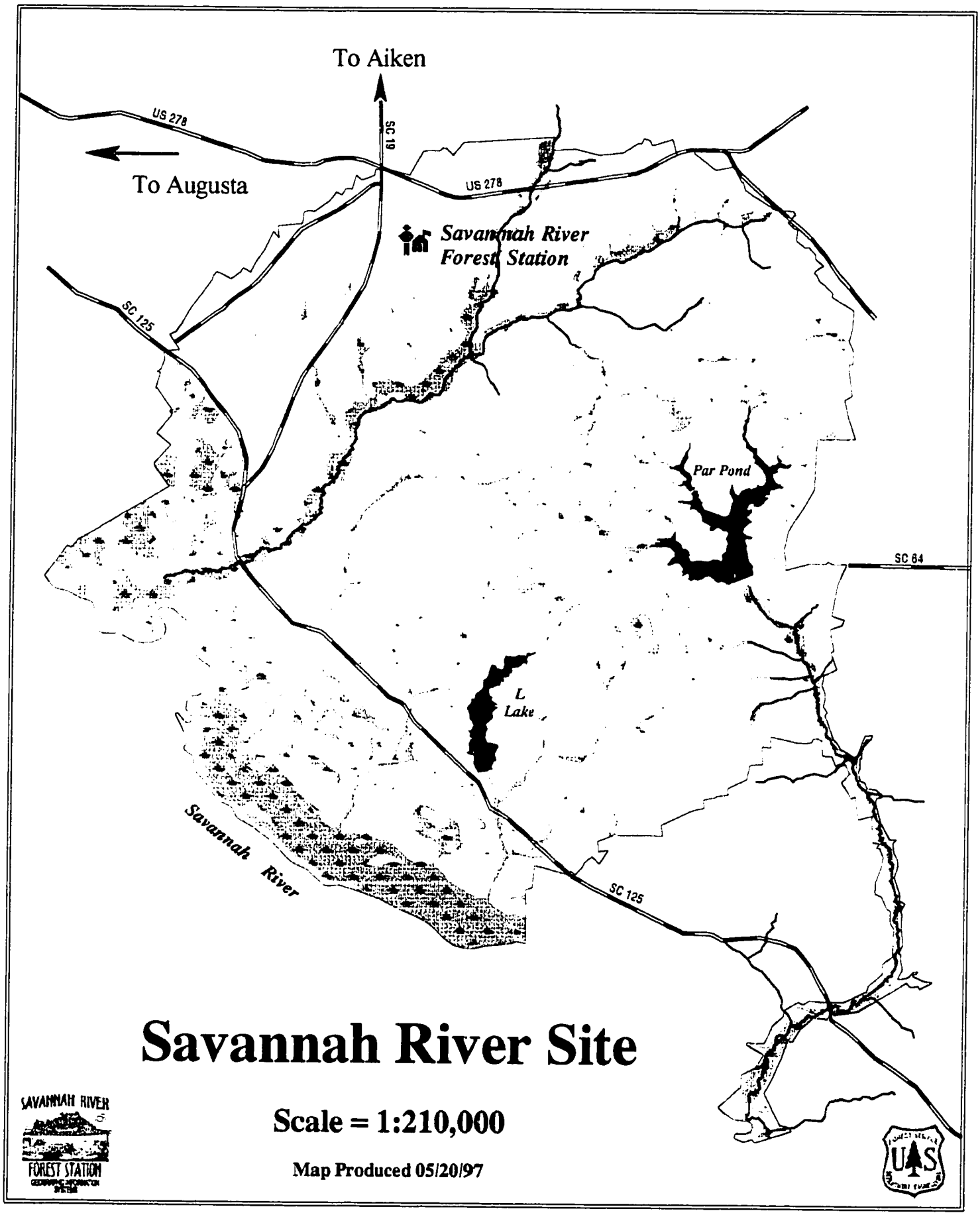
The objective of this project was to create a map of presettlement vegetation of the Savannah River Site, for guidance in managing and restoring examples of longleaf pine, pyrophytic hardwoods, canebrake, pocosin and other natural ecosystems originally present. Rather than mapping existing vegetation, the intent was to produce the best approximation of the natural vegetation that existed prior to arrival of the first European settlers around 1730. This was the vegetation that had dominated the landscape for the preceding 6,000 years. Key tasks were 1) to investigate presettlement fire frequency of the Savannah River Site; 2) to determine presettlement vegetation of the site, and 3) to conduct the first large-scale demonstration of the pyrographic method for making maps of original or presettlement vegetation. Field data were collected in 1994, 1995 and 1996. A new mapping method, developed in the course of a doctoral dissertation by the author, was used to reconstruct presettlement fire frequency and presettlement vegetation. This involved field sampling of the best remnant vegetation on each of the 29 soil series of SRS (Rogers 1990); compilation of historical information relating to vegetation; characterizing fire effects in each kind of vegetation on each soil series; and identification of fire-frequency indicator species and fire-frequency indicator plant communities. Rare species found included *Delphinium carolinianum*, *Carex tenax*, *Baptisia lanceolata* and *Nolina georgiana*. A population of some 90 plants of *Fothergilla gardenii* was a new species for SRS and a range extension for the species. Several examples of fire-suppressed former canebrake and pocosin were new plant communities for SRS. Soil series from recent soil maps were then used to put boundaries on vegetation types. Accuracy was tested by comparison with trees identified on historical survey plats. Based on results of this study, about 82.4% of original vegetation of

the Savannah River Site was in some way structured by fire. The presettlement vegetation method applied here is expected to be useful throughout the South and in other landscapes where frequent fire was an important determinant of vegetation in presettlement times. Understanding original vegetation is essential to managing lands for perpetuation of rare species, natural vegetation communities, and the full range of animal and plant species, which depend upon them for habitat.

KEY WORDS: Fire Frequency, Landscape Fire Ecology, Presettlement Fire Frequency, Presettlement Vegetation, Vegetation Mapping

Figures C4.1 and C4.2. The Savannah River Site, Aiken, Allendale and Barnwell Counties, South Carolina.


SOUTH
CAROLINA
Columbia
Atlanta
Savannah River
Savannah
River
Site
GEORGIA
Atlantic
Ocean
SAVANNAH RIVER
FOREST STATION
GEOGRAPHIC INFORMATION
SYSTEMS

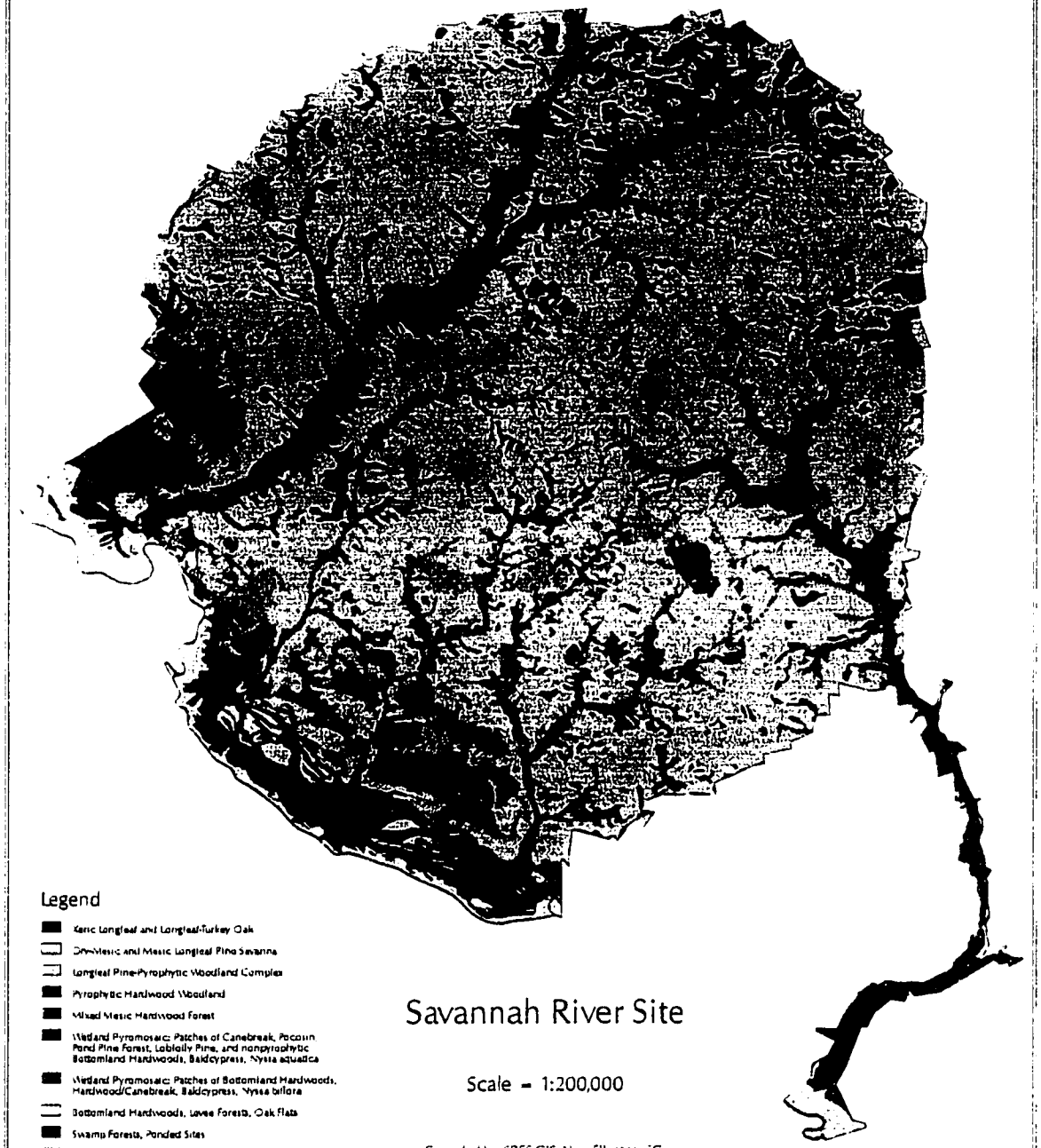


Savannah River Site

Scale = 1:210,000

Map Produced 05/20/97

Presettlement Vegetation Types



Legend

- Xeric Longleaf and Longleaf-Turkey Oak
- Dry-Mesic and Mesic Longleaf Pine Savanna
- Longleaf Pine-Pyrophytic Woodland Complex
- Pyrophytic Hardwood Woodland
- Mixed Mesic Hardwood Forest
- Wetland Pyromosaic: Patches of Canebreak, Pocosin, Pond Pine Forest, Loblolly Pine, and nonpyrophytic Bottomland Hardwoods, Baldcypress, Nyssa aquatica
- Wetland Pyromosaic: Patches of Bottomland Hardwoods, Hardwood/Canebreak, Baldcypress, Nyssa biflora
- Bottomland Hardwoods, Levee Forests, Oak Flats
- Swamp Forests, Ponded Sites
- Carolina Bays, Upland Depressions
- Udorthents
- Surface Water - No Type Identified

Savannah River Site

Scale = 1:200,000

Compiled by: SRFS-GIS, New Ellenton, SC
Using current GIS Data as of 05/21/97
Vegetation Types Defined by Cecil Frost from Soils, Historical Data, and Remnant Vegetation.

INTRODUCTION

In the southeastern U.S. it is possible to reconstruct original vegetation and natural fire regimes, even where human land use practices dating to the Colonial Era have radically transformed upland vegetation. An independent test of mapping methods described below confirms that this can be done even without witness tree records from early surveys, because of the pervasiveness of fire in the presettlement southeastern landscape and the predictability of fire in shaping vegetation (Chapters 2 through 7). Witness trees from 18th and 19th century survey plats provided an independent test to verify the effectiveness of mapping using landscape fire ecology methods. Given modern soil maps as a basis for examination of vegetation, and any available historical data, it was demonstrated that a close approximation of original forest and other vegetation types could be obtained. Because it is necessary to simultaneously determine original fire frequency and fire behavior in the landscape, I have been calling this vegetation mapping approach the landscape fire ecology method or the pyrographic method.

The Savannah River Site (SRS) is near the western margin of the most frequent-fire region of the Southeast, with historical records of almost annual fires over large areas (see map, Chapter 4). The landscape now occupied by the Savannah River Site is topographically and pedologically complex, but has lost some of its complex natural vegetation and species diversity as the result of human disturbance and twentieth century fire suppression. Still there are enough historic materials, remnant native species and high quality plant community examples on the site, as well as information from natural fire vegetation on similar soils beyond the site boundaries, to substantially reconstruct original vegetation and fire regime.

In a long-disturbed landscape, reconstructing presettlement vegetation requires synthesis of every shred of available physical, vegetational and historic information. In the southeast this also requires interpretation of the role of fire using pyrographic methods (Chapters 6 and 7). The overall region of which SRS is a part originally experienced a 1-3 year fire frequency on most of the sandy uplands (Frost 1993, 1995). But despite frequent fire on the more fire-exposed portions of the landscape, topographic complexity, particularly along the east slopes of Upper

Three Runs Creek, Fourmile Branch, Pen Branch and Steel Creek, permitted the coexistence of frequent fire types like longleaf pine/wiregrass on uplands, along with highly fire-intolerant hardwoods like beech, in naturally fire-protected refugia (steep slopes and ravines), sometimes within the space of a hundred meters. Pyrophytic woodlands dominated by hickory, oaks and pines occupied the fire-tension zones between these extremes. The objectives of this study were:

1. Determine the community types and species composition of original vegetation types and their soil, topographic and fire relations.
2. Reconstruct the generalized presettlement fire regime for the Savannah River Site.
3. Create the best approximation presettlement natural vegetation map, at the resolution of the soil series.

The original vegetation map was transferred to GIS, as a layer for use in planning, for future studies, and for restoration and management of natural forest communities and wildlife habitats. This document and accompanying maps can also be used to help delimit habitat for endangered and threatened animals and plants. The project constitutes a demonstration of the pyrographic or landscape fire ecology method for reconstruction of presettlement vegetation and fire frequency regime. It illustrates the applicability of this new method for public lands, natural areas and preserves throughout the Southeastern U.S. Figures C4.1 and C4.2 outline the study area. See a separate report by Brooks and Crass (1991) for background on climate, Indians, archaeology, and historical settlement patterns.

Geology and Soils

The following discussion of is summarized from geologic work done at SRS by Nystrom, Willoughby and Price (1991), Soller and Mills (1991), and other authors, as well as from interpretation based on the topographic and soil maps of the site. The Savannah River Site lies near the middle of the Upper (Inner) Coastal Plain. This region is bounded on the east by the Orangeburg scarp, which passes through central Allendale County, and on the west by its contact with the Piedmont, near the Aiken-Edgefield County line. The youngest surface on SRS is the Savannah River floodplain, the features of which range from sediments deposited last month, to mid-Holocene--perhaps 5,000 years ago--when post-glacial seas began to approach modern levels and the present Savannah River stream gradient was stabilized.

Next youngest, Pleistocene in age, are the Savannah River terraces, shown as elements of the Wicomico Terrace in Brooks and Crass (1991), citing Langley and Marter (1973). There are two distinct elements, a lower and an upper terrace (see Figure C4.7). The lower terrace may date to the Sangamon Interglacial, some 40,000-80,000 years ago, when sea level was higher than today, and the river gradient would have been less steep. The break between the two terraces is apparent on the topographic map and also on the slope class map (Figure C4.4), appearing as a narrow, undulating line. This mid-terrace scarp is distinct in some places, but too gradual to distinguish in others. It could represent a high water mark for the Sangamon Interglacial, in which case the upper terrace might correspond to the previous (Yarmouth) Interglacial or it might correspond with two different highstands of the sea during the Sangamon.

The floodplain and both river terraces slope slightly downstream along the river's elevational gradient. The upriver toe of the upper scarp, at its contact with the sandhills near Jackson, lies about 200 feet above sea level. It drops to about 150 feet near the southern boundary near Barricade 5. The poorly defined mid-terrace scarp lies at around 130 feet at its upstream end near Cowden, and falls to 100 feet at the southern boundary. The wet toe of the scarp at the edge of the Savannah River floodplain is about 95 feet at the upper end near Possum Eddy, and declines only to 85 feet at the southern end near Steel Creek Landing. The three terraces then, have different degrees of tilt, the floodplain losing only 10 feet, the first terrace 30 feet and the upper terrace 50 feet.

Breaks between geomorphostratigraphic units on the uplands above the terraces are much less distinct, and seem not to have had much effect in differentiating plant communities. Geologists in the past two decades have shied away from using traditional coastal plain terrace names like Sunderland and Brandywine because of the difficulty of correlating them from place to place, and because tectonic changes may not have permitted them to develop as continuous features.

The oldest features exposed at SRS are the calcareous deposits, of Late Cretaceous age, cropping out at the lowest elevations along the Savannah River (Nystrom, Willoughby and Price

1991). Over this, and apparently underlying the whole of SRS, is the sandy Upper Paleocene Lang Syne Formation. This formation is overlain by the lower Eocene Orangeburg Group. This group has two members in the area, the Huber Formation, which begins near Jackson, and the Congaree Formation, which outcrops along Upper Three Runs Creek, extending upstream from its junction with Tinker Creek. This major formation is up to 27 m (89 ft) thick, and may be is a major source of parent material for soils that outcrop at low to medium elevations. The dominant lithology is a pale yellow, medium grained sand. This is overlain by the Middle Eocene McBean Formation, about 15 m thick. It outcrops at a site just downstream from the juncture of Upper Three Runs Creek and Tinker Creek. It accounts for some of the calcareous outcrop at Shell Bluff Landing on the Savannah River, and may be responsible for some of the unusual flora, such as walnut, found on lower slopes along Upper Three Runs. Above this is the Barnwell Group of Upper Eocene age. Its Dry Branch Formation (Griffins Landing Member) outcrops along Lower Three Runs and the Savannah River. This contains many of the beds in the "calcareous zone" at SRS, and may be the marl first discovered by Edmund Ruffin at Boiling Spring and 4 miles downstream at Roaring Spring (Ruffin 1843a,b,c). It also contains sandy lithologies. The Dry Branch Formation averages 6 to 12 m thick. Next over this lies the Upper Eocene Tobacco Road sand, about 15 m thick. This is capped with the Upland Formation, the highest and youngest geological unit identified on the interior uplands of SRS. Age of this sandy deposit is uncertain, but may be of lower to middle Miocene age.

The majority of longleaf pine soils of the site, including the sandy Blanton, Dothan, Troup, Lucy and Vaucluse, appear, then, to owe their origin to ancient Eocene deposits, with only some of the high-elevation Lakeland soils belonging to the younger Miocene. This would give an age range of all the SRS uplands, exclusive of the Savannah River floodplain and terraces, and recent alluvium in stream valleys, of some 20 to 50 million years.

Vegetation and soils at SRS. Table C4.1 lists the soils of SRS, from the driest to the wettest, along with the principal vegetation types associated with each soil series. In the table I grouped the 29 soil series into twelve ecological moisture classes from soil taxonomy, NRCS soil drainage class, water holding capacity and landscape position. One or more symbols following each soil

Table C4.1. VEGETATION AND SOILS OF THE SAVANNAH RIVER SITE
RANKED APPROXIMATELY FROM DRIEST TO WETTEST

MOISTURE CLASS	SOIL SUBGROUP	NRCS SOIL DRAINAGE CLASS	WATER HOLDING CAP'Y	SOIL SERIES
1	Typic Quartzipsamments	ED	L	Lakeland□
2	Grossarenic Paleudults	SED	L	Blanton□
3	Grossarenic Paleudults	WD	L	Troup□○●
	Arenic Paleuduults	WD	L	Lucy□
	Arenic Plinthic Paleudults	WD	L	Fuquay□
	Plinthic Paleudults	WD	M	Dothan□
4	Typic Hapluduults	WD	L	Neeces□
	Arenic Paleuduults	WD	L	Wagram□○
	Typic Paleudults	WD	M	Norfolk□
	Typic Paleuduults	WD	M	Orangeburg□○
	Arenic Hapludults	WD	L	Ailey□○
	Typic Hapludults	WD	L	Vaucluse□○
5	Aquic Hapludults	MWD	M	Hornsville●
	Aquic Hapludults	MWD	M	Eunola○*
	Fluventic Dystrochrepts	WD	H	Shellbluff■
	Typic Udifluvents	WD	L	Ochlockonee○
	Typic Udifluvents	MWD	M	Toccoa■
	Grossarenic Paleudults	SPD	L	Albany○●*
	Aquic Arenic Paleudults	SPD	L	Ocilla○*
	Aeric Paleaquults	SPD	M	Smithboro○●*
6	Fluvaquentic Dystrochrepts	SPD	M	Tawcaw■
	Typic Ochraquults	PD	M	Rembert■●◊
7	Arenic Ochraquults	PD	L	Williman◊♦^
8	Typic Ochraquults	PD	M	Ogeechee ponds★
9	Fluvaquents	PD	L	Fluvaquents★♦◊■^*
10	Cumulic Humaquepts	VPD	L	Pickney♦◊^★
11	Typic Fluvaquents	PD	M	Chastain★
	Typic Fluvaquents	PD	M	Kinston★
12	Typic Medisaprists	VPD	H	Dorovan★

□ Longleaf dominant stands.
○ Pyrophytic woodland.
_ Pond pine dominant or a significant component.
◊ Canebrake or pocosin.
♦ Wetland pyromosaic.
● Hardwoods dominant: Mixed Mesophytic Hardwood Forest on steep, fire-sheltered slopes, and only lightly fire-influenced river terrace hardwood flats.
■ Hardwoods dominant: bottomlands, levees and floodplain islands.
★ Swamps: baldcypress, tupelo, swamp black gum.
* Presettlement habitats for loblolly pine.

series indicate vegetation types, with the typical dominant types first, followed by less frequent types. More than one symbol appears when there is within-series variation in aspect, fire exposure, landscape position or depth to water table.

Calcareous soils at SRS. Calciphiles or species of nonacid soils, such as Echinacea laevigata and walnut, are sprinkled widely across SRS. Their presence suggests the influence of calcareous geologic strata on vegetation along the zones of subsoil exposure along side slopes. Edmund Ruffin was the first to note extensive calcareous deposits underlying the Savannah River Site (Ruffin 1843a, 1843b, 1843c). Ruffin found shells and marl at a number of locations along Lower Three Runs and the Savannah River. On May 31, 1843 he traveled, "to the Boiling Springs 10 miles from Barnwell, & near the Lower Three Runs", where he began explorations for marl. The springs were named for a strong spring "of weakly impregnated limestone water." Marl was exposed near the foot of the sloping hill by the spring. He also found marl & shells in Roaring Spring, two miles down, and at Gen. Erwin's mill, 4 miles from Boiling Spring village, on another branch of the Lower Three Runs. On June 1 he ascended the Savannah River to the plantation of Rev. Elliot Estes, finding a marl deposit where a stream disappeared under the surface. This stream "...passed along the foot of a hill-side & through a piece of narrow low ground emptying into the Savannah below." He then found marl at Holly's plantation on the low grounds of the Lower Three Runs Near Harley's Bridge [on Mills' map, 1825] & mill." Ruffin was followed by a geologist, Tuomey (1848) who verified his finds and reported his analyses (Table C4.2).

Table C4.2. "Percent carbonate of lime as determined by Mr. Ruffin" at the Savannah River Site (Tuomey 1848).	
1.	On a branch of Lower Three Runs, near Boiling Spring, Col. Hay's: 74%
2.	From a spring half a mile lower: 62%
3.	On main stream of Lower Three Runs, W. Holly's low ground: 64%
4.	Thin, soapy layer, forming the upper surface of the marl, and found in different parts of the bed of the creek: 22%
5.	From Gillett's Mill, Gen. Erwin's, firmer parts: 64%,
6.	softest part: 46%
7.	Rev. Elliott Estes's land, on Savannah River (above Lower Three Runs: 92%
8.	Same location, marlstone: 90%
9.	Major J.G. Brown's, Lower Three Runs, upper part: 50%
10.	Same location, 10 ft below the surface: 32%

While Ruffin only found marl at low elevations, Tuomey discovered beds at several higher sites. "On Tinker's Creek there are several localities at which I found Eocene fossils, and among them the large *Ostrea Georgiana*, so abundant at Shell Bluff." He also found silicified shells along Upper Three Runs. Modern work (Soller and Mills 1991, Nystrom et al. 1991) confirm at least three major formations at SRS having some calcareous strata. It seems likely that such strata, even where they do not outcrop conspicuously, may modify soil pH and provide calcium availability in many places at SRS. The relations between vegetation and soils affected by marls have not been investigated to any extent at SRS. Many rare plant species, such as smooth coneflower (*Echinacea laevigata*) are associated with circumneutral soils.

METHODS

The preparation for the map of presettlement vegetation of the Savannah River Site subsumed all that was learned in previous work in reconstructing original vegetation of Pamlico and Dare counties, North Carolina, and the Croatan National Forest. Most of the available methods discussed in Chapters 6 and 7 were applied in this study. The steps leading to production of the map of presettlement vegetation are listed in Table C4.3 below.

The final maps I and II (in the enclosed map pocket) were made using natural fire vegetation remnants found in the field, historical records, and principles of landscape fire

ecology (Chapters 6 and 7). Soil series maps were used to put boundaries on vegetation types. As a the test of map accuracy, historical ground truthing was employed to compare the mapped vegetation types with boundary tree species mapped by past surveyors at specific points on historic survey plats from the 18th and 19th centuries. Using the scoring rules described below, the mapping accuracy was 97%.

Table C4.3. Field Methods. For each site on a particular soil series:

1.	Verify soil taxonomy in the field and correlate with vegetation types.
2.	Assemble complete species list by vegetation layer (canopy, subcanopy, shrub layer, herb layer). Make cover estimates by layer to gauge degree of woody succession. Record existing community type and make preliminary estimate of presettlement community type.
3.	Determine recent fire history from fire char, fire scar cores, shrub stem age classes.
4.	Examine vegetation change along local soil, moisture and fire frequency gradients.
5.	Determine extent of human disturbance history, including evidence of turpentining, logging, grazing and fire suppression.
6.	Determine fire compartment size.
7.	Assign first estimate of presettlement fire return interval.
8.	Determine number and effectiveness of natural firebreaks.
9.	Collect any local and regional records of original vegetation.
10.	Assemble any historic and recent vegetation records and studies from other parts of
11.	the southeastern landscape that apply.
12.	Record any fire-frequency indicator species present and map them onto the specific soil series on which they are or were found.
13.	Assign tentative estimates of recent fire frequency and revise original fire frequency estimate.
14.	Assign tentative estimates of presettlement vegetation type and species dominants.
15.	Determine variation, if any, by slope and aspect.
16.	Determine range of variation in vegetation between pedons of the same soil series within the study site.

Plot Methods. For sampling at SRS I used species lists for individual soil pedons on particular soil series to document natural vegetation. A plot consisted of a particular pedon of one soil series. All species were identified by stratum and the cover value of each species on the soil

pedon, also by stratum, was estimated using the cover classes below. The following ten cover classes defined by the North Carolina Vegetation Survey (Peet et al. 1998).

COVER SCALE:		5	5-10
10	95-100 %	4	2-5
9	75-95	3	1-2
8	50-75	2	0-1
7	25-50	1	Trace (as with one seedling, no appreciable cover)
6	10-25		

Cover area for each species, by layer, was estimated for an area of about 100 meters square and then adjusted while wandering through the plot. The species lists and cover values are roughly equivalent to those that would be obtained from 1/10 hectare plots. See Chapter 7, Table 7.3 for an example of a species list with cover values for a plot on Lakeland sand (the same site as in Figure C4.16).

SYNTHESIS AND MAPPING

After obtaining soil photomaps and assembling the historical data, the method consists of the following major steps. Plant taxonomy generally follows Kartesz (1994), with recent updates from Weakley (1996). Following are some guidelines for this stage of mapping.

1. Approximating presettlement community types.

a. Sample remnant natural vegetation on each soil series in the area under study, according to the scheme in Table C4.3. This should include burned examples if fire is believed to have played a role in presettlement vegetation. If some series have no natural remnants, then sample remnants on the same soils in any nearby counties for which they are available.

b. Watch for fire frequency indicator species (such as *Astragalus michauxii*, smooth coneflower (*Echinacea laevigata*) and wiregrass (*Aristida beyrichiana*), and fire-frequency indicator communities (like canebrake, pocosin, white cedar or beech forest), both in the field, in

herbarium records, and in the historical record. Each site for these indicators can be assigned a fire frequency, based on the known range of fire frequency tolerance for each species (for examples see Appendix 2. Fire regimes of selected rare and common fire dependent species of the southeastern U.S.). Adjust these figures slightly upward or downward depending upon soil type and topographic situation for each specific occurrence.

c. Build species lists and make cover estimates by layer (canopy, subcanopy, shrubs, herbs, vines) for all communities on each soil series, under natural fire regimes, and under fire suppression. Learn to recognize the degree of fire suppression for each.

d. Record evidence of successional changes resulting from fire exclusion, reduction in fire frequency or change in season of burn.

2. First approximation vegetation map. Decide upon appropriate mapping units like beech forest, pine savanna, or canebrake, and assign vegetation types to each slope class of each soil series. Group related soils with similar vegetation and assign a color to each group on GIS.

3. First approximation presettlement fire frequency map. Using a copy of the soil series base map, plot all known existing or historical fire indicator species and communities. This should begin to yield a picture of the regional pattern of fire regimes. Where data is scarce, it is useful to reconstruct fire frequency over the larger region that includes the study area. Since there will then be many more examples found, the information can be extrapolated to portions of the study area where information is lacking. Threading contours along lines of equal fire frequency will produce something like a topographic map, only the isopleths will represent different fire-return intervals, or different levels of fire effects, rather than elevation. Alternatively, fire frequency can be mapped by fire compartment.

4. Second approximation vegetation map. Compare the first map of vegetation with the first fire frequency map. At this point some adjustments can be made and areas needing more field work will become obvious. Return to the field to resolve any apparent discrepancies, such as frequent-fire vegetation types and non-pyrophytic vegetation that occur in immediate proximity (this may not be an error--there may just be a locally steep fire-frequency gradient). Pyrophytic wetlands usually require further work because they may have more than one vegetation type on

the same soil series. The effects of local natural firebreaks may need to be investigated.

5. **Readjust the vegetation map**, using the new field data.

6. **Refine the fire frequency map**, using any new fire frequency data and the adjusted vegetation map.

7. **Return to the historical record** for discussions or information that may be better interpreted now, after the questions are better known.

8. **Refine both the presettlement vegetation and fire frequency maps**, using any new insights from the historical record. At this point there will probably be more field questions to answer. There may be more iterations of steps 5, 6, 7 and 8 before a final map is arrived at (see enclosed map supplement).

9. **Apply an external test** to determine accuracy of map results. In Case Study 1 below, historical sources were used to test map accuracy at 200 random points. Within the somewhat broad categories of vegetation available in historical records map accuracy was 83%. The map was further refined to include the historical information which had been reserved up to that time as a way to test the map built up strictly with existing remnant vegetation and landscape fire ecology. In Case Study 4, at the Savannah River Site, two different types of tests using historical information were applied. See this case study for a full application of the methods developed.

Figure C4.4. Slope class map, generated from digital elevation data on the Savannah River Forest Station geographic information system (raster cell size 30 m). This classification was developed to help delimit firebreaks and natural fire compartments, as an aid to estimating presettlement fire frequency. Most of the uplands fall into the 0-2 and 2-10% slope classes. This kind of terrain offers no impediment to fire, either backing, flanking or head fire. On the other hand, steep slopes greater than 20% are effective firebreaks if they have water or nonflammable vegetation at the slope toe, and may serve as refugia for non-pyrophytic species such as beech and mulberry. Note in Figure C4.7 that such refugia are mostly found along the southeastern sides of the four parallel stream systems draining southwest into the Savannah River (Upper Three Runs Creek, Fourmile Branch, Pen Branch and Steel Creek). Between these two extremes, slope classes between 10 and 20% may serve as fire filters in situations where fire must move downslope. Fire filters slow down rate of spread, and whether fire passes successfully all the way through the filter depends upon fuel, wind speed, wind direction, temperature, humidity, and fuel moisture at time of burn.

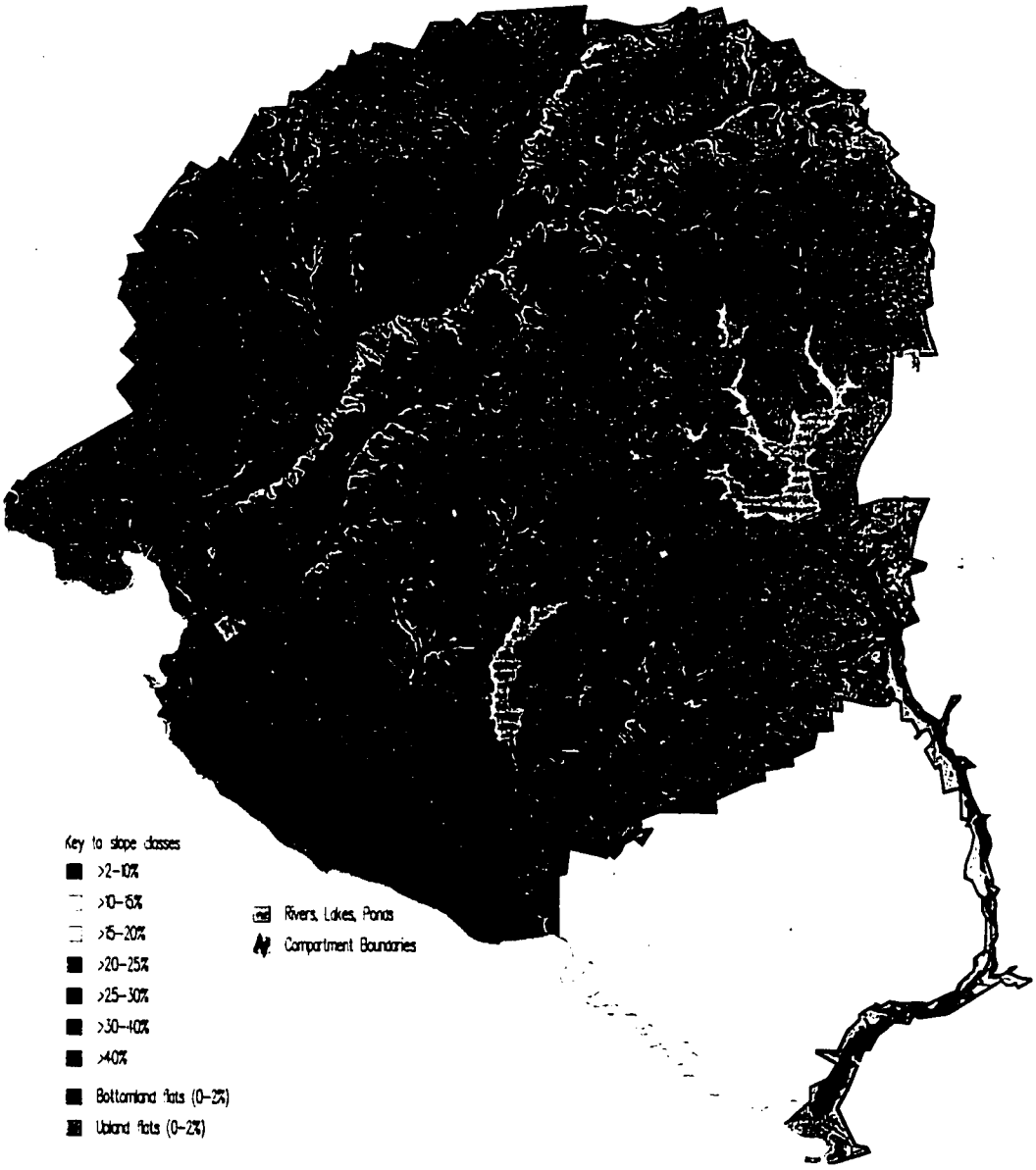

Key to slope classes
>2-10%
>10-15%
>15-20%
>20-25%
>25-30%
>30-40%
>40%
Bottomland flats (0-2%)
Upland flats (0-2%)
Rivers, Lakes, Ponds
Compartment Boundaries

Figure C4.5. Spring and summer fire compartments. Assuming that most ignitions were caused by lightning during the April-September convection storm season, there were nine fire compartments in the presettlement SRS landscape. Given that the greatest area of land was burned during the spring fire season (Barden 1973), this map is likely a better approximation of fire behavior in the original landscape than with cool season burns--see Figure C4.6 below--where many more ignitions would be required to maintain the same overall fire frequency. Typical conditions during growing season fire events might be: temperature 85-92 degrees F, humidity 10-15% during hottest part of the day, and winds south or southwest at 10-15 mph (15-30 mph for as much as 24 hours during frontal approach and passage: a fire passing through during such times would constitute a severe fire event).

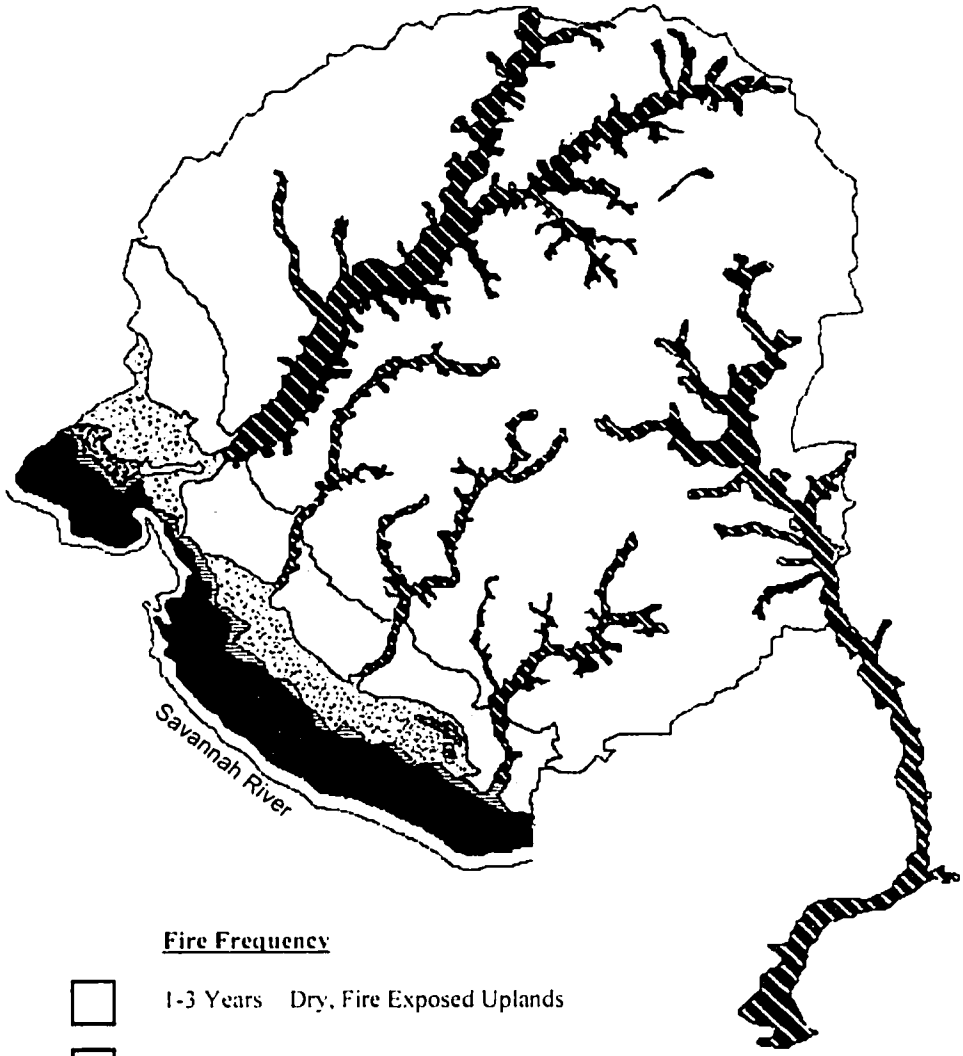
The low scarp between the Savannah River terrace and the dry uplands above, is more of a fire filter than a firebreak, and may not have served as a firebreak during most growing season fires. Also, during a severe summer fire event, even the natural firebreaks between the few major fire compartments might not serve to prevent spotting over, so that it is conceivable that one ignition inside or beyond the boundaries of SRS, might burn the entire site. Thousand square mile fires in the sandhills have been reported in the historical literature (Charleston Daily Courier 1855).

Figure C4.6. Cool season fire compartments, under typical winter burning conditions (temperature 40-60 degrees F, winds 5-10 mph, direction various, moderate humidity within normal prescription limits, litter/duff layer moist. There are potentially 110 fire compartments under these conditions versus 9 in summer (Figure C4.5), and there would be twice as many if roads and other man-made firebreaks were considered. Most fires in nature, however, would not have occurred under these conditions. Dashed lines show constrictions between large fire compartments where fires would easily pass under hot, dry conditions, but might not pass during cool season burns. This could happen when a fire backing slowly toward the corridor to the next compartment might die out during the night when temperatures drop and humidity rises (National Wildfire Coordinating Group. 1981). The probability is that fewer fires would spread from compartment to compartment than during summer. Work on military bases (Fort Bragg and Camp Lejeune, NC) indicate that summer fires pass through bottomlands and small pineland drains that would serve as effective fire barriers in winter. The net effect is that a much greater number of ignitions would be needed in winter to burn a given amount of land than in summer.

Figure C4.7. Presettlement fire regimes of the Savannah River Site, derived by combining historical records--some of which mention annual fires--with the presettlement vegetation map. The map is based in part on remnant fire-frequency indicator species like wiregrass, and fire-frequency indicator plant communities like canebrake.

Table C4.4 Eight Fire Frequency Classes in the Presettlement Fire Landscape

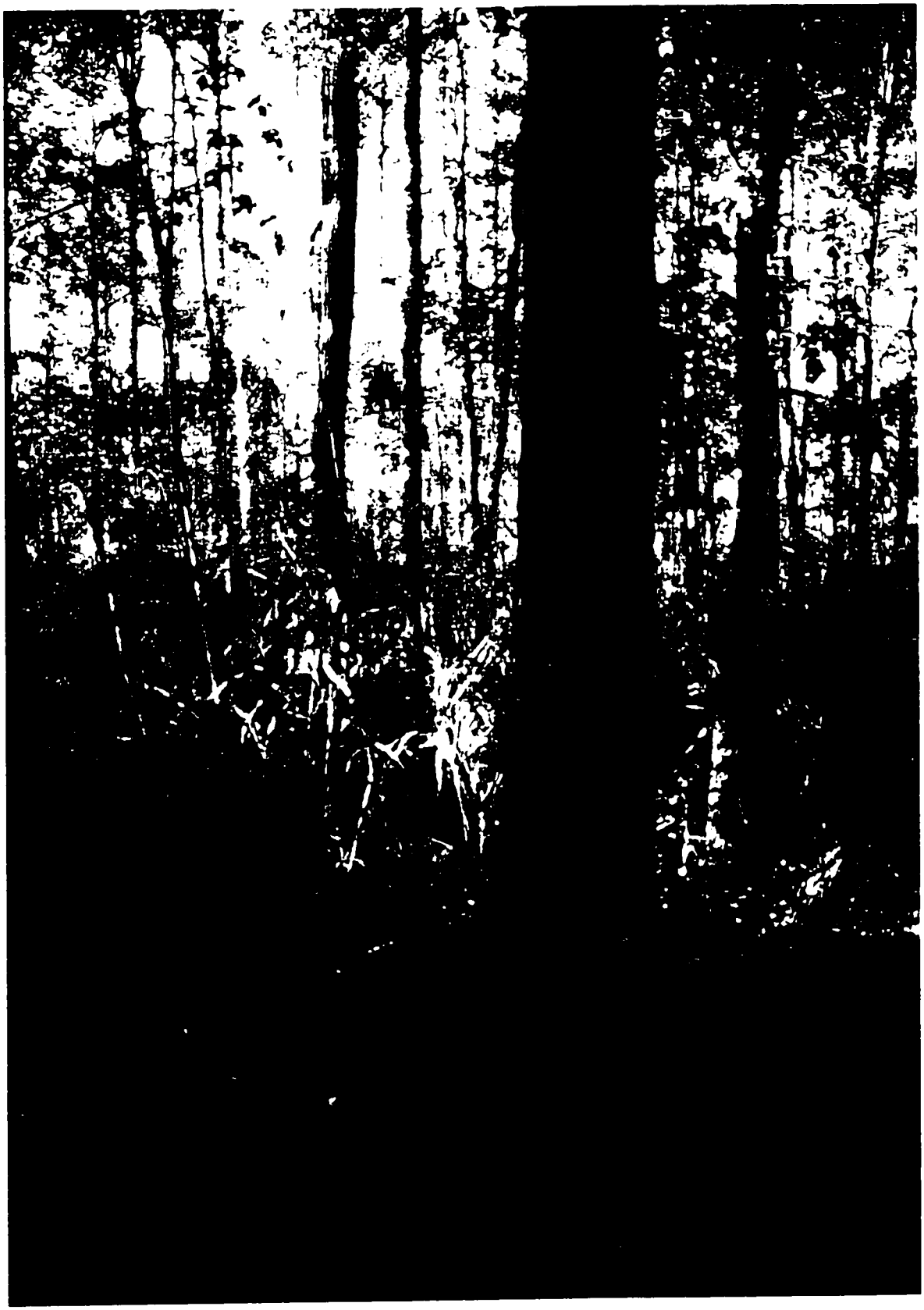
FIRE FREQ. CLASS	FIRE FREQUENCY	MAP UNIT
1.	1-3 yrs	Dry, fire-exposed uplands.
2.	2-4 yrs	Savannah River Terrace - Upper member.
3.	4-6 yrs	Savannah River Terrace - Lower member.
4.	7-12 yrs	More remote, fire-sheltered sites on the Savannah River Terrace.
5.	Variable	Wetland pyromosaic, ranging from frequent fire-influenced communities along margins, to non-pyrophytic cypress and tupelo in the wet swamp interior.
6.	Unburned	Savannah River Floodplain.
7.	Variable	The shaded band parallel to the river indicates the scarp between the Savannah River floodplain and the first (lower) terrace. The river scarp communities range from fire-influenced live oak and longleaf, to mesic hardwood forest.
8.	Variable	Black areas indicate steep, fire-protected slopes along deeply incised streams. Vegetation grades from frequent-fire pyrophytic woodland on the upper slope shoulder to nonpyrophytic mesic hardwood forest below.



Fire Frequency

	1-3 Years	Dry, Fire Exposed Uplands
	2-4 Years	Savannah River Terrace- Upper member
	4-6 Years	Savannah River Terrace- Lower member
	7-12 Years	Partially fire-sheltered sites on the Savannah River Terrace
	Mixed	Wet pyromosaic fire-influenced communities along margins with cypress and tupelo in the wet swamp interior
	Unburned	Savannah River Floodplain
	Variable	River scarp communities ranging from fire-influenced live oak and longleaf to mesic hardwood forest
	Fire-Sheltered	Steep fire-sheltered slopes along deeply incised streams. Vegetation grades from frequent-fire woodland on the upper slope shoulder to nonpyrophytic mesic hardwood forest below.

Figure C4.8. A fire-frequency indicator community, pond pine/canebrake becomes increasingly shady as length of fire-free period increases. In this site at the toe of the scarp between the upper river terrace and the sandhills uplands (SRS compartment 42), the oldest trees are pond pine, along with a few longleaf and loblolly. The pond pine in the foreground survived the last fire some 25 years ago, while the hardwoods present in the background are new saplings or sprouts from stems that were killed to the ground. These include canopy-height tulip poplar sprouts, now up to 12 inches dbh. Such sites on relatively fertile, moist sands like the Williman series here succeed rapidly to loblolly pine and bottomland hardwoods, especially tulip poplar, red maple, sweetgum and water oak, once fire is removed. As hardwood shade increases, cane density decreases. If fire suppression continues long enough, cane becomes too sparse to generate enough heat to thin canopy trees when burned later, and conversion to hardwoods becomes permanent. Compare with Figures in Chapters 3 and 6 for appearance of canebrake under a natural fire regime.



TESTING ACCURACY OF PRESETTLEMENT VEGETATION MAPPED USING THE PYROGRAPHIC METHOD

No adequate method for reconstructing presettlement vegetation by strictly quantitative methods exists. Given that the pyrographic method requires synthesis of many different kinds of information, and relies heavily on expertise of the investigator, a way to test the results is desirable. Two testing approaches were used for the Savannah River map. The first is a kind of historical ground truthing, comparing actual points from historical survey plats with the vegetation predicted for each point by the presettlement vegetation map. The second approach compares the profile of each tree species recorded on historical surveys over the whole site, with the acreage of each vegetation type over the whole site.

The first step involved finding early survey plats that mentioned tree species or vegetation types, and plotting each plat onto the presettlement vegetation map. The most serious drawback was that, even with title searches and the ability to plot the approximate location of the tract in question, it might not be possible to locate the surveyed lines precisely enough to say that a particular tree occurred on a particular soil series. Most early plats were not drawn to scale or with accurate angles at the corners, and the surveyors had no aerial photos so that placement of creeks and other landmarks were only the surveyor's impressions. Consequently both the plats and the natural landscape features were usually considerably skewed.

Problems with locating individual trees proved to be mostly surmountable. For one thing, each boundary line tree had only to be located within a particular soil pedon, wherein it was assumed that vegetation was relatively uniform. There was little to suggest that this was not the case. Almost all early plats were anchored at one or more points along the margins of creeks. These points were usually represented by wetland species like ash, elm, cypress and tupelo. The plat could often be placed approximately by matching the pattern of bends in creeks and the location of forks and mouths of tributary creeks. The plat position could then be adjusted on the master vegetation/soil series map, by using vegetation to locate landscape features. Flat uplands

invariably were indicated by only pines and stakes, while slopes could be detected and placed by the appearance of oaks and hickories. This, of course, introduced a source of bias since vegetation was used to help position the survey plat, and the intention was to use the historical survey plat to test the accuracy of vegetation mapping. This bias only affected a few points however, and there were many other boundary trees along the straight boundary lines that could be located by measuring the distance between points (as actually measured and recorded by the surveyor) and plotting them on the vegetation map. Lacking any other way to refine the position of the historic plat, it often made sense to use distinctive vegetation features to anchor points in the survey. Vegetation anomalies on uplands, for example, were especially valuable. There are many isolated upland depressions that are excellent landmarks. Where a boundary line passing through extensive longleaf pine savanna suddenly recorded a single tupelo, it was often easy to find the isolated pond or bay that would have supported hydric species. This allowed precision alignment of the survey plat and it made sense to do so, regardless of any bias that may have been introduced.

Test 1, historical ground truthing. No plat information was used in constructing Map C4.1 (see enclosed map supplement). All historical survey plat information was intentionally reserved for testing accuracy of the map. The map was produced by using all of the other kinds of evidence described in the methods section above. Archaeologists at SRS had assembled some 160 survey plats relevant to the Site (Brooks and Crass (1991), and access to these was graciously provided by Dave Crass. Seven plats were selected at random for examination. Of these, one plat, surveyed in 1851, proved especially locatable because it happened to lie between Pen Branch and Steel Creek at the point of their closest approach (Figures C4.9 and C4.10).

This plat had 23 witness points identified as follows: Ash (1), Hickory (1), Holly (1), Maple (1), Marsh (1), Pine (10), Post oak (1), Stake (5), and Water oak (1). The plat was superimposed on the vegetation map (Figure 16) as well as could be approximated, considering that the original plat was not to scale, and the general lie of the creeks and their bottomlands was only roughly sketched by the surveyor. The actual sequence of trees, beginning with the Steel Creek bottomland in the southeastern corner, and continuing clockwise around the plat is: Ash-Pine-Pine-Post oak-Stake-Pine-Hickory-Holly-Pine-Stake-Pine-Pine-Marsh-Pine-Stake-Water

oak-Pine-Pine-Pine-Stake-Stake-Pine-Maple.

Because the surveyor stippled in two kinds of wetlands and made notes on the plat, four major historical vegetation types can be inferred from this plat. First is longleaf pine savanna. By examination of the survey plat and examination of the site in the field, it became apparent that nearly all the lands not shown as wetlands on the survey plat were dominated by longleaf pine. Furthermore, in fire-suppressed lowlands along Pen Branch, several old, dead longleaf stems that had been worked for turpentine were found in woods that have now succeeded to loblolly pine and hardwoods (Figure C4.14 below). All but one point on uplands in the survey plat were recorded as either pine or stake, as might be expected of open, longleaf pine savanna

Figure C4.9. Inferences about historical vegetation may be made from old surveys. This plat map from an 1851 survey shows a farm about 1.5 square miles in size, situated between Pen Branch (the wetland on left) and Steel Creek (right). The only place where these two creeks approach this closely is in the vicinity of SRS Road B. The bend in Steel Creek and the angle of divergence of the two also agree with that in the plat, allowing it to be positioned for comparison with Map I. The distribution of trees follows that expected in a fire landscape. Four presettlement vegetation types are suggested: longleaf pine uplands, stream bottomland hardwoods, pyrophytic woodlands, and canebrake, here labeled "marsh". The plat was superimposed onto Map 1 to test for agreement between predicted and historical vegetation (Figure C4.10). Plat courtesy of Dave Crass.

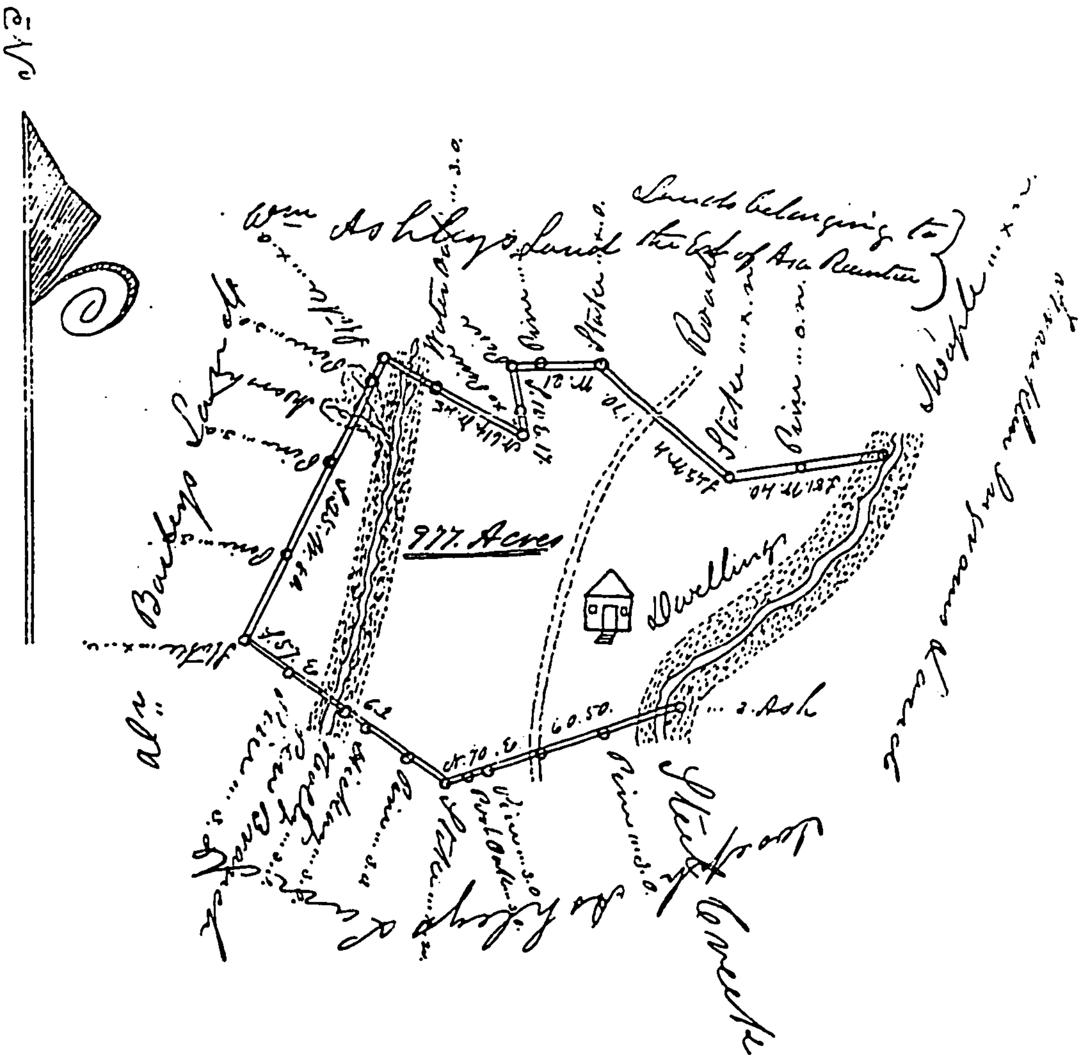
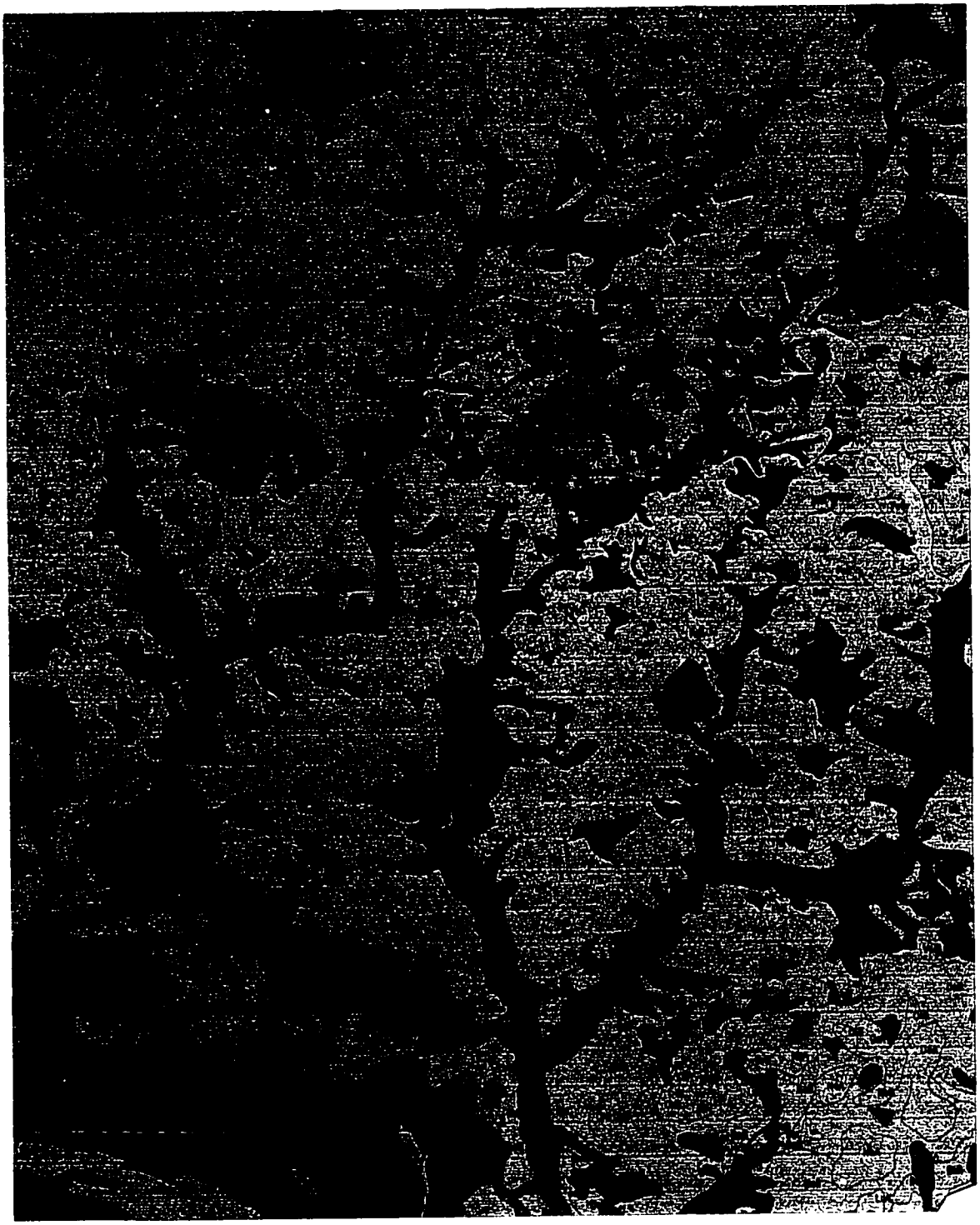

No 3
Wm Ashleys Land
Lands belonging to the Est of Asa Rountree
Road
977 Acres
Dwelling
Baileys Land
Pine
Stake
Maple
2 Ash
Hickory
Red Oak
Creek

Figure C4.10. The 1851 survey plat superimposed onto Map I, presettlement vegetation of SRS. Beginning at the lower right corner in the Steel Creek bottomland, the first corner tree is ash. This spot is mapped wetland pyromosaic, of which bottomland hardwoods like ash are a component. Proceeding clockwise, the next two points are pines, in an upland of Troup soils mapped dry mesic and in mesic longleaf pine savanna. These are followed by a post oak on Wagram soils in a small patch mapped pyrophytic hardwood woodland. This mapping unit is dominated by longleaf pine, but with inclusions of dry and mesic woodland in which post oak is a dominant. The next two points are a stake and a pine on Lucy soils, another longleaf pine savanna type. Next is hickory in an area mapped mixed mesic hardwood forest. As explained in the text, this type is found mostly on slopes, and hickory is an important component in the fire-influenced transition between moist slopes and longleaf uplands. Holly, a component of bottomland hardwood understory, is the next point, in the Pen Branch bottomland. The next boundary tree is pine, in an area now disturbed and mapped as Udorthents. As described in the text, nearly all Udorthents at SRS were cleared from well-drained longleaf pine uplands. The next boundary line points are a stake and two pines, all in Troup and Orangeburg soils mapped longleaf pine savanna. The line then crosses a small wetland labeled "marsh". As discussed in the text, this site, examined earlier in the field had been determined to be canebrake, and canebrake was often called marsh in the 19th century. In one lobe of the "marsh" the surveyor noted the only pine in wetlands. The site was on Fluvaquents mapped wetland pyromosaic, of which canebrake is a component. There follows a water oak on the edge of the bottomland and a sequence of 4 pines and three stakes as the line crossed the dry uplands of Orangeburg, Norfolk, Blanton, Udorthents and Dothan soils, all mapped as longleaf dominant types. The final point is a maple, a component of the pyromosaic wetland along Steel Creek. All 23 points of the survey, then, are in plausible agreement with the vegetation map.



(see further discussion of the association of pines with survey stakes in the second testing method below). The second upland type, pyrophytic woodland, was suggested at two points by the survey. The only tree besides pine on the uplands was one point midway between the creeks, marked by a post oak. Post oak and hickory are the most common dominants in pyrophytic hardwood woodland, and that spot fell in a patch of vegetation mapped as Pyrophytic Hardwood Woodland on Map I. A hickory was recorded on the margin between longleaf pine uplands and the Pen Creek bottomland. As discussed in a chapter below, one of the principal habitats of pyrophytic woodland, of which hickory is a common dominant, is the narrow fire-tension zone between frequent-fire uplands and less flammable wetlands, and this corresponded with a narrow zone of Troup soils along the margin of the bottomland. The third vegetation type is bottomland hardwood forest, an element of the fire-influenced wetlands along Pen Branch and Steel Creek, as indicated at four points by ash, holly, maple, and water oak.

The fourth vegetation type suggested by the survey plat is canebrake. The most problematical area was a small, bilobed wetland, draining eastward into Pen Branch, sketched by the surveyor and recorded as "marsh". In early surveys wooded wetlands were appropriately called swamps, while a variety of names were used for open, treeless wetlands. The term "marsh" was often used for canebrake in the 18th and 19th centuries, before that term was introduced into the region. In the Carolinas, the term "canebrake" seems to have been unknown during the Colonial Era and did not come into general use until the late 19th century. A vast canebrake of about 50 square miles in North Carolina, called the Green Sea, was described by William Byrd (1728) and later by George Washington (1763) both of whom referred to its vegetation as "reeds", the most common name for cane in Colonial times. Another large canebrake in Pamlico County, North Carolina was called "Reedy Pocosin". The "marsh" indicated on the 1851 survey was visited in the field, and proved to be one of the two best remnant canebrakes seen at SRS. At this site canebrake graded into pocosin close to the channel of Pen Branch. At the site both the canebrake and pocosin were dominated by pond pine. This was the site of the only pine that appeared in wetlands on the 1851 survey. Pond pine/canebrake is an element of wetland pyromosaic, which was the type mapped at the point represented as "marsh".

The 1851 survey was superimposed on Map I (Figure C4.10). It had to be "stretched" about 10% because the angle of divergence of the creeks was greater than that sketched by the surveyor. Based on the various field and map interpretations above, all 23 points on the 1851 survey plat agree with vegetation predicted by Map I, Presettlement Vegetation of the Savannah River Site. Of seven such plots that could be reliably mapped and compared with the vegetation map, the error rate was less than 3%.

Test 2 of the Landscape Fire Ecology Method--Estimating Presettlement Vegetation from Profile of Witness Trees.

2,081 data points were collected from 1,820 trees and 261 stakes that were recorded on survey plats dating from first settlement around 1730, to 1810[1]. The two most abundant types recorded were "pine" and stake, which in combination represented 54% of all points (Figure C4.11). This is believed to largely represent the longleaf pine uplands. Examination of four survey plats on which surveyors had stippled in wetlands (such as those in Figure C4.9) showed that none of the stakes were placed in wetlands. The necessity to use stakes suggests a scarcity of trees that might fall on the survey line. This would be consistent with open longleaf pine savanna instead of forest. In contrast, the surveyors had no trouble finding boundary trees in the bottomlands. For the whole data set, the hypothesis that occurrence of pine is independent of the occurrence of stakes or of other species was tested and rejected at the 0.05 level. Stakes appeared to be strongly associated with pine.

Other tree species, for which the hypothesis of independent occurrence with pine was also rejected, were red oak, sweetgum, water oak, cypress and "blackjack". As explained below, the common historical name for turkey oak was blackjack. The association with red oak probably refers to southern red oak that is found with both longleaf and loblolly in wetland transitional pyrophytic woodlands. Association of pine with cypress, water oak and sweetgum probably represents pine on wetland fringes, the major habitat for loblolly pine in fire landscapes.

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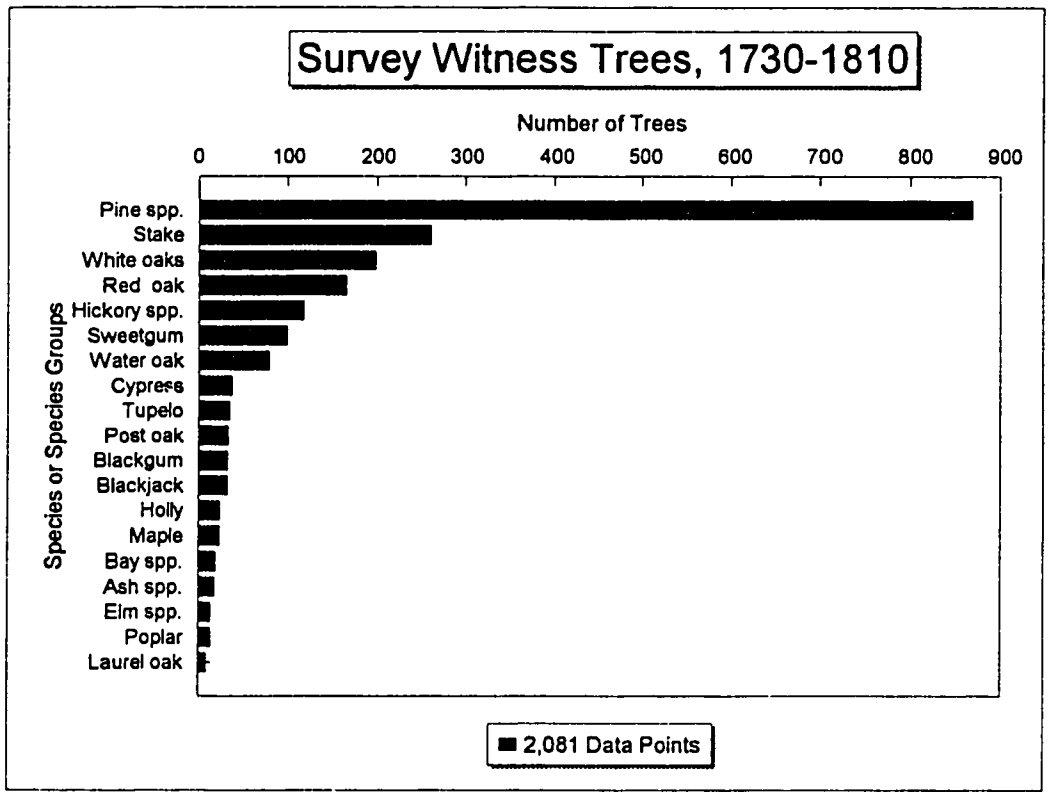
[1]Surveys were examined by Ben Doty and analysis carried out by Ben Doty and John Blake, Savannah River Natural Resource Management and Research Institute.

Thirteen of the 19 names used by surveyors in Figure C4.11 below are unambiguous, six others; pine, white oak, red oak, black gum, blackjack and bay require some interpretation. In the 19th century the term "blackjack" was used for scrub oaks in general. One publication (State Board of Agriculture 1883), referred to "the forked leaf blackjack" (*Quercus laevis*) and the round leaf blackjack (*Q. marylandica*). Small's Southeastern Flora (1933) gives "sand blackjack" as the preferred name for *Q. laevis*. Acceptance of the term "turkey oak" for *Q. laevis* seems not to have become widely established until the 20th century.

Since longleaf pine is dominant in dry pyrophytic woodland, also the primary habitat of turkey oak, we can add the 1.54% attributable to this species to that of pine and stake for a total estimate of 56% of the landscape. This is only 6% lower than the 62% of the total landscape (uplands and wetlands) estimated by Map C4.1 to have been occupied by longleaf pine savanna. Furthermore a certain percentage of pine would have been other shortleaf, pond pine and loblolly. Because all three of these species were confined to narrow zones along slopes and wetland fringes, they probably comprised only about 2-3% of the pine stems on the site. This would reduce the number of stems attributable to longleaf pine to 53%, or 9% lower.

There are, however, several reasons for which we might not want to credit the lower figure. Most obvious is the lower density of longleaf pine stems in dry and frequently burned savanna. We have already suggested that the pine stands were more open than hardwood sites,

Figure C4.11. Chart of the distribution of witness trees recorded on property boundaries from historic surveys.


Survey Witness Trees, 1730-1810
Number of Trees
0
100
200
300
400
500
600
700
800
900
Species or Species Groups
Pine spp.
Stake
White oaks
Red oak
Hickory spp.
Sweetgum
Water oak
Cypress
Tupelo
Post oak
Blackgum
Blackjack
Holly
Maple
Bay spp.
Ash spp.
Elm spp.
Poplar
Laurel oak
2,081 Data Points

since surveyors had to use stakes to mark points on the line where trees were not available in pine uplands. Since stem density varies between vegetation types, we cannot directly compare savanna and forest, or predict the acreage of each type from the number of stems on the survey plats. The 53% of stems would be a substantial underestimate of acreage occupied by longleaf pine, so the 62% acreage of longleaf pine estimated by Map I should be much more accurate.

Furthermore, there is the likelihood that fewer points were taken in longleaf pine uplands because the land was open, the surveyor could see farther and did not need as many points as in hardwood forest or wetlands. This also would lead to an underestimate of acreage of longleaf pine. This idea has not been tested, but if mean distances between witness trees or stakes in pine uplands, versus the distances in bottomlands, could be determined, an adjustment could be made. Balancing competing adjustments, the 9% difference between the extent of longleaf estimated by the pyrographic method and that from survey data is probably not significant.

There are four species of pines at SRS. Judging according to the available habitat for each seen in the field and on the presettlement vegetation map, the pines may have been distributed approximately as follows: longleaf 88%, loblolly 8%, pond pine 2%, shortleaf 2%.

Next to "pine", the most problematic label was "white oak". This is an amalgam of at least three species in drastically different habitats. White oak (*Quercus alba*) was certainly a component of vegetation type 5, Mixed Mesic Hardwood Forest, both the steep slope variant and that found on certain soils of the river terrace flats, such as the Hornsville. Not all surveyors distinguished post oak from white oak, and this may account for the somewhat low percentage of post oak suggested from surveys, which seems less than that expected from Map 1. A few stems of *Q. margarettiae* were probably also included as "white oak". Most importantly, however, 19th century surveyors and foresters rarely distinguished swamp chestnut oak (*Q. michauxii*) from white oak. Ashe (1894) simply included it as white oak or, sometimes on the same page, as "swamp white oak". Michaux (1871) called it *Quercus prinus palustris* or "the chestnut white oak". Small (1933) calls it "cow oak", "basket oak", "swamp white oak", or "swamp chestnut oak" in that order. Since white oak is the only name which appears on historical survey maps that include the Savannah River Floodplain, which has swamp chestnut oak now, and probably

had much more before exploitation for oak staves beginning in Colonial times (see chapter 3 below), it seems certain that SRS surveyors just lumped the two species. Using acreage obtained from Map 1, there are 6,883 acres of Mixed Mesophytic Hardwoods Forest, of which *Q. alba* is a component, and which comprises most of its habitat at SRS. There is 5,278 acres of bottomland hardwood forest and oak flats, of which *Q. michauxii* is a component. This, along with a small portion of the 5,719 acres of bottomlands mapped as wetland pyromosaic, comprises most of that species habitat at SRS. This would give an expected ratio of about 50:50 between the two "white oaks", which would reduce their importance in Figure C4.11 to that of hickory, sweetgum and water oak.

Of the remaining problematic species, the "red oak" recorded by surveyors was almost entirely southern red oak (*Quercus falcata*), with a rare stem of scarlet oak, black oak or shumard oak included. Some large turkey oaks in mesic pyrophytic woodland were likely also included as red oaks. The number of points for cypress and tupelo are almost equal, as might be expected if they only called *Nyssa aquatica* by that name. Since *Nyssa sylvatica* is not abundant at SRS it seems likely that "black gum" refers mostly to *Nyssa biflora*. Surveyors almost never distinguish individual species of hickories, so this is another group lumped by genus. At SRS, the hickory genus is overwhelmingly dominated by *Carya tomentosa* (*C. alba*), with some water hickory and an occasional sand hickory, pignut hickory and bitternut hickory (*Carya cordiformis*). "Bay" could have referred to any of three species found at SRS: red bay (*Persea palustris*), sweet bay (*Magnolia virginiana*) and bull bay (*Gordonia lasianthus*). Table C4.5 below summarizes the percentage of tree stems in Figure C4.11. White oak and swamp chestnut oak have been separated.

Table C4.5. Profile of tree stems from historical survey plats.

	NUMBER	PERCENT	SPECIES
1	869	41.76	Pines
2	261	12.54	Stake
3	166	7.98	Red oaks
4	118	5.67	Hickory spp.
5	99	4.76	Sweet gum
6	99	4.76	White oak
7	99	4.76	Swamp chestnut oak
8	79	3.80	Water oak
9	37	1.78	Baldcypress
10	35	1.68	Tupelo
11	33	1.59	Post oak
12	32	1.54	Black gum
13	32	1.54	Blackjack (mixed scrub oaks)
14	24	1.16	Holly
15	24	1.16	Maple
16	19	1.16	Bay
17	18	0.91	Ash
18	14	0.67	Elm
19	14	0.67	Tulip poplar
20	9	0.43	Laurel oak

TOTAL 2,081 points.

Historical survey plats, especially those that provide some distinction between vegetation habitats like upland and stream bottomland, provide the best possible test for accuracy of presettlement vegetation mapping. This can serve as ground truthing, which just happens to have been done a century or two in advance of the mapping experiment. The simple test of Map I using the 1851 survey plat, agreed with vegetation predicted at all 23 points. The comparison of 2,081 trees with percentage of land occupied by their likely habitat on the map is less specific. It nevertheless provides some confirmation of general accuracy for the whole site. Neither test presented any substantial reason to question accuracy of the pyrographic mapping method. Based on the results, I am confident that this technique exceeds any previous method, and finally yields a map of original vegetation with practical use at the level of the soil series.

HISTORICAL EVIDENCE OF ORIGINAL VEGETATION TYPES AND FIRE FREQUENCY OF THE SAVANNAH RIVER SITE

The earliest settlers arrived in the 1730s and 1740s, first taking up the best lands along the river--those closest to civilization downstream--then spreading upriver and up the principal stream corridors to the interior of SRS. Edmund Ruffin noticed that all of the farms in 1843 were at least 15 feet above river level, not surprising considering that flood amplitude on the Savannah River puts all of the bottomland islands under water periodically (Ruffin 1843). By the 1770s at least 17 farms occupied the Savannah River terraces (Brooks and Crass 1991). So vegetation of the terrace uplands may be expected to be the most transformed on SRS, having been subjected to European land use for 200 years before establishment of the Savannah River Site.[2]

In contrast, least altered are the dry longleaf pine communities on the high-elevation, excessively drained Lakeland sands (Figure C4.16). The reason for this is not that dry sands are particularly preferred by longleaf as habitat. Along the coast sites can be found where longleaf pine grows to within 10 inches of sea level on the edges of brackish marshes, and its roots lie spread along the top of the water table exactly at sea level. Rather, persistence of longleaf pine is related in part to the relatively low degree of disturbance from human uses on the dry sandy soils, and, more significantly, because the dry sands resist succession to mesophytic hardwoods longer than any other soil type. Removal or reduction of fire from the landscape initiates succession from longleaf/grass savannas, toward multistoried hardwood forest. Most remaining unmanaged woodlands in the South can be identified as having reached some stage in this transition (Blaisdell et al. 1974. Frost 1993, Ware 1978, Ware et al. 1993). Succession proceeds at very different rates on different soils (see Case Study 3, Figures C3.6, C3.7, C3.12 and C3.13 which compare rate of succession on sand versus loam soils). On the driest upland sands, even wiregrass may be absent, although there are no sites this xeric at SRS. On dry sands like the

[2]See White (1998) for additional land use history of the Savannah River vicinity.

Lakeland, Blanton and Dothan, the first stage of transformation--accumulation of shrubs and understory of mesophytic hardwoods--may take 30 years of fire exclusion. The resistance of sands to mesophytic succession is undoubtedly the primary reason that the Sandhills are the greatest remaining stronghold of longleaf pine.

On the other hand, on loamy soils the transformation of longleaf/wiregrass savanna to other species of pine and hardwoods may make the site unrecognizable in a decade (see Case Study 3, Figures C3.12 and C3.13). Essentially all mesic loam soils in the South had been sought out and converted to farmland by the Civil War. Remnant examples of species-rich longleaf pine savanna on loam soils are extremely rare. This is almost equally true of loamy sands. At SRS I was unable to find a single patch of Norfolk or Orangeburg soils which had not been farmed. In the original landscape, longleaf dominated all of the fire-exposed upland soils across the entire textural gradient from sand to loam and even clay.

The degree of dominance of longleaf pine, although extensively remarked by historical writers, is not easy to accept, given the diversity of hardwoods and other pines in today's landscape. It is possible, however, to follow early travelers around the longleaf pine landscape until a thorough image is accumulated. Beginning with the travel diary of the son of a London Merchant in 1786, we can put together a winding transect from Norfolk Virginia to Aiken, South Carolina. Robert Hunter had been sent to America from England when he was 20 years old to check on the family business (Hunter 1786 [1943]). He was required by his father to keep a daily diary of the country. Beginning in Virginia, he described the extensive naval stores trade in turpentine, tar, rosin and pitch from Norfolk, Portsmouth and Suffolk. While on the Albemarle Sound at Edenton, North Carolina, he described naval stores made from longleaf pine as among the principal exports of the area. His route from the Albemarle Sound south to Jackson's Tavern was described for the first 15 miles as "pine barrens", "the road is entirely through a pine wood." For the next 20 miles, and on to Washington, NC, "...the whole way, (excepting one small plantation of a few hundred yards) through a pine wood." It is clear from his frequent comments on turpentine and other naval stores that the pines were longleaf: "When you approach Washington, it's astonishing the number of pines you see boxed to get the turpentine from. In a few years after, they die, and then they are cut up for tar." This was 58 years before introduction

of the copper still made turpentine distillation efficient and portable, touching off the wave of exploitation that decimated the remaining longleaf forests of the Carolinas in 60 years.

At Washington he observed that tar, turpentine and other naval stores were three of the six main exports shipped from the town, which is located on the Tar River, a name that dates to around 1732. The river was first explored by men who had gone there to make tar from the longleaf along the river. Today only single old longleaf trees can be found in this region. From the Pamlico River at Washington to New Bern "The road is through a pine wood the whole way. We saw just one house and did not meet a human being." Hunter began to tire of longleaf pine and the primitive conditions in coastal backcountry North Carolina around New Bern. From there, setting out south toward Wilmington, to Noble's Tavern, a few miles of "pine & oak wood." Then 16 miles "...all the way through a pine wood...." to Prescot's Tavern, where he "...proceeded on my journey through another tiresome pine wood to Robert Sage's Tavern,..." Then followed a stretch, with no comment, to Woodward's Tavern. From Woodward's to Bernard's tavern "...through the charming pine woods...." Then to Wilmington "I am at length arrived in this miserable town, which is situated, on the river Cape Fear, in a sandy desert...." Hunter summarized his North Carolina survey of over 200 miles to his father: "All the livelong day you travel through pine woods of fifty and sixty miles without meeting a human being or passing a hut--I cannot call them houses. Now and then some oak trees relieve you a little from the innumerable pines."

The transect was continued from Wilmington to Charleston, SC in 1788 by German diarist, Johann David Schoepf, who observed that from the NC line south, "We saw nothing but sand and pine-woods for 16 miles..." There was a stop at an indigo plantation, then 16 miles along the shore from Long Bay. This was followed by a "Gloomy and lonesome" wooded road from beach to Waccamaw River (probably maritime forest of live oak and loblolly pine). Then he continued on to "Winguah" Bay and to the bay at the mouth of Black River, where he crossed on the shoreward side, seeing Georgetown only from a distance. Twelve miles farther, from the banks of the Santee, he noted, "The remainder of the road to Charleston was as little remarkable as that which went before, the way lying through barren, flat, sandy pine-forest, seldom a house or cabin to rejoice the eye, since everything is crowded near to or on the rivers, or where there is

water." In the vicinity of Charleston, Schoepf wrote botanical descriptions of longleaf, loblolly, shortleaf and *Pinus glauca* (Schoepf 1788[1911]).

We can connect Charleston to the Piedmont with another transect by Francois Andre Michaux in 1802. His route was from Lincolnton, NC to Chester, SC and Winnsboro. Continuing toward Columbia, he first encountered longleaf pine 15 miles southeast of Winnsboro, near the Fairfield/Richmond County line. This establishes a good point in reconstructing the boundary of the original range of longleaf pine: "Fifteen miles on this [south] side of Winesborough the *pine barrens* begin, and thence to the seaside the country is one continuous forest of pines" (Michaux 1805 [1966]).

South Carolina was divided by Michaux, according to general usage at the time, and later by Mills (1825), into the Upper Country, meaning Piedmont and Mountains, and the Lower Country which included the Sandhills and the rest of the Coastal Plain. This region he said was 120 to 150 miles wide, widening towards the south. This would easily include the entire sandhills region, including the Savannah River Site. Michaux reported, "Seven-tenths of the country are covered with pines of one species, or *Pinus palustris*, which, as the soil is drier and lighter, grow loftier and not so branchy. These trees, frequently 20 feet distant from each other, are not damaged by the fire that they make here annually in the woods, at the commencement of spring, to burn the grass and other plants that the frost has killed." He noted that the pines "sometimes" were interspersed with scrub oaks. See the hardwoods section below for description of the two principal scrub oak habitats.

We can further connect Charleston to Aiken by the 136 mile South Carolina Railroad, completed in 1833, providing yet another transect across the longleaf pine country, from Charleston through Barnwell and Aiken Counties to Hamburg (Derrick 1930). Construction on the first railroad in the U.S. had begun on January 9, 1830 using longleaf pine heartwood. The bed was laid by "driving piles of lightwood 8 by 8 inches square, 6 1/2 feet apart along the line, and 6 feet apart laterally..." as a foundation. Over these were placed ties of longleaf pine lightwood or live oak and rails of longleaf pine. The rails were made of heartwood of "the best yellow pine", 16, 24 or 32 feet in length, and lined on the outside by bands of iron 1/2 inch thick

(Derrick 1930).

Describing the Christmas Day debut of the railroad in Charleston, a writer for the Charleston Courier observed that the engine "feeds upon lightwood"..."scattering sparks and flames on either side". To prevent rot, it required 200 barrels of longleaf pine tar per mile to cover the whole wood work, at 75 cents/barrel. An October 1833 statement of expenses included "Turpentining Road, includes amounts paid for turpentine, tar, etc. and labor--$4,424.74" (Derrick 1930).

Along the railroad, early travelers recorded descriptions of the countryside. The following observations were by one of the first year's passengers (1833 newspaper accounts recorded in Derrick 1930): "The rails of the track are built of the timber of the country, hard pine full of pitch." On some of the first runs the engine slowed to a crawl from lack of steam and had to stop while hands ran and chopped pine lightwood for fuel. Beyond Charleston, "The country, as far as the eye could see, was shaded with here and there a solitary liveoak, and woods of pitch-pine" (longleaf, because of the early practice of distilling tar and pitch from dead lightwood, was widely called pitch pine in South Carolina). At Blackville (Barnwell County) the traveler commented on "...a half burnt forest of pitch pine,...", "We had accomplished the wonderful distance of 90 miles from 8 A.M. to 6 1/2 P.M. on a rail road, through a country with a hard soil, and not a hill rising twelve feet the whole journey. The whole country for 100 miles from the seacoast is as level as your frog pond." Beyond Blackville the land grew more hilly toward Aiken, 120 miles from Charleston.

Tuomey (1848) observed that, "From Aiken to South Edisto the country sinks gently, but the ridge between the two rivers is elevated, and is an uninterrupted pine barren..." Mills (1825) confirmed that this was longleaf pine. With exception of scrub oaks, hardwoods in historical descriptions are almost uniformly confined to sloughs and bottomlands. Mills (1826) described Barnwell District, which at that time included all of what would become SRS, as follows, "Extensive forest of the finest pine timber covers this whole country in the high lands. On the clay lands and bottoms, the oak, hickory, poplar, gum, cypress, cedar, dogwood, sassafras, etc. abound. In the swamps the cypress is very plenty." The "clay lands" probably refer to the river

terraces and floodplain islands, with fine textured soils such as Smithboro, Hornsville, Rembert, Toccoa and Tawcaw.

Longleaf pine/Piedmont transition region. Several references place the upper boundary of longleaf forests in Edgefield County, 20 to 30 miles upriver from SRS, beyond Hamburg (West Augusta). Michaux (1871) found the boundary around 1800, on the Georgia side, to be 12 miles north of Augusta. This agrees closely with Mills (1825) map, which placed the upper limit of longleaf at the mouth of Foxes Creek in Edgefield County. In the transition region Chapman (1897) reported that in May, 1750 a party of Monongahelas were fleeing after an attack on the Euchees, who lived near Silver Bluff, through, "...the pine woods about ten miles from where Hamburg is now, moving in a direct line for the then weak settlement of Ninety-Six."

Beyond the uppermost sands, longleaf pine lapped for a short distance onto Piedmont clay: "Immediately above the sand hills, there is a belt of country about twenty miles wide, which is very broken, formed of a stiff red or yellow clay, covered with a thin soil, having a growth of long leaf or pitch pine, and Spanish or red oaks" (Mills 1825).

On Mills 1825 map of Edgefield County, the longleaf pine boundary is shown by a line labeled: "The land above this line is oak and hickory, below pine." From the upstream limit of pine at Foxes Creek, it passed eastward just south of the town of Edgefield. The line continued into Newberry and ended at the Fairfield County line a few miles northwest of Columbia. Unfortunately Mills did not continue the boundary across the northern half of the state. The portion of the boundary he did draw is indicated on the longleaf pine map in Figure C4.15. If the line were extended just beyond where Mills stopped, it would include at least a corner of Fairfield County, which Michaux (1805 [1966]) indicated to be on the border of the range. The existence of longleaf pine in Fairfield is supported by the report of a turpentine still in operation there in 1880 (U.S. Census of Manufactures).

Numerous historical photos in frequently burned areas throughout the South show pure stands of longleaf pine with no hardwoods (Harper 1913, 1928, Reed 1905, Sherrard 1903). In virgin longleaf forest in a hilly section of central Alabama, Reed (1905) found that 97% of stems

were longleaf pine. Other plots showed that fire confined loblolly pine and hardwoods to ravines and bottomlands. Many other historical sources also talk of the almost absolute dominance of longleaf pine on the fire-exposed upland landscape. The height of fire-killed hardwood sprouts in the photo help assign a fire frequency of 3-5 years at time of photo in 1905. The rare sites today still maintained with annual fire exhibit nearly 100% dominance by longleaf.

Historical fire frequency and ignition source. Numerous authors referred to not only frequent, but *annual* fires, especially in the spring. While the residents took frequent fire for the natural condition of things, Europeans, coming from a long-domesticated landscape where fire played no role, were invariably startled by a fire-blackened landscape. One such traveler, (Hall 1829) described the route from Columbia to Charleston:

> "The road led us sometimes across enormous swamps, and sometimes through extensive pine forest.... There was no underwood properly so-called, while the shrubs had all been destroyed a week or two before by a great fire. The pine-trees, the bark of which was scorched to a height of about 20 feet, stood on ground as dark as if it had rained Matchless Blacking for the last month. Our companions assured us that although these fires were frequent in the forest, the large trees did not suffer. This may be true, but certainly they did look very wretched, though their tops were green as if nothing had happened."

Michaux, cited above, commented on "...the fire that they make here annually in the woods...." Until the 20th century, almost no writers mention lightning. In the early settlement period, burning was done to green up grass for cattle, and nearly all accounts by outsiders and historians assign all fires to human causes. Actual observation of a lightning ignition would be extremely rare, so it is not unexpected that all fires would be assumed to have been started by humans. Residents in the pine lands, however, had made the connection between lightning and fire at least by the 1830s.

James Averit in the 1830s and 1840s grew up on a plantation in Onslow County, North Carolina that had 20,000 acres of longleaf pine. The plantation had, around 1840, two large stills

that processed "some hundreds of barrels" of crude gum turpentine daily. The lands, which Averit described as large tracts of virgin pine forests, were worked and reworked for turpentine for nearly 100 years, and had an elaborate system for suppression of lightning fires (Averit, excerpted in Gambel 1921). The virgin longleaf pine stands were called orchards where worked for turpentine.

> "The great disadvantage in the crop, however, is that the distilleries, the spirits of turpentine, the resin and in fine the whole plant and its yields, are so combustible that no insurance company, domestic or foreign, will insure the property. The only protection against fire that can be had is to police the premises as thoroughly as possible. How is this done? By placing here and there all over the orchards double log cabins for the families of some twenty or more white men. These people occupy these cabins free of rent, with as much land as they choose to cultivate..." "These men are required...to guard the orchards from fire, and *if a small fire occur, as it often does in the summer time by lightning striking and igniting a resinous pine tree*, they and their families must extinguish it. If it gets beyond their control they are to blow horns, summoning the neighboring tenants, sending all around for help, fight the fire until it is put out."

While early settlers used fire, and later plantation owners and farmers avoided it, we now know that a great number of fires are ignited by lightning (Barden, L.S. and F.N. Woods. 1973). As the landscape became fragmented into smaller and smaller fire compartments by roads, green crops and other manmade firebreaks, more and more separate ignitions would be needed to burn the same amount of land. The probable result was that fire frequency dropped, compared with the time when fires moved unimpeded across the huge fire compartments in the virgin landscape (see Chapter 6). As fragmentation proceeded, it seems likely that fires of human origin simply may have maintained an approximation of the natural fire frequency by supplementing lightning fires.

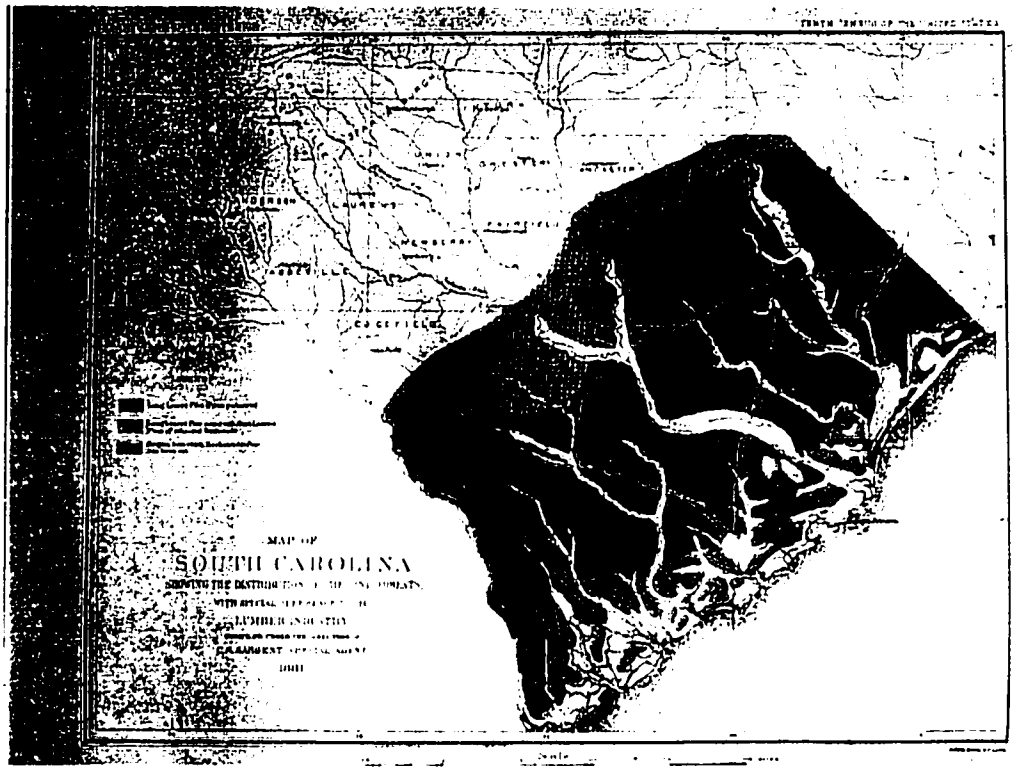
Decline of longleaf and replacement by loblolly pine and hardwoods. Perhaps first to describe the demise of the virgin longleaf pine forest in South Carolina, and its impending

replacement with hardwoods and loblolly pine, was Edmund Ruffin, editor of an agricultural newspaper in Petersburg, Virginia. He was an expert on soils and the use of marl to improve fertility of cropland, and was commissioned in 1843 to conduct a survey for marl deposits in South Carolina (Ruffin 1843, 1844). This eventually led him to SRS. On his way to Barnwell on the road on the ridge between the Cooper and Ashley rivers out of Charleston, he observed changes in the forest, on lands long settled. "The trees are nearly all pine, & generally of second growth, the land having been formerly cultivated & afterwards turned out." "The pines of original forest are mostly of the 'long leaf' species, & many of the great size & beauty for which that kind is distinguished. But whenever of second growth, whether after culture, after mere cutting down the first growth for fuel, the second growth pines are of the 'loblolly' or 'old-field' kind, of mean sized appearance."

As early as 1855, there was public sentiment against woods burning in South Carolina, and by 1883 substantial changes had resulted in some localities, as a result of fire suppression. One writer, apparently from one of the more domesticated parts of the State, commented on understory succession: "The uplands were covered, as they still are, with a large growth of yellow pine [longleaf], but a deer might then have been seen, in the vistas made by their smooth stems, a distance of half a mile, where now, since the discontinuance of the spring and autumn fires, it could not be seen fifteen paces, for the thick growth of oak and hickory that has taken the land" (State Board of Agriculture 1883).

Decline of grasses. Hall (1940) commented that "In pre-colonial times, the mixed pine and hardwood forest of the Piedmont was sufficiently open to permit the growth of grasses and legumes." "The decrease in natural forage was beginning to be noticed in the early part of the nineteenth century, and by the 1850s the once important range plants were to be found only in isolated spots inaccessible to cattle or in areas adjacent to the Blue Ridge." In 1836 James Davis of Richland and Fairfield Districts said that he could remember the time when "'almost the whole surface of [South Carolina's] soil, especially in the upper country, was a rich natural meadow, of the most succulent and nutritious herbage and grasses." Hall feared that many native grassland species had already become extinct.

Figure C4.12. Map of the longleaf pine region of South Carolina in 1882 (Sargent 1884). The dark green area, which includes all of SRS except the Savannah River floodplain, was described by Charles Sargent as dominated by longleaf pine on the uplands. The lighter ribbons running through the Coastal Plain are areas from which all merchantable timber had been removed by 1882, mostly within a few miles of major rivers and railroads. Note one such timbered band just east of Barnwell along the route of the South Carolina Railroad, the first railroad in the U.S. Newspaper accounts of the first runs between Charleston and Hamburg (West Augusta) in 1833 recount that the train's steam engine was fueled by longleaf pine lightwood, sometimes gathered en route (Derrick 1930).


MAP OF
SOUTH CAROLINA

Logging history in the SRS region. The water-powered sawmill was introduced to the Carolinas in the 1700s, and commercial logging along waterways seems to have reached the SRS vicinity around 1820, around 80 years after first settlement. Large-scale commercial logging of the interior was still more than 50 years in the future, and the turpentining business had not yet reached the interior (Mills 1826). Mills commented that, "The pine timber is now used mostly for [local] building." Along streams tributary to major rivers, though, numerous water-powered sawmills were under construction. These had reached even the upper reaches of the small streams at SRS by 1843 (Ruffin 1843a).

On May 26, 1843, travelling to SRS from Orangeburg, Edmund Ruffin noted that the North Edisto River furnished "...good navigation for rafts of lumber, our road passed through pine forest for the whole ride, with the exception of a few scattered & small spaces under cultivation." "Every stream of any size in this region is dammed to turn a saw-mill, & immense quantities of lumber are sent from them in rafts down both the North and South Edisto." Ruffin crossed South Edisto at Johnson's bridge (see Mills' 1825 map) into Barnwell District where he found, "The plantations are small & very thickly placed, on both sides of the road to Midway, on the railroad."

Always a keen observer of the landscape, Ruffin's comments of vegetation at SRS are tantalizing but uncharacteristically sparse. On June 3 he wrote, "My route along the Savannah River is generally within from 1 to 3 miles of the termination of the high land [apparently following the road along the highlands just above the Savannah River Terraces, shown on the Mills map]. The sensitive brier plant is common in the most sandy lands." This ground vine, *Schrankia microphylla* is a typical plant of open savannas, but is no longer common, now being found only here and there at SRS. Its decline can be taken as an indicator of reduced fire frequency and increased shading at SRS. Ruffin's most remarkable contribution to logging history is his description of man-made floods for timber transport at Tinker Creek and other small interior streams of SRS:

"...Tinker's Creek to 5 miles above [the road], & the Lower 3 Runs to within 3

miles of the [uppermost] road, carry rafts of lumber to Savannah. The streams appear much too small for this; but when a number of rafts are started together from a saw-mill, the flood gates are hoisted, & a transient overflow produced, which serves to convey the rafts to sufficiently deep water. The great demand for lumber some years ago caused saw-mills to be constructed on every one of the numerous sites afforded by the streams." Forty acres of swamp land owned by Jesse Cherry on Tinker Creek had been cleared, "... but could not be farmed because of the overflows produced by the lumber men above" (Ruffin 1843a).

The steam era. After the Civil War, logging railroads and steam sawmills proliferated, but there was still a great deal of virgin longleaf timber in South Carolina. Sargent (1884) reported the following amounts of longleaf pine timber still available.

Table C4.6. LONGLEAF PINE TIMBER REMAINING IN SOUTH CAROLINA, 1884

Counties	Feet, board measure.	Counties	Feet, board measure.
Aiken	209,000,000	Kershaw	171,000,000
Barnwell	340,000,000	Lancaster	5,000,000
Beaufort	49,000,000	Lexington	76,000,000
Charleston	458,000,000	Marion	326,000,000
Chesterfield	183,000,000	Marlborough	191,000,000
Clarendon	332,000,000	Orangeburgh	465,000,000
Colleton	453,000,000	Richland	88,000,000
Darlington	337,000,000	Sumter	380,000,000
Fairfield	7,000,000	Williamsburgh	536,000,000
Georgetown	128,000,000		
Hampton	202,000,000		
Horry	380,000,000	TOTAL	5,316,000,000

Turpentining and naval stores. Boxing of longleaf pine for turpentine seems to have reached SRS only around the Civil War. The industry began at the northern end of the range (Virginia and North Carolina), where longleaf was worked for turpentine for 200 years, and did not spread southward until northern supplies had been nearly exhausted (Frost 1993). Commercial turpentining entered South Carolina between 1830 and 1840, spreading southward from the northeast corner of the Coastal Plain, from Horry County to Charleston and then inland to the middle Coastal Plain.

The U.S. Census of Manufactures for 1810 reported 24 turpentine operations and 94,900 gallons "oil or essence of turpentine" produced in North Carolina, but none at all from South Carolina. Neither was there any recorded for 1830. In 1834, adaptation of the copper whiskey still to distillation of turpentine made the process vastly more efficient than in the past, when much of the gum had to be shipped to New England for distillation in crude retorts. Turpentine could now be distilled locally, making the process much more profitable and causing a boom that lasted for decades. Still, while North Carolina forests were being exploited, the industry was slow to develop in South Carolina. In 1840, the census listed 593,451 barrels of tar, pitch, turpentine and rosin produced in North Carolina, and a mere 735 barrels in South Carolina! This came almost entirely from Horry, the northeasternmost county (705 bbl), with only 10 barrels from Marlborough, and 20 from Richland County. The U.S. Census of Manufactures for 1850 listed 444 "turpentine makers" in North Carolina and only 3 in South Carolina.

The first record of commercial distillation of turpentine in the SRS area was not noted until 1860 (U.S. Census of Manufactures 1866). The first turpentine still, in Barnwell District, reported some $6,000 production. Charleston District that year reported 2 stills, Chesterfield 2, Darlington 3 distilleries and 6 establishments producing crude gum, Georgetown 10 distilleries, Horry 28, Lexington 1, Marion 5, Marlborough, 5 stills and 1 making crude gum, Sumter 9 stills, Williamsburgh 12 stills, giving a total of 95 establishments producing naval stores. The boom had finally arrived in South Carolina, only to be summarily interrupted by the Civil War.

Census methods and the types of articles reported varied from census to census, so it is not possible to follow progress of the turpentine industry very closely on a county by county

Table C4.7. Barrels of distilled turpentine and rosin shipped from the port of Charleston after the Civil War.

YEAR	BARRELS
1865-66	32,000
1870-71	90,000
1875-76	279,000
1880-81	283,000
1881-82	330,000
1882-83	366,000
1883-84	328,000
1885-86	200,000
1890-91	199,000
1895-96	81,000
1900-01	20,000
1903-04	11,000

basis. There was a drop in number of stills region-wide between 1860 and 1870 as a result of the Civil War, and those in South Carolina declined from 95 in 1860 to 54 in 1870. There were only 227 tar and turpentine establishments listed in the entire U.S. for 1870. Of these there were 147 in NC, 54 in SC, and only 26 in all the rest of the southern states.

After the war, turpentining regained momentum, touching off a 30-year boom in South Carolina. By 1870, South Carolina was producing 1,582,348 bbls turpentine and 115,945 of rosin, a by-product of distillation (U.S. Census of Manufactures, 1870). While never approaching the naval stores volumes processed through ports at Wilmington, North Carolina or Savannah, Georgia, Charleston came into prominence around 1870. By 1874, Charleston naval stores reports began to appear in the market columns of the leading daily newspapers. Table C4.7 shows the rise and fall of the industry between the years 1865 and 1904 (Gamble 1921).

By 1880 Aiken had 25 sawmills, and Barnwell 22, but neither reported any turpentine in the Census of Manufactures. Those counties that did report were Charleston, 25 establishments, Chesterfield 22, Clarendon 11, Colleton 9, Darlington 12, Fairfield 1, Georgetown 11, Hampton 4, Horry 21, Kershaw 9, Marion 20, Orangeburg 3, Sumter 14, and Williamsburg 20, for a total of 192. There was little useful information in the 1890 census, other than that South Carolina had 201 turpentine establishments. The Census of Manufactures for 1900 reported a 48% decrease in value of turpentine and rosin produced in South Carolina between 1880 and 1890, adding only the comment that "This decrease is due to the partial exhaustion of the forests." At the turn of the century, the boom was over in South Carolina, but the industry continued on a small scale, hanging on in the Sandhills, including the SRS area, until WWII.

Almost all commercial naval stores activity in the late 19th century was concerned with production of distilled turpentine and rosin, the byproduct of distillation. Tar and pitch, distilled from dead longleaf pine lightwood since colonial times had fallen into disfavor. The countryside in the Aiken-Barnwell vicinity, however, still had abundant lightwood. The Charleston News and Courier reported around 1889: "Blacksville is built on an elevated pine ridge four or five hundred feet above the level of the sea...." "There are thousands of cords of fine lightwood rotting in the woods that would be available for fuel" (for a proposed steam powered cotton factory) (Moore 1989).

Figure C4.13. While at least one turpentine still was placed in operation in the SRS area before the Civil War, intensive turpentining did not reach the Aiken-Barnwell region until late in the 19th century. Virtually all of the remaining virgin longleaf in the area came down during the same era, a period of intensive logging. This group of virgin longleaf, between 200 and 300 years old, has been protected near a house on the east side of U.S. Highway 1, a few miles from Aiken. The trees are boxed on three and four sides. For a tree to support this many turpentine faces, they must already have been quite large when the operation occurred, around the turn of the century.

In 1909 all crude turpentine production in South Carolina still used the destructive box system. Most of the longleaf pine in the SRS region probably looked like those in Figure C4.13 during this era. By 1914, 87.2% of production in South Carolina was by boxes, while 12.8% was produced by the new cup and gutter method, which had been introduced in Bladen County, North Carolina in 1894 (Ashe 1894). By 1919, the balance had shifted from 42% boxed to 58% cup method. Most U.S. production at that time took place in Florida, Georgia, and Louisiana, in that order. South Carolina had fallen to 7th and North Carolina to 8th of the eight turpentine producing states (U.S. Census of Manufactures 1920).

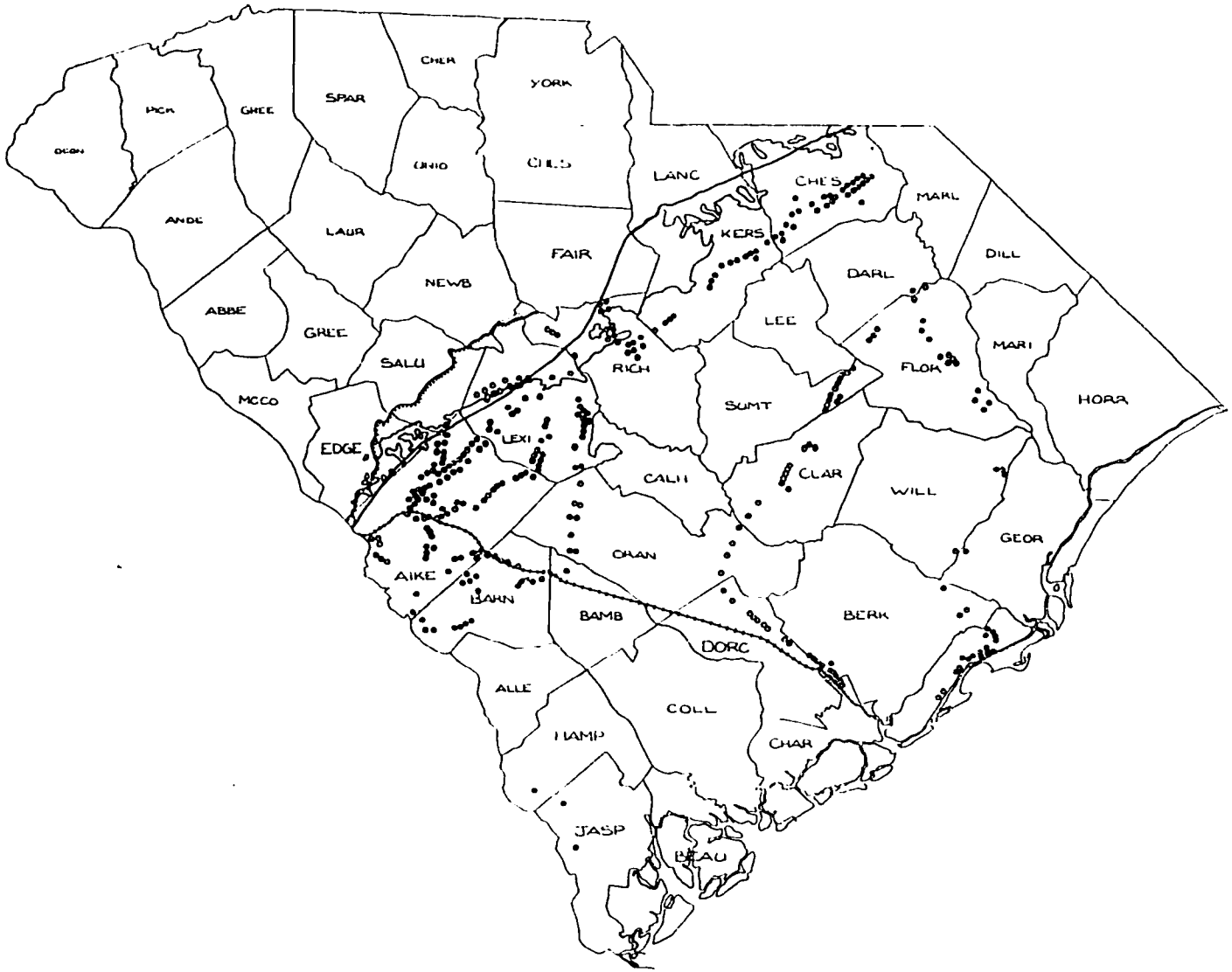
Naval stores in the SRS area. Aside from the one turpentine still in operation in Barnwell County in 1860, there is little record in the Census of Manufactures concerning naval stores operations in the SRS vicinity until after the Civil War. It is likely that some production in the area resumed after the war. Data are sketchy, but evidence suggests that the industry, while winding down on the lower Coastal Plain, moved into the Aiken-Barnwell area as a substantial industry in the late 1900s and continued there until WWII. In 1914 there were still 221 turpentine operations in South Carolina, declining to 84 in 1919 during WWI. One U.S. Forest Service report shows locations of forest industries in South Carolina In 1936, when there were 5 turpentine stills in Aiken and 1 in Barnwell County (Faulks and Spillers 1939). Two of the Aiken sites appear to be near the northern border of SRS. If the placements are accurate on the map, the Barnwell site was in the vicinity of Meyer's Mill Road, near where it crosses Meyer's Branch and Steel Creek. This is within 2 or 3 miles of sites in forestry compartments 40 and 71 where I found old longleaf tapped for turpentine by the cup and gutter method (Figure C4.14).

The last record for turpentine production at SRS comes from a map showing four turpentine stills remaining in Aiken County and one in Barnwell in 1940. Four of these appear to have been on SRS, one near Dunbarton, one south of Jackson, and two near the northeastern edge of the Site. Accuracy is unknown but there seems to have been some attempt at placing the map symbols for stills near their actual location, since they are not randomly placed (South Carolina State Planning Board 1944). There may still be a few local residents old enough to remember the end of the turpentine era at SRS.

All of the turpentine trees I have seen on SRS were tapped using the cup method (Figure C4.14). All appeared to be second growth. One downed tree through which I took a cross-section, was 10 inches diameter and proved to be only 39 years old--32 annual rings near ground level, and allowing 5 years for establishment--at the time it was first tapped for turpentine, probably in the 1930s. The small size of trees used suggests that the last virgin longleaf remaining at SRS had already come down during the steam-powered logging boom of 1870-1890.

Figure C4.14. A dead longleaf pine trunk worked for turpentine by the cup and gutter method. This process, less destructive than the boxing method, was advocated by Charles Mohr (1893). Ashe (1994) reported that perhaps the first trial of this method was conducted in 1894 in Bladen County, NC, after which the technique became widely adopted in the South. Bark was removed from the tree and angled pieces of tin were attached with nails (on right side of trunk in photo). This directed the extruded gum into a rectangular tin cup. The process started at base of the tree and the cup was moved up in steps, each time the gum ceased to flow. Fresh bark had to be removed above each time. The photo was taken on the west side of Pen Branch, north of Road B. A sprinkling of such trees across widely scattered locations at SRS suggests that the entire site was worked for turpentine. Longleaf on this site had been almost completely replaced by hardwoods.

Figure 12.15. Stand conditions and fire in 308 longleaf pine stands I examined briefly in South Carolina. Most of the sites shown are along major highways. Circles with dots are localities with only 1 to 5 individual trees persisting in woods that have succeeded to loblolly pine and hardwoods. Circles with a vertical line are stands with more numerous but widely scattered longleaf. Half circles are fire-suppressed longleaf-dominant stands having a dense understory of hardwoods and loblolly pine. Such stands are unlikely to regenerate longleaf in the future unless fire is reintroduced. Solid circles indicate some of the few high-quality, fire-maintained longleaf communities. The solid line on left is the edge of the historical range as indicated by Sargent (1884). The hachured line on far left is a partial boundary of the original range of longleaf pine drawn by Mills (1825). The 1833 route of the South Carolina Railroad is shown as a line running from Charleston to West Augusta. While not at all complete, this map of shows the near extirpation of longleaf pine from much of its range, particularly from most of the agricultural regions. All circles other than the 30 shaded solid black can be considered in transition from longleaf to other forest types. Many of these have already lost much of their species diversity. The 90.3% of sampled stands that are in transition demonstrate that the 100-year decline of longleaf pine is continuing over most of the state.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Thomas Gamble (1921) summarized the wave of turpentining that decimated the virgin longleaf forests of the State:

> "The exhaustion of the South Carolina pine forests so far as heavy supplies of naval stores were concerned, was astoundingly rapid. Such a thing as conservation was undreamed of. The vast forests of Georgia and Alabama and Florida were too inviting to promote the thought of care in the use of what remained of the Carolina pine forests that had evoked the admiration of the early discoverers and explorers. No section of the primeval longleaf pine forests was more quickly or more effectively obliterated than that through which the 'Tar Heelers' pressed on their way from North Carolina to Georgia. A very few years and they had cut their last boxes, hacked their last trees, gathered their last crops of crude gum, and, like an army of locusts leaving a Kansas wheat farm, moved on to fields new and pastures green."

By the end of the 19th century, most virgin forest of South Carolina was gone. Longleaf had already been extirpated from much of the tidewater region, and its decline in the 20th century can be followed on range maps by Sudworth (1913), Wahlenberg (1946) and recent surveys by the U.S. Forest Service. As can be inferred from Figure C4.15, this decline continues today. It seems probable that in the future, fire-maintained examples of the longleaf pine ecosystem may only be seen on public lands like the Savannah River Site, Fort Jackson, the Sandhills National Wildlife Refuge, and a few private preserves such as Hitchcock Woods. Only on sites maintained with fire, will the original tree canopy/savanna structure be preserved, as well as the full range of plant and animal species diversity dependent upon the ecosystem of which longleaf and wiregrass are only keystone species.

PRESETTLEMENT VEGETATION OF THE SAVANNAH RIVER SITE

The discussion below follows the 10 major vegetation types depicted on Map I, "Presettlement Vegetation Types, Savannah River Site." Table C4.8 gives the acreage and percent of land included in each of the presettlement vegetation mapping units for SRS. These 10 units (not counting Udorthents) are constrained by those communities that could be mapped with confidence at the level of the soil series, the mapping base. The 11 units may be thought of as something similar to vegetation Formations. These units are divided below into a second level of groupings that resemble vegetation Alliances, indicated in Table C4.8 by decimal numbers, an intermediate level between the Formation, and more specific local assemblages like the Community Type (Radford 1981, Weakley et al. 1996). The second level provides a degree of detail that could not be accurately mapped at the scale used for Map C4.1. Within each vegetation grouping below, vegetation types are listed roughly according to the moisture gradient, from the driest to the wettest. Examples of specific presettlement Community Types are given for each in the text below.

Certain presettlement communities of the Savannah River Site do not fit well with recent vegetation classifications. This is because, in the presettlement landscape, the role of fire in distributing species and shaping vegetation was pervasive. Much vegetation classification, itself a young science, has been derived from existing, mostly fire-suppressed vegetation, fire only recently having come into serious consideration. The three master gradients affecting presettlement vegetation of SRS appear to have been the moisture gradient, the fire frequency gradient and, to a lesser extent, the soil texture gradient. Instead of trying to force vegetation of SRS to fit a pre-existing classification, I classified vegetation below according to the principal gradients and processes as they would have occurred in the presettlement landscape, rather than as they appear now. Fire relations, then, become one of the major elements used to define vegetation groups.

Table C4.8. Presettlement Vegetation Types and Percentages of Land Area Occupied by Each at SRS.

	VEGETATION/COVER TYPE	ACRES	PERCENT
1.	Xeric Longleaf Pine and Longleaf-Turkey Oak	7,551	3.8
2.	Dry-Mesic and Mesic Longleaf Pine Savanna	102,610	51.7
3.	Longleaf Pine-Pyrophytic Woodland Complex	7,384	3.7
4.	Pyrophytic Hardwood Woodland	19,865	10.0
5.	Mixed Mesic Hardwood Forest	6,883	3.5
6.	Wetland Pyromosaic—Sandy or Mucky Soils: Patch Mosaic of Fire-influenced Canebrake, Pocosin, Pond Pine Forest and Loblolly Pine; as well as Nonpyrophytic Bottomland Hardwoods, Baldcypress and Nyssa.	18,485	9.3
7.	Wetland Pyromosaic—Silty or Clayey Soils: Patch mosaic of Bottomland Hardwoods, Hardwood/canebrake, Baldcypress, Nyssa biflora.	5,719	2.9
8.	Bottomland Hardwoods, Levee Forests, Oak Flats	5,278	2.7
9.	Swamp Forests, and Ponded Sites other than Carolina Bays	12,089	6.1
10.	Carolina Bays, Upland Depressions	1,938	1.0
11.	Udorthents	7,241	3.6
12.	Surface Water	3,407	1.7
	TOTAL	198,450	100%
	TOTAL TERRESTRIAL (including Udorthents and bottomland hardwoods)	156,812	79%
	TOTAL WETLAND AND WATER (including manmade ponds and lakes), Types 6, 7, 9, 10, 12.	41,638	21%

Table C4.9. Presettlement Vegetation Types of the Savannah River Site

1. **Xeric Longleaf Pine and Longleaf-Turkey Oak.**
   - 1.1 Xeric longleaf pine/turkey oak/wiregrass.
   - 1.2 Dry-mesic longleaf pine/wiregrass.

2. **Dry-Mesic and Mesic Longleaf Pine Savanna.**
   - 2.1 Dry-mesic longleaf pine/wiregrass savanna.
   - 2.2 Mesic longleaf pine/wiregrass savanna.
   - 2.3 Wet-mesic longleaf pine slough.
   - 2.4 Sandhill seep.

3. **Longleaf Pine-Pyrophytic Woodland Complex.**
   - 3.1 Longleaf pine/wiregrass.
   - 3.2 Dry pyrophytic hardwood woodland.

4. **Pyrophytic Hardwood Woodland.**
   - 4.1 Slope shoulder fire-tension zone woodland.
   - 4.2 Mesic pyrophytic woodland.
   - 4.3 River scarp live oak-longleaf pine woodland.
   - 4.4 Mesic pyrophytic hardwood flats.
   - 4.5 Wet-mesic streamhead pyrophytic woodland.
   - 4.6 Wetland fringe mixed pine-mixed hardwood pyrophytic woodland.

5. **Mixed Mesic Hardwood Forest.**
   - 5.1 Steep slope fire-refugial hardwood forest.
   - 5.2 River terrace oak flats.

6. **Wetland Pyromosaic--Sandy or Mucky Soils:** Patch Mosaic of Fire-influenced Canebrake, Pocosin, Pond Pine Forest and Loblolly Pine; as well as Nonpyrophytic Bottomland Hardwoods, Baldcypress and Nyssa. Arranged below from margins to center:
   - 6.1 Wetland fringe mixed pine-mixed hardwood pyrophytic woodland.
   - 6.2 Pond pine/canebrake.
   - 6.3 Pond pine/pocosin.
   - 6.4 Bay forest.
   - 6.6 Atlantic white cedar forest.
   - 6.7 Bottomland hardwood forest.
   - 6.8 Beaver-structured wetland mosaic.
   - 6.9 Sandhill small stream swamp.

7. **Wetland Pyromosaic--Silty or Clayey Soils:** Patch mosaic of Bottomland Hardwoods, Hardwood/canebrake, Baldcypress, Nyssa biflora.
   - 7.1 Bottomland hardwoods.
   - 7.2 Bottomland hardwood/canebrake.
   - 7.3 River terrace swamp.
   - 7.4 River terrace marsh and bog.

8. **Bottomland Hardwoods, Levee Forests, Oak Flats.**
   - 8.1 Levee forest.
   - 8.2 Oak flats on floodplain islands.
   - 8.3 Bottomland hardwoods.

9. **Swamp Forests, and Ponded Sites other than Carolina Bays.**
   - 9.1 Sandhill Small Stream Swamp.
   - 9.2 Cypress-gum swamp.

10. **Carolina Bays, Upland Depressions.**
    - 10.1 Carolina Bay (Small Depression Pond)

11. **Udorthents (mostly longleaf type 2 above).**

12. **Surface Water - aquatic communities.**
    - 12.1 Savannah River.
    - 12.2 Oxbow lakes.
    - 12.3 Sandhills interior streams.
    - 12.4 Lakes in Carolina bays.
    - 12.5 Seasonally ponded areas.

For each vegetation type in Table C4.8, forestry compartments with "exemplary sites" are listed. Species lists for many of these sites are on file at the Savannah River Forest Station. These are some of the best remnants seen during this study. Most communities, however, have experienced some degree of vegetation change resulting from fire exclusion, reduction in fire frequency or change in season of burn. Consequently, almost none are as they would have appeared in the original landscape. Most of those listed as exemplary sites, however, have the potential to be fully restored.

Naming conventions for communities below, using latin names for species, are adapted from Radford (1981). A species had to have at least 20% cover to be named as a dominant in a

layer. Descriptive terms like "sparse" were occasionally added, for example: *Pinus palustris/Quercus laevis* (scattered)/sparse *Aristida beyrichiana*-sparse xeric sandhill herbs. Decimal numbers, such 71.2, for example, refer to my study sites; in this case forestry compartment 71, study plot 2.

Presettlement acreage of longleaf pine. There were some 124,786 acres of longleaf pine at SRS in presettlement times. This is the sum of vegetation types 1, 2, 3 and 11, in which longleaf pine was originally dominant (Table C4.9). There were perhaps 20% in hardwood patches in type 3 but this is offset by the fact that there was a similar amount of longleaf in type 4, pyrophytic hardwood woodland. Since nearly all Udorthents were formed by land leveling and construction on dry-mesic and mesic longleaf pine soils, the 3.8% of SRS now occupied by Udorthents was added to the sum for longleaf pine. This gives a whole site acreage of 62.9%, or 79.6% of the terrestrial vegetation in longleaf pine dominant communities. The range between 62.9 and 79.6% agrees nicely with Michaux's assessment that about 70% of "the country" of the Sandhills and Coastal Plain was covered with longleaf pine around 1800 (Michaux 1805 [1966]).

1. Xeric Longleaf Pine and Longleaf-Turkey Oak.

SOIL SERIES	MAP CODES
Lakeland sand	LaB

Presettlement extent: 7,551 acres.

Presettlement Community Types:

1.1 Longleaf pine-turkey oak scrub:

Pinus palustris/Quercus laevis (scattered)/sparse *Aristida beyrichiana*[3]-sparse xeric sandhill herbs.

Exemplary sites may be found on dry ridges in extensive areas of Lakeland sand in northeastern portion of SRS. Xeric longleaf pine/turkey oak/wiregrass (turkey oak scrub) is the driest plant community that occurred on the Site. Found only on the driest localities on the subxeric Lakeland sand, it occupied small sand peaks and ridges. Besides the sparse grasses, only the

[3]The separation of wiregrass into a northern species (*Aristida stricta*) and southern wiregrass (*Aristida beyrichiana*) by Peet (1993) is followed in this report.

Figure C4.16 Even the excessively drained Lakeland sand undergoes succession to loblolly pine and hardwoods given enough time without fire. This site on a dry peak had not been burned for 36 years. The midstory was hand thinned and the site burned the year before the photo. Note the strong response of wiregrass, *Andropogon* and other grasses a year after fire. Only small, isolated clumps of grasses were in evidence before burning.

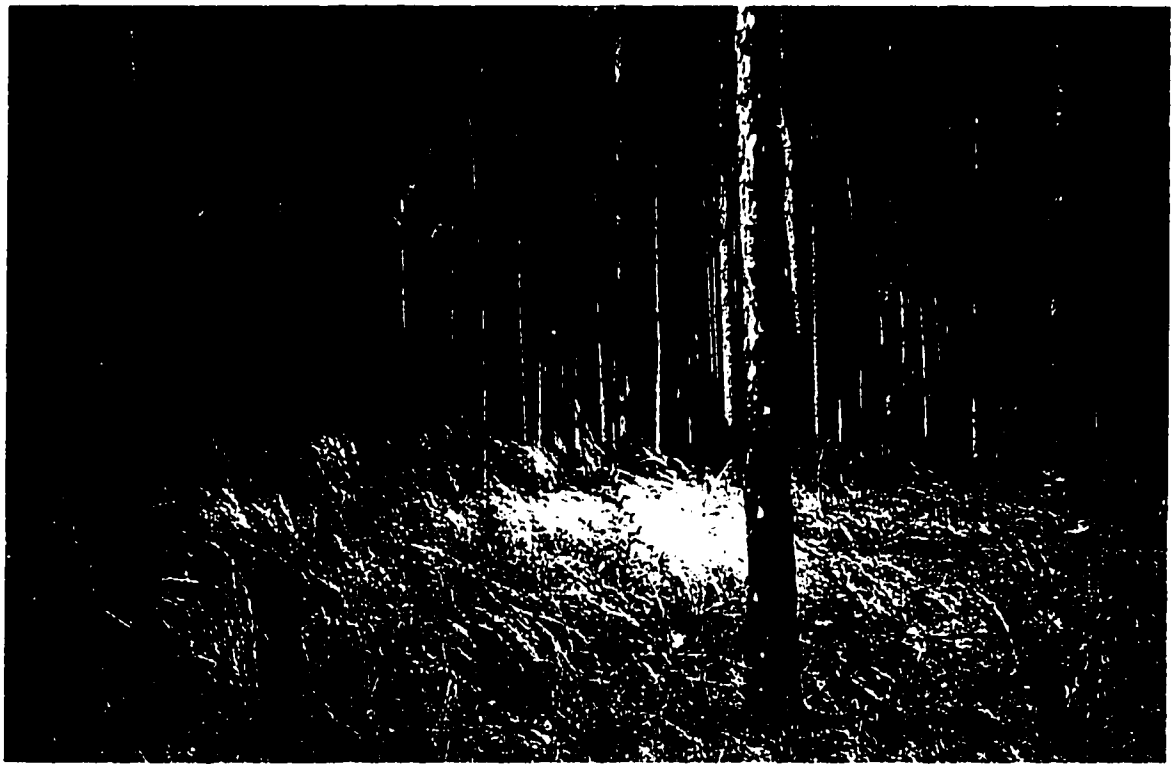


Figure C4.17. A rare species, *Baptisia lanceolata*, on Lakeland sand (LaB). Note the scanty grass cover and heavy leaf litter on this fire-suppressed site. (Forestry compartment 84).

most drought-tolerant forbs, such as *Stipulicida setacea*, *Euphorbia ipecacuanhae* and *Heterotheca gossypina* were common. See the hardwood chapter below for discussion of the bimodal distribution of turkey oak between high, xeric habitats and lower partially fire-sheltered sites. The partitioning of longleaf pine communities along the moisture gradient, from driest to wettest follows Peet and Allard (1993).

1.2 Longleaf pine dry-mesic savanna:

Pinus palustris/Aristida beyrichiana-mixed dry savanna graminoids and forbs.

Exemplary sites: Pleasant Hill, compartment 27; and hill above *Pinus clausa* plantation in compartment 84. Dry-mesic longleaf pine/southern wiregrass is the dominant vegetation type on the Lakeland sand, only limited areas being xeric enough for longleaf/turkey oak. Species diversity ranges from low on the driest sites to moderately high (80 species per 1/10 hectare found at one site in compartment 84) on lower slopes. Original vegetation was distinctly bilayered, with virtually no shrubs or subcanopy trees (Figure C4.16). Occasional pockets of pyrophytic woodland having mixed longleaf, scrub oak and other hardwoods may be found on partially fire-sheltered slopes and swales within areas mapped Lakeland sand.

2. Dry-Mesic and Mesic Longleaf Pine Savanna.

SOIL SERIES	MAP CODES
Blanton sand	BaB, BaC
Dothan sand	DoA, DoB
Fuquay sand	FuA, FuB
Lucy sand	LuA, LuB
Neeses loamy sand	NeB
Norfolk loamy sand	NoA, NoB
Orangeburg loamy sand	OrA, OrB
Troup sand	TrB
Vaucluse sandy loam	VaB
Wagram sand	WaA

This category comprises by far the largest vegetation type at SRS, calculated from Map C4.1 at over 100,000 acres (> 50% of the total lands of SRS) in the presettlement landscape. Two broad types, dry-mesic longleaf, and mesic longleaf pine savanna make up probably 99% of the type. Two rare types of limited extent, wet-mesic longleaf pine slough, and sandhill seep, are included within these lands.

Presettlement extent: 102,610 + 7,241 acres now converted to Udorthents.

Presettlement Community Types:

2.1 Dry-mesic Longleaf Pine Savanna.

Pinus palustris/Aristida beyrichiana-mixed dry-mesic savanna graminoids and forbs. This type occurs on the drier phases of all of the soils above and is the same community described for map unit 1.2 on Lakeland sand.

2.2 Mesic Longleaf Pine Savanna.

Pinus palustris/Aristida beyrichiana-diverse mesic savanna graminoids and forbs.

Exemplary sites: sites having intact herb layers on the above soils occur in compartments 81, 82 and 84. The term "mesic" is often misused to refer to moist or wet sites. It was intended to describe the most optimally-drained portion of the landscape for agricultural or sylvicultural purposes, neither too wet nor too dry. This is how the term is used here, to indicate the most average soils in terms of moisture. Habitat for mesic longleaf pine savanna is defined in part by topography and in part by soils. Vegetationally, this large group is similar to dry-mesic longleaf pine savanna except for slightly higher species diversity and a greater susceptibility to invasion by scrub oak and loblolly pine.

2.3 Wet-mesic longleaf pine slough.

Pinus palustris/diverse wet-mesic savanna graminoids and forbs.

Exemplary sites: compartment 81, east of Roundtree Road.

A rare habitat type throughout the longleaf pine ecosystem, a disproportionate number of rare plant species are found in this community type. Such sites also contain the highest species richness on a small scale recorded in the U.S., sometimes exceeding 40 species per square meter (Norquist 1984, Walker 1985, 1995). Only one intact example was seen at SRS, in compartment

81. Species diversity was high and several rare species, including *Nolina georgiana*, were present. Variants of wet-mesic longleaf pine savanna probably once occurred in moist flats in the vicinity of some of the low-lying Carolina bays like Craig's Pond, and on the fire-accessible flats on the east side of the Savannah River terraces, near the toe of the sandhill scarp. All such sites must have succeeded to loblolly pine and hardwoods long ago.

2.4 Sandhill seep.

Pinus palustris/Quercus margarettiae/diverse sandhill seep graminoids and forbs.

Exemplary sites: compartment 81, east of Roundtree Road. Seeps occur on side slopes of soils such as Fuquay and Vaucluse, having perched water tables. Where the impervious hardpan

Figure C4.18. A rare habitat, Sandhills seep, at SRS. This is an important site with high species diversity on Vaucluse (VeC) soils on the east side of Roundtree Road. The mass of tree saplings in center marks the location of a sandhill seep (see community description in the Appendix). This is an area where moisture from the water table perched above a hardpan in adjacent pinelands intersects a side slope. When regularly burned, such seeps often support pitcher plants and other unusual and rare species. All such sites at SRS have developed dense woody cover during several decades of reduced fire frequency. Foreground is habitat of *Delphinium carolinianum*, a rare plant and a new species for SRS. Compartment 81.

Figure C4.19. Known from only one other site in South Carolina, *Delphinium carolinianum* was found in a sandhills seep in the upper drainage of a tributary of Lower Three Runs, near its origin in a moist longleaf pine savanna. The *Delphinium* here differs in several characters from those described in Radford (1968) from McCormick County, the only other site in South Carolina. This site needs to be burned at least every three years to maintain the savanna herb layer and to prevent woody succession. There were a number of other unusual species, such as *Nolina georgiana* at this site, which needs further survey for rare species after restoration with fire, and at different times of the year.

intersects the surface, water is diverted laterally causing a seep. Because of extended seasonal water availability after other soils have gone dry, such sites are especially susceptible to dense growth of shrubs, loblolly pine and hardwoods (see the patch of woody growth in the center of Figure C4.18. At this site, species richness was high and a rare species, *Delphinium carolinianum*, previously known from only one other site in South Carolina, was found (Figure C4.19). Rare species reported elsewhere in sandhills seeps include *Calamovilfa brevipilis, Carex barrattii, Carex exilis, Carex tetanica, Carex turgescens, Cladium mariscoides, Dionaea muscipula, Eriophorum virginicum, Eupatorium resinosum, Glyceria obtusa, Parnassia caroliniana, Rhynchospora alba, Rhynchospora pallida, Sagittaria engelmanniana, Sarracenia rubra, Schwalbea americana, Scleria minor, Solidago verna, Tofieldia glabra, and Xyris baldwiniana*. There are likely many such seeps in the pinelands of SRS. While most have been obscured by dense woody growth, some could be restored with fire, and some may still retain unusual species.

3. Longleaf Pine-Pyrophytic Woodland Complex.

SOIL SERIES	MAP CODES
Vaucluse sandy loam and Ailey sand complex.	VeC

This group is a mosaic of communities of which mesic longleaf pine savanna comprised by far the greatest acreage, forming a matrix for patches of dry pyrophytic woodland and small amounts of mesic pyrophytic woodland. These patches were in gentle sloughs and on slightly fire-sheltered positions on ridges and gentle slopes, habitat types that are common in the rolling Vaucluse-Ailey soil complex. These soils are in gently rolling or concave areas transitional between the longleaf pine upland flats and linear pineland drains. Small patches of pyrophytic woodlands too small to map can occasionally be found on other longleaf pine soils, especially along wetland margins.

Presettlement extent: 7,384 acres.

Presettlement Community Types:

3.1 Longleaf pine/wiregrass. Same as 2.1. 2.2 and 2.3 above.

3.2 Dry pyrophytic hardwood woodland.

Pinus palustris/Quercus marylandica-mixed scrub oaks/diverse dry pyrophytic woodland graminoids and forbs.

Pinus palustris/Quercus laevis-mixed scrub oaks/diverse dry pyrophytic woodland graminoids and forbs.

Exemplary sites: compartment 40 on a ridge of Ailey sand adjacent to a smooth coneflower site. This type is composed of mixed scrub oaks, including turkey oak, blackjack oak, scrubby post oak, post oak (often stunted), with scattered longleaf pine. See further description of dry pyrophytic woodland in the hardwoods chapter below. Blackjack oak is sometimes dominant in the scrub oak mix on sites having finer textured soils, or soils with a loamy or clayey layer not far beneath the surface, and can usually be taken as a field indicator for these features. Turkey oak is most often dominant on sands.

4. Mesic Pyrophytic Hardwood Woodland.

SOIL SERIES	MAP CODES
Ailey sand	AeB
Albany loamy sand	AnB
Eunola fine sandy loam	EnA
Fuquay sand	FuC
Lakeland sand	LaC
Lucy sand	LuC
Ocilla loamy sand	OcA
Orangeburg loamy sand	OrC
Smithboro loam	Sm
Troup sand	TrC
Vaucluse sandy loam and	

Ailey sand complex	VeD
Wagram sand	WaB

Lands mapped in this group are also a mosaic of longleaf pine with smaller patches of pyrophytic woodland. The type can be readily identified by the presence of post oak or hickory, often in mixture with longleaf and other pines. Fire-maintained examples have a species rich herb layer and almost no understory. Most stands at SRS are fire suppressed, with a depauperate herb layer. All of the vegetation types in types 2 and 3 above can also be found as patches. On the uplands, though, the great majority of mesic pyrophytic hardwoods can be found in this mapping unit. A few patches can be found on lower slopes of other soils than those indicated. Upland soils include those with finer texture, or with subsurface fine-textured soils, or subsurface moisture, and soil slope classes that offer some shelter from fire. Some of the soils are more steeply sloping or in lower landscape positions that in type 3 above. On the Savannah River Terraces, several of the upland soils just mentioned mingle with flat-lying series such as Ocilla loamy sand and Smithboro loam that are largely confined to the terraces and to small patches in the small stream bottomlands.

In the presettlement frequent-fire landscape these stands would have been more sunny and open. Fires kept litter removed and enough light reached the ground to support a species-rich herb layer. These would have been important areas for wildlife. With fire suppression, the legumes and other food plants characteristic of this type vanish and this appears to have been the case with elimination of fire from hardwoods at SRS.

Presettlement extent: 19,865 acres.

Presettlement Community Types:

4.1 Steep slope shoulder fire-tension zone woodland.

Pinus echinata-Pinus taeda-mixed oaks and *Carya tomentosa*/mixed pyrophytic woodland graminoids and forbs.

Exemplary sites: compartment 33 on steep slopes of Troup (TuE, TuF) soils on Upper Three Runs Creek south of Tyler Bridge Road. The narrow bands of pyrophytic woodland on steep upper slopes and slope shoulders are an important presettlement habitat for shortleaf pine. This

habitat occurs in the fire-tension zone between frequently burned longleaf pine uplands and truly nonpyrophytic vegetation such as beech on moist lower slopes. The slope shoulder probably burned at the same rate as adjacent longleaf pine uplands, but with less effect, since any fire had to burn downslope. Fires died out on the lower half of the same slopes, the lower half of which comprised an important fire refugium for nonpyrophytic plant species.

A fire-tension zone is any area transitional between frequent fire and nonpyrophytic vegetation (see Appendix 1, glossary of terms and concepts of landscape fire ecology). In the case of abrupt slopes, this zone may only be 10-20 meters wide. In some large coastal plain wetlands it may range to over two miles in width, with vegetation changing gradually as fire frequency and fire impact decreases. Some species, such as shortleaf pine, find their primary habitat in fire-tension zones. At the site in compartment 33, shortleaf pines up to 21 inches dbh were about 75 years old when cored in 1994, dating them approximately to WWI. In a natural situation, the distribution of pines changed across the zone. Pure longleaf pine occupied the upland flats, while on the upper arm of the slope shoulder, longleaf and shortleaf formed a mixed pine savanna. Just below the slope shoulder, the community graded into pyrophytic woodland with longleaf, shortleaf, post oak and white oak, and occasional loblolly. The slope below was habitat for nonpyrophytic hardwoods, with occasional loblolly pine. In Aiken County, remnants of this natural distribution can be seen in parts of Hitchcock Woods, small portions of which appear to be virgin forest. The oldest canopy trees follow the distribution above, albeit with a long fire-suppressed brushy understory from which the herb layer has long since vanished.

4.2 Mesic pyrophytic woodland (Figure C4.21).

Quercus stellata-Pinus palustris/diverse pyrophytic woodland grasses and forbs (plot 40.3).
Carya tomentosa-Pinus palustris/diverse pyrophytic woodland grasses and forbs (Figure C4.21).
Pinus palustris-Quercus stellata-Quercus margarettiae/diverse moist savanna graminoids and forbs. (Ailey soil in an upland depression, plot 81.4).

Figure C4.20. Federally endangered smooth coneflower is a species endemic to grassy openings in pyrophytic hardwood woodland. Typical canopy species on Piedmont sites are post oak, blackjack oak and shortleaf pine. In the sandhills, scattered longleaf pines replace shortleaf in the mix. This is an extremely rare habitat since, in past management plans on most sites throughout the South, such stands were pronounced loblolly or hardwood sites. The stands were then fire-suppressed, and many were actively converted to loblolly. No pristine example of smooth coneflower woodland habitat exists anywhere. The woodland in Figure C4.21, which has remnant smooth coneflower on the sunny margin, would be a prime site for restoration of this rare habitat type at SRS.

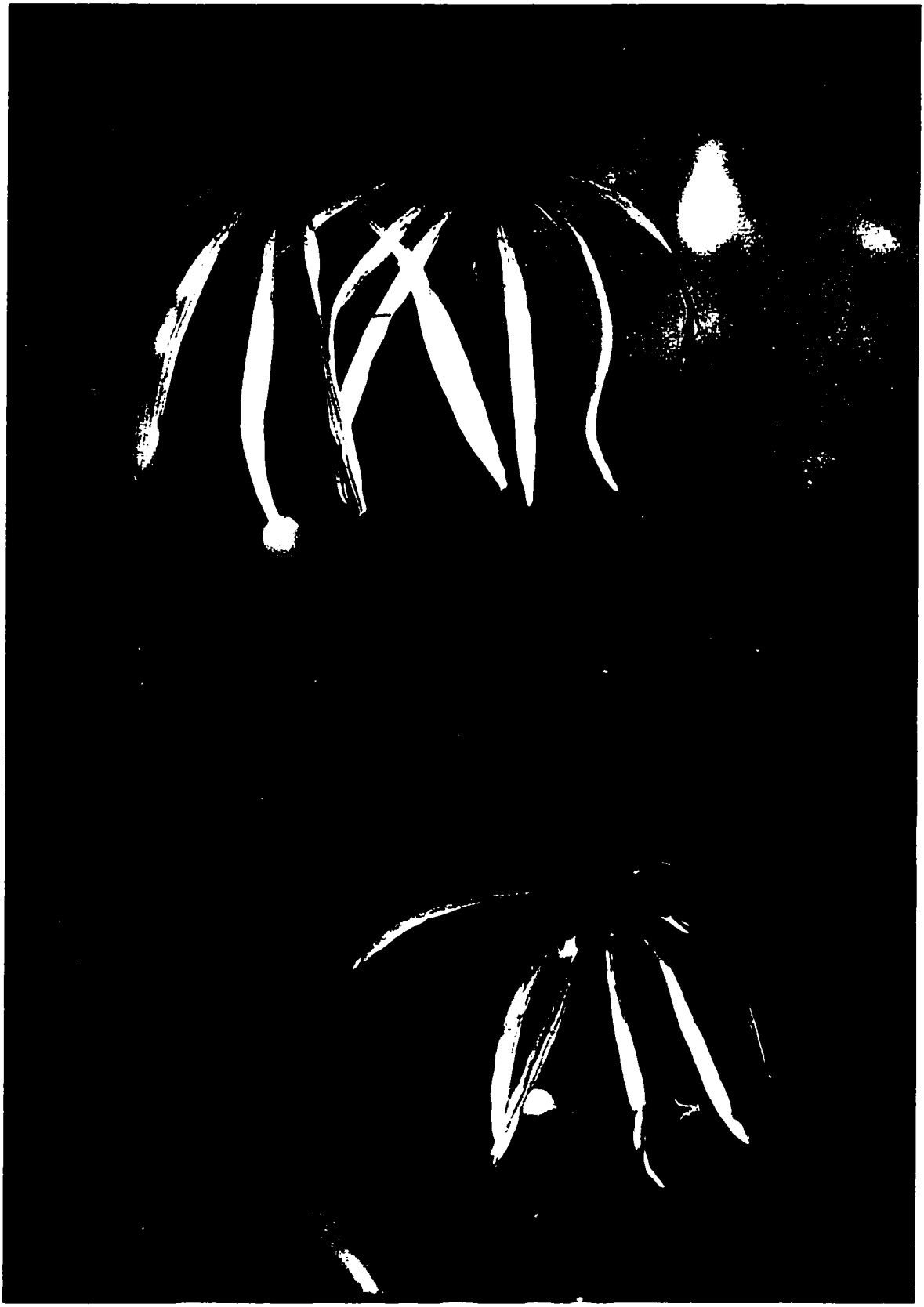


Figure C4.21. Mesic pyrophytic woodland, most often dominated by post oak or mockernut hickory, is found on sites slightly less fire-exposed, slightly moister, and with slightly finer-textured soil that dry pyrophytic woodland. Any of the scrubs oaks, as well as longleaf, loblolly and shortleaf pine also may be present. Rare species may often be found in the herb layer if the hardwood woodland has been maintained with fire. At this fire-suppressed site the last fire was around February 1989, 6 years before photo. *Fothergilla gardenii*, a new species for SRS, was discovered on the ridgetop (see Batson et al. 1985). Smooth coneflower (*Echinacea laevigata*) occurs on the margin toward road B-5. When in a more open, oak savanna-like condition maintained by fire, this is the major natural habitat for this federal endangered species. Most rare species and wildlife food plants are found in the grass-forb layer. Compare the amount of light reaching the forest floor on this abnormal site with that of Figure C4.22 below, a similar woodland which has experienced growing season burns.

Figure C4.22. Effect of aspect on upland hardwood distribution. This pyrophytic woodland on a lower north slope is dominated by mockernut hickory (*Carya tomentosa*). Pure longleaf pine can be seen on the south-facing slope in the distance. Longleaf and hardwood can coexist in woodland in dynamic tension between fire effects: there is just enough fire effect to permit occasional longleaf establishment in gaps (note the longleaf sapling on right and the old canopy longleaf trunk on left). On the other hand, this partially fire-sheltered site is slightly cooler and moister than adjacent south, east, and west slopes, just sheltered enough to permit successful establishment of hardwoods. Prolific sprouters like mockernut hickory have the advantage in being able to resprout if killed to the ground. The numerous paired stems testify to such an origin for many of the canopy trees present. With reduced fire frequency and with winter burns, hardwoods at SRS have expanded beyond their original boundaries and their original density. Nevertheless, pyrophytic hardwood is a natural vegetation type, and the core refugium can usually be identified. Reintroduction of growing season fire would help confine hardwoods to their presettlement fire-sheltered habitats, and maintain sunny, species-rich herb layers.

Figure C4.23. This former Longleaf pine/wiregrass savanna illustrates how sites with the same slope, aspect and soil type can have radically different vegetation, depending upon how the landscape setting permits access by fire. This site, on a west aspect, is a 24% slope on Troup and Lucy sands (TuE). Nearly identical sites elsewhere on SRS support mixed mesic hardwood forest, and even beech forest can be found on slopes of Troup and Lucy TuE soils along Tinker Creek and Upper Three Runs. Such sites, however, are protected from fire approach from below by a wet swamp, so that the sand is only approachable by fire backing downslope. In Figure C4.23 fire can approach from below and carry upslope with great heat and fire effect. When slopes exceed 20%, fire moves downslope poorly and may not reach the wet slope toe before going out (downslope ignition by rolling pine cones is a western phenomenon; in the east vegetation and litter are usually too dense to permit rolling firebrands to be a factor). Fire intensity and effects on vegetation are dampened as fire is reduced to creeping litter fire. In contrast, the slope in Figure C4.23 stands above a plain, once forested with pyrophytic woodland and moist longleaf pine savanna, both types that would carry frequent fire to the toe of the slope. Fire intensity and effects on vegetation are greatly intensified when fire moves upslope (National Wildfire Coordinating Group. 1981) so that only the most fire adapted species can exist. The result is replacement of mesophytic hardwoods by longleaf pine. Restoration of this site began in 1994 with thinning of invasive understory hardwoods and loblolly pine, and the site was burned in October 1994. By the following summer, wiregrass remnants (not visible in photo) near top of slope were conspicuous, responding to increased light availability (forest compartment 82).

Exemplary sites: compartment 40 in concave area of Vaucluse-Ailey soils, 10-15% slopes, adjacent to smooth coneflower site. Mesic pyrophytic woodland in the pinelands is most often dominated by post oak or mockernut hickory, and is found on sites slightly less fire-exposed, slightly moister, and with slightly finer-textured soil that dry pyrophytic woodland. Any of the scrubs oaks, as well as longleaf, loblolly or shortleaf pine may be present.

4.3 River scarp live oak-longleaf pine woodland.

Quercus virginiana-Pinus palustris/mesic woodland graminoids and forbs.

Exemplary sites: Along the scarp between the Savannah River floodplain and the lower river terrace. Frequently burned live oak-longleaf pine woodlands once occurred in many places along the coast. Small remnants can still be found in a few places (Wentworth et al. 1992). One historical report, describing the open low country on the coastal plain just west of Charleston in 1833, mentioned that, "The country, as far as the eye could see, was shaded with here and there a solitary liveoak, and woods of pitch-pine [longleaf]" (Derrick 1930). Generally, even though the canopy oaks and pines may be intermixed, the longleaf is rooted on drier microsites while live oak is in moist microsites. At SRS, live oak seems to have been confined to the scarp along the Savannah River floodplain.

4.4 Mesic pyrophytic hardwood flats.

Quercus alba-Quercus stellata/flatwoods graminoids and forbs.

Quercus stellata-mixed pines/flatwoods graminoids and forbs.

Exemplary sites: compartment 39 and extensive areas of Smithboro and Ocilla soils on river terrace flats. Presettlement vegetation communities of the river terraces are the most problematic at SRS. Because they are more fertile, finer textured, and well supplied with moisture, the terrace flatwoods are the most susceptible to mesophytic succession in the absence of fire. For the same reasons, they were the most valuable lands in the region for agriculture. The town of Ellenton, on the edge of second terrace, was the center of a fully domesticated local agricultural landscape. Being near water transport, which was vital in colonial times, the terraces were the first lands settled, and the lands were used for 200 years before establishment of SRS (Brooks and Crass 1991).

Original forests of the Savannah River terraces. Historical descriptions of bottomland canebrakes and annually burned longleaf pine flats having standing water in winter demonstrate that fire moved freely in flat wetlands. Original vegetation of the flat river terraces would have been a mosaic of longleaf pine savanna, and pyrophytic hardwoods, separated by zones of wetland fire communities like canebrake, and bottomland hardwoods, with pockets of fresh marsh, bog and pocosin-like vegetation in wet depressions kept open by fire, as well as nonpyrophytic bottomland hardwoods and swamp. There may have been small zones of species-rich wet longleaf pine savanna near the upland scarp. Appropriate soils and hydrology are present, and the site once supported the necessary fire regime, but no traces remain.

Remnant pockets of former pond pine/canebrake and pocosin, however, as well as scattered longleaf in mixtures with shortleaf, pond pine, loblolly and hardwoods, are evidence of the former fire regime. I could find no remnant patch of longleaf that could be called a "stand" on the terraces, but given the long history of exploitation as plantations and farms, this was hardly unexpected. One stand of longleaf, indicated as natural on GIS mapping, proved to be an old pine plantation in which the rows had become obscured by loss of a number of trees. Natural longleaf, however, are sprinkled here and there in mixed pine and hardwood stands, particularly on the flat to gently convex soils such as the Ocilla sand, and the drier sands like Blanton. In one place I found a mixture of four species of pines on the same site. This small lens of Ocilla sand had longleaf, pond pine, loblolly and shortleaf, as well as post oak. Because of the complex microtopography, the most complex vegetation at SRS most likely occurred in the terrace flatwoods. Complexity was augmented by variation across the fire frequency gradient, ranging as high as 1-3 years near the upland scarp, and declining across the terraces toward the river scarp.

Fire tends to sharpen the differentiation of plant communities in complex wet sites, by letting in light so that a great variety of grasses and forbs can find their particular microsites along the moisture gradient. On the other hands fire exclusion tends to blur community distinctions. Reintroduction of fire in canebrake and other wetland sites near the sandhills scarp might reveal remnant rare species, and restore a sample of the original community structure and variety.

4.5 Wet-mesic pyrophytic woodland - stream head variant.

Mixed mesic pyrophytic woodland hardwoods-*Pinus palustris*/diverse mesic and wet-mesic pyrophytic woodland herbs (plot 81.1).

Exemplary sites: Compartment 81 on east side of Roundtree Road. This type of woodland occurs near the origin of pineland drains, in places where there is enough relief within the drainage bottom so that it acts as a fire filter, decreasing the effects of fire. Most fires pass through, but because of the irregular topography, there are microsites for a variety of trees, despite the frequent fire regime. Important canopy trees are water oak, post oak, mockernut hickory, sweetgum, loblolly pine and longleaf. This is one of the natural habitats of loblolly pine in a frequent-fire landscape.

4.6 Wetland fringe mixed pine-hardwood pyrophytic woodland.

Pinus taeda-mixed pines-mixed oaks, wetland fringe pyrophytic woodland (plot 33.4).

Exemplary sites: compartment 33 near juncture of Tinker Creek and Upper Three Runs. This is an important type because it was the principal habitat at SRS for loblolly pine, as well as for scarlet oak and southern red oak. This fringing woodland type occurs in a narrow zone along the margins of the type mapped pyromosaic wetland, but only in those places where the side slopes are gentle enough to permit access by fire. Width varies from around 10 to 100 meters. The type is more prevalent than suggested by Map C4.1, because most occurrences are linear features too narrow to map. All four species of pines may occur. Loblolly may be found in mixture with shortleaf and longleaf on the upland side, while both loblolly and pond pine may occur on the wet side, sometimes in a narrow zone of canebrake. The oaks range from post oak on the upland side to post oak-scarlet oak-southern red oak-white oak in the center, to semi-evergreen oaks like water oak and willow oak along the wetland edge. Most of the wider sites, on Eunola and Albany soils, were farmed in the distant past.

5. Mixed Mesic Hardwood Forest.

SOIL SERIES	MAP CODES
Hornsville fine sandy loam	HoA
Troup sand	TrD
Troup and Lucy Sands Complex	TuE, TuF

Presettlement extent: 6,883 acres.

Presettlement Community Types:

5.1 Steep slope fire-refugial hardwood forest.

Fagus grandifolia-Mixed mesophytic hardwoods/mixed mesophytic subcanopy trees/diverse mesophytic hardwood graminoids and forbs.

Quercus alba-Fagus grandifolia/Kalmia latifolia/mesophytic hardwood graminoids and forbs.

Exemplary sites can be found in compartments 22, 32 and 33 along Upper Three Runs Creek near Tyler Bridge Road, and on almost any slopes mapped as Troup and Lucy soils with TuE (15-25% slope) and TuF (25-40%) slope classes. The steep slopes bordering Tinker Creek, Upper Three Runs Creek and many of their tributary streams are important fire refugia for mesophytic plant species like beech. Unusual species such as walnut, *Ruellia carolinensis* and *Chasmanthium sessiliflora* near the slope toe, may be related to calcareous strata in the slope geology. Most of the fire-free habitat is on the lower half of the slopes. This habitat, comprising only about 1% of the lands within SRS, is the only true "southern mixed hardwood forest" on the site.

Upstream from SRS, the settlement named Beech Island, which was called Beech Highland in the early settlement period (Crass 1994 pers. comm.), likely refers to beech habitat similar to that at SRS. The locality consists of bluffs with a series of deep ravines having slopes up to 25% and protected from fire below by a wet swamp and an old oxbow of the Savannah River. There is fire-sheltered beech habitat on the steep slopes and on some low flats of sandy soil at the slope toes. At one point, the bluffs truncate the river terrace and steep slopes stand directly above the river, probably the highland that gave the locality its name.

5.2 River terrace oak flats.

Quercus stellata mixed mesophytic hardwoods/mixed mesophytic shrubs/*Chasmanthium laxum*.
Quercus alba-Quercus stellata/flatwoods graminoids and forbs.
Carya glabra-Carya tomentosa-Quercus alba-Quercus stellata/*Cornus florida*/sparse ericad shrubs (*Vaccinium tenellum-Vaccinium stamineum* and *Gaylussacia frondosa*)/mixed mesophytic graminoids and forbs.

Exemplary sites: compartment 44 along Water Gap Road. There is a small amount of this kind of hardwood forest on some of the other soils of the river terraces, such as the drier phases of the Rembert and Smithboro, especially where remote from fire, but the fine-textured Hornsville loam with its clayey substratum seems to be the most significant mesophytic hardwood soil. The terrace hardwood flats differ from the steep slope forests, in that they are less protected from fire. In the original landscape they would have experienced fairly frequent light litter fires. This probably accounts for the presence of post oak, which seems to be fire-related, and the complete absence of beech, whose reproduction is prohibited by even light litter fires, if fairly frequent.

6. Wetland Pyromosaic--Sandy or Mucky Soils: Patch Mosaic of Fire-influenced Canebrake, Pocosin, Pond Pine Forest and Loblolly Pine; as well as Nonpyrophytic Bottomland Hardwoods, Baldcypress and Nyssa.

SOIL SERIES	MAP CODES
Fluvaquents, loamy sand	Fa
Ochlockonee loamy sand	Oa
Pickney sand	Pk
Williman sand	Wm
Dorovan muck	Da

Presettlement extent: 18,485 acres.

Presettlement Community Types:

6.1 Wetland fringe mixed pine-hardwood pyrophytic woodland.

Pinus taeda-mixed pine-mixed oak, wetland fringe pyrophytic woodland. This is the same community as 4.6 above. It occurs on the fringes of the wetland pyromosaic and on small patches of Eunola and Albany soils within it, too small to map.

6.2 Pond pine/canebrake.

Pinus serotina/Arundinaria gigantea (Figure C4.8)(plots 42.1, 71.2, 82.3).

Pinus serotina-Pinus palustris-Pinus taeda/Arundinaria gigantea (plot 42.1).

Exemplary sites: compartments 42, 71, 82. All former canebrakes at SRS have experienced some degree of succession to bottomland hardwoods. One canebrake in plot 71.2 had succeeded to the following community type after some 25 years without fire: *Pinus serotina*-mixed bottomland hardwoods/*Acer rubrum*-mixed bottomland hardwood saplings/*Arundinaria gigantea*-mixed wet-mesophytic shrubs. Soil, probed in the wettest part of this site, was sandy muck to 1.2 meters deep. At another site, in compartment 42 on the river terrace at the toe of the upland sandhills scarp, 30 years without fire was resulting in succession to tulip poplar, sweetgum, water oak, swamp black gum, holly, sweet bay and red bay. A third site, on wet soils mapped Fluvaquents, near the railroad track in compartment 82, appeared to have had canebrake around the margin, which graded into mesic longleaf pine savanna on the upland side and into pocosin in the wet interior. This site had old pond pine and *Gordonia* in the canopy. In the sandhills, canebrakes often occurred in wetland sloughs immediately adjacent to longleaf pine savanna (see map in Reed 1905, Figures 6.12 and 6.13 in Chapter 6, and Figure C4.8). The site in compartment 82 had a likely fire return interval of about 2-4 years. It was the most fire-exposed canebrake site seen at SRS, being contiguous with extensive longleaf pine savannas with remnants of wiregrass and other frequent-fire indicators.

The remnant canebrake areas in the small stream drainages occur typically on fine-grained mosaics of several soil series, including Williman, Ochlockonee, Fluvaquents and pockets of Pickney and other soils. Vegetation complexity is increased because most of these sites lie along the margins of drainages, and consequently some are fire-exposed, while others have varying degrees of natural protection from fire. Even though they occur in wetlands, the dense understory is conducive to carrying hot fire. One site on the west side of Pen Branch at road B, is an important natural area. It may have the largest stand of pond pine remaining on the Savannah River Site. This includes remnants of pond pine/canebrake and pocosin, which could be easily restored to their presettlement structure by reintroduction of fire.

In general, on wet sands and sandy muck soils like those along Pen Branch, canebrake is favored by high fire frequency, around every 2-5 years, such as likely was found in those portions of the site further from Pen Branch (a natural firebreak) and adjacent to former, frequently-burned longleaf pine uplands. On the other hand, pocosin is favored by lower fire regimes, averaging about every 5-12 years. This fire-return interval allows permanent establishment of a dense layer of evergreen pocosin shrubs. The natural fire regime and pattern of fire flow at this site could be simulated by burning the longleaf pine uplands along the road and to the west of the site, and letting fire run into the pond pine canebrake and pocosin as it would have under natural conditions. This should reestablish the natural zonation and create sustainable examples of these two threatened natural vegetation types.

The original extent of sandhills canebrake at SRS is unknown. There are several distinct remnants, and it is tempting to speculate that "Reedy Branch", a tributary of Tinker Creek in compartment 31 refers to presettlement canebrake. Cane was most often referred to as "reeds" in the colonial literature, until the term canebrake became widespread in the late 19th century. Judging from the distribution of suitable sites and soils there were probably some 40 or 50 canebrakes at SRS in presettlement times. Most were small, but one or two, such as occurred along Pen Branch, and at the toe of the sandhills scarp in compartment 42 occupied several hectares.

Canebrake, once a major natural habitat in sandhills drains, is now a rare plant community in the Southeast. Logan (1859) described extensive canebrakes in the Piedmont of South Carolina. While Hughes reported that some 2 million acres persisted in Virginia, North and South Carolina as late as the 1960s (Hughes 1966), today there are probably fewer than 10,000 acres, mostly in the coastal peatlands. The canebrake remnants are habitat for rare animal and plant species like Swainson's warbler and sandhills lily (*Lilium iridollae*). The first Swainson's warbler ever collected was taken around 1808 by the naturalist John Abbot only 20 miles from SRS. The site was along Brier Creek near the Burke-Screven County line in Georgia. The first scientifically published occurrence came when Bachman collected it in 1833 from the Edisto River near Jacksboro, South Carolina. Canebrake is the prime habitat for Swainson's Warbler (Meanley 1971), and the rarity of the warbler is almost certainly tied to the disappearance of cane. To my

knowledge, no site in the South has yet specifically included canebrake maintenance as an objective in a fire management plan. There at least three sites at SRS, however, where examples of sandhills canebrake could be restored with one or two burns.

6.3 Pond pine/pocosin.

Pinus serotina/mixed evergreen pocosin shrubs-*Smilax laurifolia*/*Woodwardia virginiana*-*Sphagnum* (plots 39.1, 71.1, 82.3).

Acer rubrum/mixed evergreen pocosin shrubs/mixed ferns/*Sphagnum* (plot 18.2).

Exemplary sites: compartments 18, 39, 71, 82. Species diversity in pocosins is relatively low except on their margins with pine savannas, where very high species richness may be encountered. The several fire-suppressed former pocosins seen at SRS had succeeded to pond pine-*Gordonia*, pond pine-bottomland hardwoods, or red maple, all typical patterns of change in the absence of fire (see Table 3.2 in Chapter 3). In fire-maintained pocosin, pond pine is the only tree. *Gordonia* is maintained as a shrub but with 15-20 years of fire exclusion it attains tree status. The distinctive pocosin layer is composed of evergreen shrubs. The four sandhills pocosins investigated at SRS had the following pocosin species: *Pinus serotina, Gordonia lasianthus, Persea palustris, Magnolia virginiana, Ilex coriacea, Ilex glabra, Ilex opaca, Aronia arbutifolia, Vaccinium corymbosum, Myrica cerifera, Myrica heterophylla, Lyonia ligustrina, Lyonia lucida, Smilax laurifolia, Woodwardia virginiana* and *Sphagnum*. These sixteen are practically a full catalog of the most typical pocosin species, with exception of *Cyrilla racimiflora*, and a few species having limited geographic distribution, such as *Zenobia pulverulenta*.

Pocosins tend to occur on soils that are wetter, and have deeper thickness of organic matter below the surface than canebrake, and they are found in landscape positions where they experience a slightly lower fire frequency. At the site in compartment 82, on wet soils mapped Fluvaquents, there were remnant pond pine and *Gordonia* on a peaty soil that was probed to 1.9 meters before encountering a hard sand bottom. One pond pine 24 inches dbh was 95 years old (90 rings + 5 yrs for establishment and growth to coring height), giving an establishment date of 1899, decades before establishment of effective suppression in the region. Another site (39.1) was found in a perched wetland on the upper river terrace. It was well above Pen Branch, into

which it drains to the north. One pond pine was 96 years old and very tall.

A third pond pine community at SRS, in addition to canebrake and pocosin, was pond pine woodland or savanna. This type occurs elsewhere, in narrow moist flats transitional between longleaf uplands and boggy pocosin. In such sites, the mineral soil is too wet for longleaf, but frequent fire keeps shrubs and other trees out, creating a bilayered fire community with pond pine the only canopy tree, over a species rich grassy layer. One likely site was found in compartment 33 at the juncture of Tinker Creek and Upper Three Runs on soils mapped Pickney. There are tall pond pine with loblolly pine and a few *Gordonia* on a low flat, transitional to pocosin-like vegetation further toward the channel of Upper Three Runs. The presettlement vegetation here was likely pond pine savanna, grading into pocosin or a zone of bay forest of *Persea palustris* and *Magnolia virginiana*. This was the only likely pond pine savanna site I saw at SRS.

6.4 Bay forest.

Persea palustris-Magnolia virginiana-Gordonia lasianthus/sparse to moderately dense evergreen pocosin shrubs.

Exemplary sites: compartment 33. Never an important type, there may have been narrow zones of bay forest in places along the major streams at SRS, especially where wet mineral soils graded into soils with considerable organic content and were accessible to fire. Under a natural fire regime, bay forest is found in narrow fire-tension zones between frequent-fire vegetation on the upland side, and water or nonflammable swamp on the wet side. With fire suppression, most examples of bay forest now found in the Carolinas are just former pocosins that have grown up in the absence of fire. Presence of pond pine is usually evidence of succession from a more open type than bay forest. Potential soils at SRS include Pickney (Cumulic Humaquepts), Dorovan (Typic Medisaprist) and some of the Fluvaquents. Characteristic bay species are *Gordonia lasianthus, Persea palustris, and Magnolia virginiana* with some of the typical shrubs of pocosins in the understory. There is little difference in species composition of pocosins and bay forest other than absence of some of the bog herb species like *Andropogon glomeratus* and pitcher plants found in pocosins.

6.6 Atlantic white cedar forest.

Exemplary sites: No white cedar is currently known at SRS but historical occurrence is likely. Sandhills white cedar occurs along small streams in the flat bottoms, sometimes extending up adjacent seepage slopes. Typical soils are wet, mucky sands like Williman, Pickney and pockets in the bottomland soils collectively mapped as Fluvaquents.

While white cedar (*Chamaecyparis thyoides*) has not been found on the site, SRS is on the edge of the original range in the Carolinas and it once occurred in the vicinity. From the great peatland white cedar stands in coastal North Carolina and the Dismal Swamp of Virginia, a tongue of cedar habitat extended south through the interior sandhills, tapering out near Augusta (Frost 1987). Michaux found it nearby in Augusta County, Georgia, only a few miles from SRS. Place names are often all that remains of vanished species. In the Carolinas, there are numerous cedar creeks, many of which had or still have white cedar, while others refer to red cedar. The Aiken County soil map shows two Cedar Creeks, one tributary to Upper Three Runs, and a Cedar Branch. There are two more cedar creeks in Barnwell County. All appear on the maps of Mills' Atlas (1825). I do not know whether any of these might refer to white cedar, or to red cedar associated with the underlying calcareous geology which has been reported from that vicinity (Soller and White 1991). Sandhill white cedar stands occur in the headwaters of second and third-order streams with valleys shallow enough that topography does not prohibit access by fire to the stream bottomland. In the deeply incised stream valleys further downstream, only a few small sites might have been exposed to the fire required to regenerate white cedar in wetlands. White Cedar is not known to persist indefinitely in any of its habitats without fire or artificial disturbance.

6.7 Bottomland hardwood forest.

Liquidambar styraciflua/Ilex opaca/mixed *Carex* spp.-*Woodwardia areolata* (33.6).
Mixed semi-evergreen oaks-mixed deciduous bottomland hardwood trees/*Ilex opaca-Acer rubrum*-mixed bottomland hardwood subcanopy trees and tree saplings/mixed bottomland shrubs and vines/mixed bottomland graminoids and forbs.
Liquidambar styraciflua-Acer rubrum-Nyssa biflora-Liriodendron tulipifera/Ilex opaca-Acer

rubrum-mixed bottomland hardwood subcanopy trees and tree saplings/mixed bottomland shrubs and vines/mixed bottomland graminoids and forbs (interpreted from Whipple et al. 1981). *Liquidambar styraciflua-Nyssa biflora/Ilex opaca-Acer rubrum*-mixed wet bottomland subcanopy trees and tree saplings/*Itea virginica*-mixed wet bottomland shrubs and vines/*Saururus cernuus*-mixed swamp and wet bottomland graminoids and forbs (interpreted from Whipple et al. 1981).

Exemplary sites: compartment 33 at head of sandhills drain on soil mapped Pickney, numerous small localities in all SRS small stream bottomlands. Small stands of bottomland hardwoods, too small to appear on the vegetation map, are numerous within the wetland pyromosaic, on wet mineral soils ranging in elevation from the pineland headwaters of many small drains, down to small flats and stands on the wet swamp margins of Upper and Lower Three Runs, Tinker Creek, Fourmile Branch, Pen Branch and Steel Creek. Other bottomland hardwoods with different flooding regime and species composition are the dominant types in the Savannah River floodplain (see vegetation mapping units 7 and 8 below).

The term bottomland hardwoods, as used in mapping unit 6, wetland pyromosaic, refers mostly to stands on wet-mesic mineral soils. Hydrology ranges from wet-mesic terrestrial to seasonally flooded palustrine. Sites dry enough to have white oak, hickory and post oak as dominants are classified elsewhere under mixed mesic hardwood forest or pyrophytic woodlands. Whipple at al. (1981) examined 22 bottomland and swamp hardwood stands along Upper Three Runs Creek and grouped them into six major types, two of which fit the description of bottomland hardwoods here. These are *Nyssa sylvatica-Persea borbonia*, and *Nyssa sylvatica-Acer rubrum* (the wetland *Nyssa* involved is now called *Nyssa biflora and the Persea is now P. palustris*). Their communities were not named strictly for dominant species, but rather for character species across a number of stands, so some species including the most common dominant, sweetgum were not used in naming. As a consequence, their community names are not comparable with naming systems based on actual dominants as used herein. Canopy dominants in their *Nyssa sylvatica-Persea borbonia* type were sweet gum, red maple, swamp black gum, and tulip poplar. The understory dominants were red maple, holly, water oak, sweetgum, swamp black gum, red bay and sweetbay. Three of their stands in this vegetation type

included beech, in Upper Three Runs bottomland flats, the only place they encountered this species.

Sweetgum is extraordinarily abundant in SRS bottomlands. Of all the hardwood and swamp communities examined by Whipple et al. (1981), it was lacking only from the deepwater Cypress-*Nyssa aquatica* community. Sweetgum may reach importance in three ways. First, because of its considerable shade tolerance, it is a natural component of bottomland hardwood forests where it occurs in mixture with other tree species like those above. Second, its dominance in many bottomlands is probably related to two effects of past logging; the tendency to leave sweetgum in favor of more valuable species like swamp chestnut oak, and its ability to exploit light gaps left by logging more rapidly than other species. Third may be its relationship to fire. Sweetgum is a prolific sprouter, and has considerable fire resistance when still as small as 6 inches dbh. In frequent-fire areas on moist mineral soils, sweetgum may form pure stands with a bilayered structure similar to many other fire-maintained communities. There may be a thin to nearly closed tree canopy, with woody understory lacking and a ground layer of wetland herbs. One variant is sweetgum/canebrake in which the two species can exist in a dynamic balance maintained by fire (see Table 3.2, Chapter 3).

Other common bottomland hardwood species, besides those mentioned as dominants above, are swamp chestnut oak, laurel oak, water oak, tulip poplar, and ironwood (*Carpinus caroliniana*). Most wet bottomland hardwoods are uninfluenced by fire, even though they may occur next to wetland fire communities.

6.8 Beaver-structured wetland mosaic.

Orontium aquaticum.

Mixed beaver pond submersed and emergent graminoids and forbs.

Exemplary sites: None seen. In the presettlement landscape, beaver ponds would have been numerous, like a string of pearls along each of the small stream swamps in the sandhills. At SRS, flood amplitude on the Savannah River floodplain would have been too great to permit construction of dams and lodges needed for beaver survival, limiting beaver ponds to the small tributaries draining the pinelands. There, the combined disturbances of beaver and fire would

have been comprehensive in structuring vegetation of all the interior streams, to an extent that is difficult to appreciate today. Whipple et al. (1981) acknowledged that some of the inexplicable compositional variation of bottomland stands they examined in the Upper Three Runs watershed was undoubtedly due to stages of recovery from beaver "damage".

Beaver activities likely amplified fire effects on wetland vegetation throughout the wetland pyromosaic. Canopy tree thinning admits more light for herbaceous aquatic vegetation and wetland shrubs, which make up the bulk of the beaver diet. Marsh and thicket succession that follows trapping and abandonment of beaver ponds is highly flammable and may have served to carry fire farther into wetlands than would otherwise be the case. This would be advantageous to fire-dependent species like pond pine and *Gordonia* and to fire-dependent community types like bay forest and pocosin.

Original beaver pond species composition at SRS is unknown but undoubtedly included all of the herbaceous species presently found in the streams, plus many more, including plants specific to that kind of habitat. Beaver ponds create a stable, shallow-water habitat not duplicated by any other hydrologic conditions in the sandhills landscape. These conditions provide habitat elsewhere for a number of rare aquatic plant species for which beaver ponds appear to have been the primary habitat. These include *Hottonia inflata, Glyceria pallida, Nymphoides cordata, Ranunculus flabellaris*, and *Ceratophyllum echinatum*. Because of subsurface marls in some of the more deeply incised stream valleys, there is probably some variation in water pH and chemistry. Consequently there was probably variation in floristic composition of beaver ponds in the original SRS landscape.

6.9 Sandhill small stream swamp.

Taxodium distichum\Nyssa biflora\Acer rubrum\Saururus cernuus.

Nyssa biflora\mixed wet-mesic bottomland and swamp graminoids and forbs.

Nyssa biflora\Acer rubrum.

Nyssa biflora\Persea palustris.

Taxodium distichum.

Taxodium distichum\Nyssa aquatica.

Nyssa aquatica.

Exemplary sites: along all of the small streams, where soils and hydrology range from permanently saturated to permanently inundated. This group comprises the wettest sites in the small stream wetland mosaic, including ponded sites with permanent standing water. This group is largely beyond the influence of fire, with exception of some wetland margin sites for cypress and swamp black gum. Both species, however, have considerable fire resistance, and are little affected by the light fires that can burn into peripheral stands during times when the surface litter is dry. Understory varies with water depth. On semipermanently flooded sites there may be little woody understory. On saturated soils, red maple and shrubs like Virginia willow (*Itea virginica*) may be common.

7. **Wetland Pyromosaic--Silty or Clayey Soils:** Patch mosaic of Bottomland Hardwoods, Hardwood/canebrake, Baldcypress, *Nyssa biflora.*

SOIL SERIES	MAP CODES
Rembert sandy loam	Rm

The extensive Rembert soils display the greatest vegetation diversity of any soil series mapped at SRS, and so are given a unique mapping category. The largest extent is on the Savannah River terraces, but there are small occurrences scattered throughout the linear pyromosaic wetlands of map type 6 above, and in a few depressions on upland flats in the sandhills. It is a fine-textured soil, with considerable admixture of black organic matter in its lower phase. The Rembert lies close to the water table. Radically different communities may obtain on sites that vary only centimeters in elevation because of the hydrologic differences created by slight variations in elevation above the water table. The Rembert is loamy or even clayey in places and the Williman is its sandy counterpart, also lying just above the water table. Water may be ponded in depressions in its lower phase, providing habitat for baldcypress, while oak flats dominated by mesophytic oaks like swamp chestnut oak and laurel oak may be found on the highest phase. The most characteristic vegetation is mesic and wet-mesic bottomland hardwood forest.

Presettlement extent: 5,719 acres.

Presettlement Community Types:

7.1 Bottomland hardwoods.

Mixed mesic bottomland trees/unknown understory type.

Nyssa sylvatica-Acer rubrum/Carpinus caroliniana/Acer rubrum/Itea virginica/mixed wet-mesic bottomland graminoids and forbs.

Taxodium distichum-Acer rubrum-mixed bottomland hardwoods (almost no understory)(plot 3.4).

Exemplary sites: compartment 3.

7.2 Bottomland hardwood/canebrake.

Mixed bottomland hardwoods/*Arundinaria gigantea*. (plot 3.2)

Exemplary sites: compartment 3. Chapter 6 for a pristine example of this rare community type with a fire frequency of 2 years at Fort Bragg, North Carolina.

7.3 River terrace swamp.

Nyssa biflora\Acer rubrum\sphagnum and mixed ferns (plot 3.1).

Taxodium distichum/Acer rubrum-mixed bottomland hardwoods (plot 3.4).

Taxodium distichum (understory vegetation extremely sparse).

Exemplary sites: compartment 3.

7.4 River terrace marsh and bog (small depression wetlands).

Panicum hemitomon-Leersia oryzoides (plot 3.3).

Exemplary sites: compartment 3, in small depressions on the Savannah River terrace, visible on aerial photos. These tend to have concentric bands of vegetation similar to Carolina bays but on a much smaller scale.

8. Bottomland Hardwoods, Levee Forests, Oak Flats.

SOIL SERIES	MAP CODES
Tawcaw silty clay	Ta

Toccoa loam	To
Shellbluff loam	Sh

Presettlement extent: 5,278 acres.

Presettlement Community types:

8.1 Levee forest.

Quercus laurifolia-mixed levee forest hardwoods/mixed levee forest subcanopy trees/*Arundinaria gigantea*/mixed ground cover vines and mixed riverbank grasses and forbs. Shellbluff soil series.

Taxodium distichum/Acer rubrum-mixed levee hardwoods/*Uniola latifolia*, on Tawcaw series (plot 6.1).

Exemplary sites: compartments 6 and 91 along Savannah River shoreline upriver from boat ramp near mouth of Upper Three Runs.

8.2 Oak flats on floodplain islands.

Celtis laevigata/Arundinaria gigantea-mixed vines and river bottom graminoids and forbs. On Shellbluff series (plot 91.2).

Quercus nigra-mixed bottomland hardwoods/*Sabal minor-Arundinaria gigantea*/patches of grassy *Carex* (almost no herbs at this site on Toccoa series).

Quercus michauxii/Sabal minor-Arundinaria gigantea-Carex. On Tawcaw series.

Exemplary sites: Compartment 91, along Savannah River shoreline upriver from boat ramp south of mouth of Upper Three Runs. More community types based upon species dominants could be defined.

8.3 Bottomland hardwoods.

Mixed bottomland hardwoods/*Carpinus caroliniana/Sabal minor* (in patches)/sparse bottomland graminoids and forbs. On Tawcaw soil.

Exemplary sites: Stave Island.

Original forests of the interior bottomland islands were probably dominated in places by swamp chestnut oak (*Quercus michauxii*). One problem with identifying original tree species

from old plats and timber cruises is that *Quercus michauxii*, being in the white oak group, was usually just called white oak, or in some cases, swamp white oak (Ashe 1894). The islands with finer-textured soils, particularly Toccoa and Tawcaw were likely habitats for swamp chestnut oak. Other bottomland hardwoods, especially the semi-evergreen oaks like water oak, willow oak and laurel oak (*Q. hemispherica*) occur in depressions on the islands and form a ring on the moist mineral soils around the wet margins.

Figure C4.24. Wet-mesic bottomland hardwood forest on Tawcaw soils on Stave Island. The clayey, wet-mesic Tawcaw is the lowest mineral soil on the floodplain islands. Soil is apparently too clayey for cane, whose rhizomes run freely in moist sandy or loamy soils such as the Toccoa and Shellbluff soils along the river. Dominant trees were bottomland hardwoods, including laurel oak, water oak, sweetgum, red maple and swamp chestnut oak, with a thin understory of ironwood over dense, but patchy palmetto. The occasional loblolly pine, along with some of the sweetgum and maple, probably represent remnant disturbance effects from past logging. Both the Tawcaw and Toccoa soils were likely major habitat for swamp chestnut oak in presettlement forests. Stave Island may have been named for use of the area for production of oak staves, a common export rafted downriver in Colonial times.

Figure C4.25. Baldcypress-dominant stand on Chastain, a firm, clayey swamp soil. The community consists only of cypress, tupelo (*Nyssa aquatica*) and submersed and emergent aquatic herbs. Flooding is too deep or prolonged for the shrubs and subcanopy trees common in small stream swamps. Note the high water mark at about 2 meters on the trunks. The species composition and community structure is essentially unchanged from presettlement forest, except that in virgin forest the cypress would have been much larger, towering above the tupelo. As the cypress mature, they will form an emergent canopy over the tupelo, which share the site. The location is between Stave Island and the lower river terrace.

On June 8, 1943, Edmund Ruffin accompanied Henry Hammond down river from Silver Bluff to some marl bluffs on the Savannah River which Hammond rented for digging calcareous material to apply to his fields upstream (Ruffin 1843a). On their return, they passed through Big Back Swamp, just north of SRS, where Ruffin mentioned oaks growing on soil too stiff and clayey for farming. This may have been along Crackerneck Road, which appears on Mills' map of 1825, and which led to Hammond's Cathwood Plantation (Bleser 1981, Faust 1982). A portion of the soils of Big Back Swamp, on the road to Hammond's Cowden Plantation, are clayey Typic Paleaquults, which have still not been cleared for farming. Big Back Swamp is on the river terrace and soils seem to be comparable to the wet, clayey Rembert and Smithboro soils at SRS. They are also similar to the Tawcaw and Toccoa soils on the floodplain islands.

The soils of Stave Island and the other interior islands at SRS are mapped Toccoa and Tawcaw, a clayey series intermediate in elevation between Toccoa and Chastain. The floodplain islands were probably worked for "white oak" timber products from very early times. Common exports listed in Colonial Era port records were white oak barrel and pipe staves. A common item of early plumbing was pipe made from white oak, one of the easiest woods to split. The center of the split stave was hollowed out using special tools, and two halves were bound together to make a hollow pipe. Stave Island probably owes its name to Colonial Era exploitation of swamp chestnut oak for production of oak staves. Hand-split oak stock for other purposes was still important in the late 19th century. Sargent (1884) commented that "The manufacture of rough red and white oak split staves and headings for the European and West Indian trade, already an important industry in this state, is capable of large development." Selective removal of swamp chestnut oak probably contributed to modern dominance of other bottomland hardwoods.

See Whipple et al. (1981) for a classification of 32 Savannah River floodplain hardwood and swamp forest stands.

9. Swamp Forests and Ponded Sites other than Carolina Bays.

SOIL SERIES	MAP CODES
Chastain clay	Ch
Dorovan muck	Da
Kinston loam	Kn
Ogeechee sandy loam	Og

Presettlement extent: 12,089 acres.

Presettlement Community Types:

9.1 Sandhill Small Stream Swamp.

Taxodium distichum\Nyssa biflora

Nyssa biflora\mixed wet-mesic bottomland and swamp graminoids and forbs.

Nyssa biflora\Acer rubrum.

Nyssa biflora\Persea palustris.

Taxodium distichum.

Taxodium distichum\Nyssa aquatica.

Nyssa aquatica.

Exemplary sites: This group of communities is discussed under wetland pyromosaic type 6.9 above.

9.2 Cypress-gum swamp, clay-based variant.

*Taxodium distichum/Nyssa aquatica/*sparse submersed and emergent wetland herbs (plot 92.7).

*Taxodium distichum-Fraxinus pennsyvanica/*mixed emergent swamp graminoids and forbs.

*Fraxinus pennsylvanica-Quercus lyrata-Nyssa spp./Acer rubrum-Ilex decidua/*mixed vines-*Leersia oryzoides-Ceratophyllum demersum.* (see Whipple et al. 1981, stand 52).

Exemplary sites: compartment 92, Chastain soils (Figure C4.25).

9.3 Cypress-gum swamp, muck-based variant.

*Taxodium distichum-Nyssa aquatica/*emergent swamp graminoids and forbs.

Taxodium distichum/Panicum gymnocarpon-emergent swamp graminoids and forbs (92.4).

Exemplary sites: compartment 42, compartment 92 on the linear body of substrate mapped Dorovan Typic Medisaprist, lying along the toe of the river terrace scarp (92.4). True muck-based cypress-tupelo swamp is more extensive downriver and is the major type on the lower Coastal Plain where there is permanent standing water. Small pockets of histosols mapped as Dorovan in the pyromosaic small stream wetlands may have very different vegetation. One site visited in compartment 18 along Upper Three Runs had young red maple swamp that appeared to represent succession from presettlement fire-maintained pocosin. This type comprises an element of wetland pyromosaic (Type 6 above)

10. Carolina Bays, Upland Depressions.

Presettlement extent: 1,938 acres in some 194 bays and depressions.

Presettlement Community Types:

The following is a small sample of the diversity of plant communities found in Carolina bays and small depression wetlands at SRS. More community types can be defined in different bays, mostly in the concentric bands of herbaceous vegetation that characterize the open bays that are largely free of woody vegetation.

10.1 Carolina Bay.

Mixed submersed aquatic and emergent palustrine graminoids and forbs.

Nymphaea odorata.

Nymphaea odorata-Brasenia schreiberi (Thunder Bay: Schalles 1979).

The community types below, defined by Hodge 1985, were reported in Schalles et al. 1989.

Craig's Pond:

Andropogon virginicus-Aristida affinis.

Rhynchospora tracyi-Lobelia boykinii.

Nymphaea odorata-Eleocharis robbinsii.

Eleocharis equisetoides-Nymphaea odorata.

Panicum hemitomon-Pontederia cordata.

Nymphaea odorata-Brasenia schreberi.

Ellenton Bay:

Panicum hemitomon-Polygonum hirsutum.
Nymphaea odorata-Panicum hemitomon.
Nymphaea odorata-Leersia hexandra.
Juncus canadensis-Nymphaea odorata
Decodon verticillatus-Panicum hemitomon

Exemplary sites: Craig's Pond, Ellenton Bay, Thunder Bay.

On June 5, 1843, Edmund Ruffin on his way from Barnwell crossed Tinker's Creek and spent the night at Jesse Cherry's house, before heading south to explore the Lower Three Runs for marl deposits. While on the road he passed by Craig's Pond, which was dry at the time, and grazed by cattle (Ruffin 1843a):

> "The route crossed the upper streams of the Big Salkehatchie, and the Lower Three Runs. The latter were two bold and rapid streams, which were as clear as to indicate that they must be of limestone water. The land generally of the wide ridges between different waters, and poorer land than usual elsewhere. The surface undulating. Craig's pond, by which the road passes, is a large savanna, said to be 3 miles in circumference, which always has more or less water, according to the season. There is but little water now and the surface is that of a beautiful green meadow, grazed closely by the numerous cattle on it."

Carolina bays are oval depressions in flat sections of the landscape, filled variously with water, mineral soil, or mineral soil overlain with organic accumulation. Under the original landscape-scale fire regime, organic accumulation may have been removed by dry season oxidation and fire more quickly than it could accumulate in most bays. Species diversity of Carolina bays is generally low, as few plant species can tolerate the irregular and severe drought/flood hydrologic regime, but Carolina Bays and small depression wetlands constitute the primary habitat for a number of rare species such as *Rhexia aristosa* and *Lobelia boykinii.*

Vegetation in Carolina bays is almost as complex as all the rest of the vegetation at SRS.

Vegetation varies over a complex multidimensional gradient that includes depth of the depression, hydroperiod, substrate and accessibility to fire (Kirkman 1995, Kirkman and Sharitz 1994, Schalles et al. 1989, Sharitz and Gibbons 1982). Fire relations of Carolina bays have been little studied. The shallowest depressions probably experienced fire at nearly the same rate as the surrounding landscape, while the deepest were semi-permanently flooded. Some, such as Craig's Pond may have only experienced fire in years in which drought was sufficiently prolonged to dry out the shallower regions. In most years, however, fires probably burned down into the bog vegetation that borders the pond, maintaining habitat for pitcher plants and other bog species.

Most Carolina bays at SRS have suffered from elimination of landscape scale fire. Their margins have been conspicuously invaded by young loblolly pine, sweetgum and other hardwoods. Fire suppression and shading of the wet margins where fire once maintained sunny bog conditions has probably led to loss of pitcher plants and rare bog species in many places.

Soil series mapped in depression wetlands. The SRS soil survey assigned soil series to the substrates of Carolina bays, distributing most to the Williman, Rembert and Ogeechee series. Distribution and abundance of vegetation in Carolina bays, however, is so determined by hydrology and stochastic factors such as circumannual variation in water depth, and the chance that the bay will be dry enough to burn when a fire happens to be moving through the landscape, that soil series are largely irrelevant as predictors of vegetation.

For mapping purposes, soil series were disregarded and a GIS overlay of the 194 Carolina bays or bay-like upland depressions identified at SRS by Schalles et al. (1989) was superimposed on Maps C4.1 and C4.2. There were 1,938 acres in bays and small depression wetlands, shaded dark blue on the maps. Six Carolina bays were examined for this study but, in view of their complexity, as well as other work done on site, no attempt was made to classify them according to kinds of vegetation. Fire exclusion or reduction in fire frequency appears to have affected mainly the sand rims and boggy marginal wetlands. The larger bays like Craig's Pond and Ellenton Bay are bordered by dense fire-suppressed thickets of young loblolly pine and shrubs, whereas in the original landscape frequent growing season fires would have maintained the margins in open longleaf savanna or bog. Original fire frequency on the Carolina bay

margins would have been the same as the local fire frequency, around 1-3 years on the upwind sides, with perhaps a slightly lower frequency on the partly fire-sheltered downwind sides. Fire frequency within the bays is harder to predict, as it would have varied with hydrologic conditions at time of burn. See Kirkman 1995, Kirkman and Sharitz 1994, Schalles et al. 1989, and Sharitz and Gibbons 1982, for further information on ecology of Carolina bays at SRS.

10.2 Small Depression Pond, Small Depression Wetland.

Panicum hemitomon-Leersia oryzoides.

*Liquidambar styraciflua/*Dulichium arundinaceum.

Nyssa biflora.

Vegetation in the numerous small pineland depressions most often mapped as Ogeechee series varies greatly from the more open bays like Craig's pond. Shading from trees around the margins may significantly reduce herbaceous diversity. In the absence of fire, some of the shallower depressions have succeeded to sweetgum and swamp black gum. Some of these are filled with dense tangles of vines, composed of *Ampelopsis arboreum, Berchemia scandens, Campsis radicans, Cynanchum palustre, Gelsemium sempervirens, Smilax bona-nox, Smilax rotundifolia* and *Toxicodendron toxicodendron*, to the complete exclusion of the herb layer. Such thickets are artifacts of fire exclusion.

True aquatic species, other than ephemerals, are absent from those sites which dry out. Concentric vegetation zones, like those in wet Carolina bays, may be dominated by only one or two species. Vegetation of one commonly-found type is maiden cane (*Panicum hemitomon*) and rice cutgrass *Leersia oryzoides*, with buttonbush (*Cephalanthus occidentalis*). Patches of *Scirpus cyparinus* are common, and *Dulichium arundinaceum* may form a narrow band at the boundary between open grass and the shaded pond margin. Trees like swamp black gum (*Nyssa biflora*), sweetgum, red maple, baldcypress, loblolly pine and pond pine occur on the immediate margins and individuals may be found in the open zones. Substantial cover by such woody species is usually an artifact of fire suppression. In the shallower sites, fire, along with wetness probably combined to prevent succession to sweet gum, red maple and swamp black gum. Other sites remained open because of deeper and longer ponding. Despite hydrologic inhibition of

succession, many of the shallower sites are experiencing encroachment of trees in the absence of occasional dry season fires.

11. Udorthents.

SOIL SERIES	MAP CODES
Udorthents	Ud, Uo, Ur, Uu

Current extent: 7,241 acres.

Presettlement Community Types: See types 2.1 to 2.3 above.

These are the intensively disturbed soils of SRS, mostly the leveled lands around reactors and other buildings, as well as soils rearranged for structures such as dams and railroads. Judging from the sites chosen for development, and from remnants of undisturbed soils around the periphery of disturbed areas, all but 2 or 3 % of such areas were carved from vegetation type 2, Dry-Mesic and Mesic Longleaf Pine Savanna. For mapping purposes most Udorthents will be considered to have belonged to this group.

12. Surface Water - aquatic communities.

SOIL SERIES	MAP CODE
None	W

12.1 The Savannah River.

12.2 Oxbow lakes.

12.3 Sandhills interior streams.

12.4 Lakes in Carolina bays.

12.5 Seasonally ponded areas.

Current extent: 3,407 acres.

Presettlement Community Types:

The natural aquatic habitats of SRS include the Savannah River itself, oxbow lakes and ponds of the Savannah River floodplain and small stream swamps, the small sandhills stream channels, permanently flooded portions of Carolina bays, and seasonally ponded areas. Some sites were examined for this study and species lists were compiled for a few sites, but the focus of this study was presettlement terrestrial and palustrine vegetation, so aquatic communities were

not surveyed in any detail. There were 3,407 acres of open water, much of it in the form of man-made lakes and ponds. Beaver ponds, not included here, were discussed under wetland pyromosaic, type 6 above.

HARDWOODS IN THE PRESETTLEMENT LANDSCAPE: TEXT TO ACCOMPANY MAP C4.2

The historic descriptions of vast unbroken longleaf pine forest from southeastern Virginia to east Texas are substantially accurate, at least for the uplands. There are hundreds of historical photographs and written descriptions to document the clear dominance of longleaf on uplands throughout its range. But the historical literature also presents numerous references to hardwoods. These are generally assignable to two categories: first are mentions of scattered single trees or patches of oaks and hickories on uplands, and second, there are descriptions of foresis of hardwoods in bottomlands and swamps. After approximating the extent of longleaf pine savanna on open uplands of SRS in Map 1, an integral question was "where were the hardwoods in the original landscape?" But for a few instances (Delcourt and Delcourt 1994, 1977, Harper 1911), this question has never been addressed in any detail for presettlement southern forests. Fire relations of southeastern hardwoods is, for all practical purposes, an untouched field. Map 2 was constructed in order best to visualize hardwoods in the original landscape of SRS. For this purpose soils were grouped somewhat differently. Whereas Map 1 categories portray dominant vegetation, Map 2 shows where the hardwoods were, whether or not they were the vegetation dominants. Mapping units 9 through 12 are the same for both maps, 1 through 8 are different.

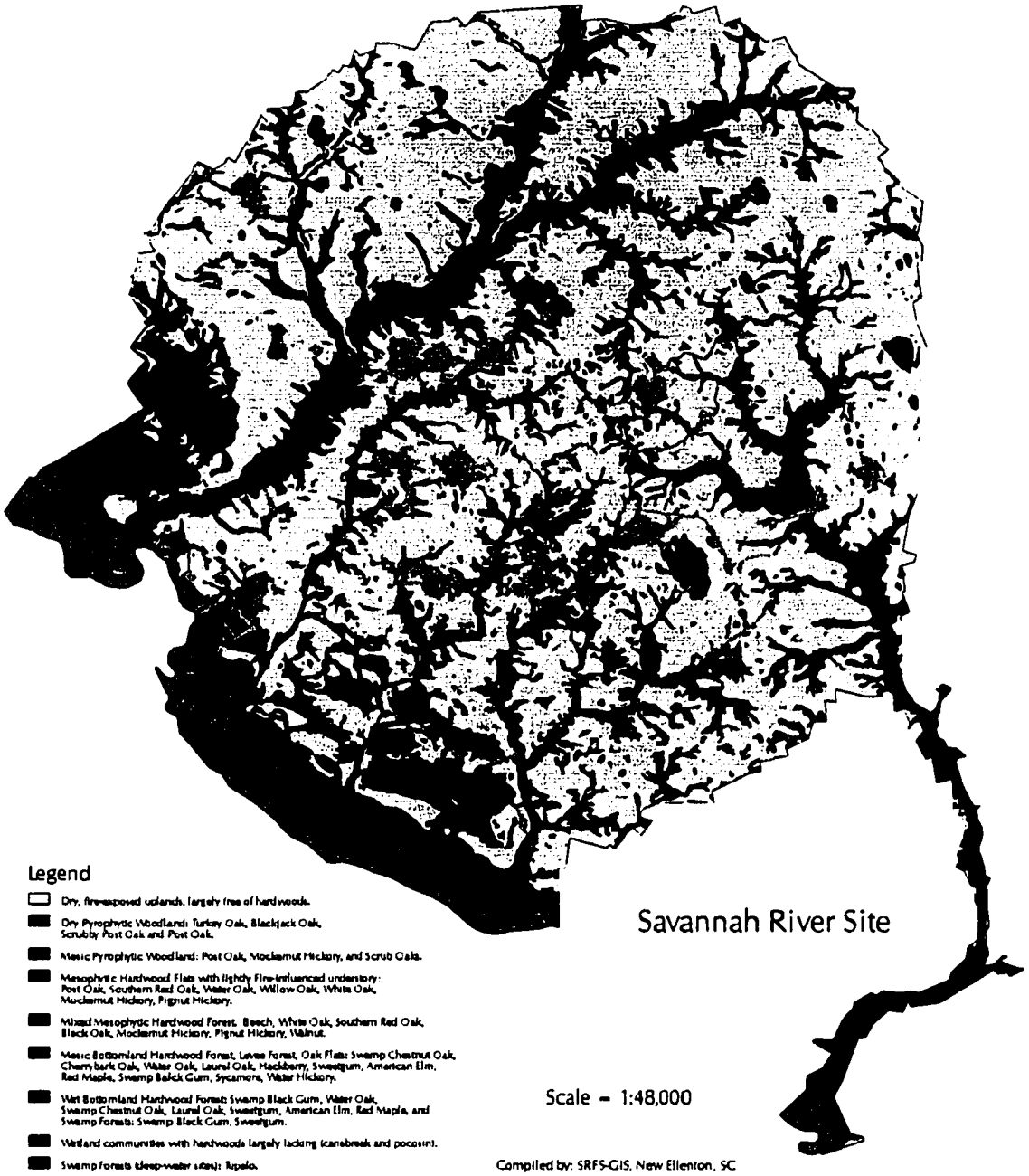
Table C4.10 shows the distribution of hardwoods depicted on Map 2, "Hardwoods in the Presettlement Landscape". Note that hardwoods are not clearly dominant except in types 4, 5, 6, 7 and 9. In Type 9, swamp forests, tupelo and swamp black gum were dominant in places, but in general were probably codominant with baldcypress, which would be expected to have been more important before logging of the virgin swamp forests. In most places, baldcypress is still recovering from early 20th century exploitation.

Table C4.10. Acreage and percentages of land with hardwood habitats in the presettlement landscape at the Savannah River Site (Map II.). * = hardwoods dominant.

	VEGETATION/COVER TYPE	ACRES	PER-CENT
1.	Dry, fire-exposed uplands, largely free of hardwoods	106,755	53.8
2.	Dry pyrophytic woodland: turkey oak, blackjack oak, scrubby post oak, post oak	7,814	3.9
3.	Mesic pyrophytic woodland: post oak, mockernut hickory and scrub oaks	20,612	10.4
*4.	Mesophytic hardwood flats with only lightly fire-influenced understory:	4,755	2.4
*5.	Mixed Mesic Hardwood Forest	4,357	2.2
*6.	Mesic bottomland hardwood forest, levee forest and oak flats:	5,278	2.7
*7.	Wet bottomland hardwood forest.	21,974	11.1
8.	Wetlands with patches of hardwoods and communities with hardwoods largely lacking (canebrake and pocosin)	2,230	1.1
*9.	Swamp Forests: tupelo (deep water sites), swamp black gum (shallow sites)	12,089	6.1
10.	Carolina Bays, Upland Depressions	1,938	1.0
11.	Udorthents	7,241	3.6
12.	Surface Water	3,407	1.7
	TOTAL	198,450	100%
	TOTAL TERRESTRIAL (including Udorthents and bottomland hardwoods)	156,812	79%
	TOTAL WETLAND AND WATER (from Table 4.1)	41,638	21%

Figure C4.26. Map of hardwoods in the presettlement landscape.

Hardwoods in the Presettlement Landscape



Legend

- Dry, fire-exposed uplands, largely free of hardwoods.
- Dry Pyrophytic Woodlands: Turkey Oak, Blackjack Oak, Scrubby Post Oak and Post Oak.
- Mesic Pyrophytic Woodland: Post Oak, Mockernut Hickory, and Scrub Oaks.
- Mesophytic Hardwood Flats with lightly Fire-influenced understory: Post Oak, Southern Red Oak, Water Oak, Willow Oak, White Oak, Mockernut Hickory, Pignut Hickory.
- Mixed Mesophytic Hardwood Forest: Beech, White Oak, Southern Red Oak, Black Oak, Mockernut Hickory, Pignut Hickory, Walnut.
- Mesic Bottomland Hardwood Forest, Levee Forest, Oak Flats: Swamp Chestnut Oak, Cherrybark Oak, Water Oak, Laurel Oak, Hackberry, Sweetgum, American Elm, Red Maple, Swamp Black Gum, Sycamore, Water Hickory.
- Wet Bottomland Hardwood Forest: Swamp Black Gum, Water Oak, Swamp Chestnut Oak, Laurel Oak, Sweetgum, American Elm, Red Maple, and Swamp Forests: Swamp Black Gum, Sweetgum.
- Wetland communities with hardwoods largely lacking (canebreak and pocosin).
- Swamp Forests (deep-water sites): Tupelo.
- Carolina Bays, Upland Depressions
- Lakes/Ponds
- Surface Water - No type identified

Compiled by: SRFS-GIS, New Ellenton, SC
Using current GIS Data as of 05/21/97
Vegetation Types Defined by Cecil Frost from Soils, Historical Data, and Remnant Vegetation.

There were 9,112 acres in upland hardwood types 4 and 5, plus perhaps 20% of the lands in longleaf pine types 2 and 3, giving a total of 14,797 acres, or 9.4% of all terrestrial lands at SRS, that can be categorized as hardwood dominant stands on dry uplands. In the Savannah River floodplain, there were 5,278 acres of mesic and wet-mesic habitats with bottomland hardwoods, levee forests and oak flats (type 6). In type 7, there were bottomland hardwoods on the wetter portions of the river terraces and the drier portions of the interior small stream bottomlands. Hardwoods of type 7 were dominant on the terraces, but scattered as marginal zones and small interior patches in the small stream wetlands, interspersed with swamp forest, pyrophytic communities and beaver ecosystems. Estimating about 50% of this type to be hardwoods, or 10,987 acres, and adding it to Type 6 would give a total of 16,265 acres of terrestrial wetland hardwoods, or 10.4% of all terrestrial lands at SRS.

Historical evidence, and field exploration of SRS sites, as well as examination of 1 to 3 year-burned hardwood sites in longleaf pine landscapes on military bases, suggested the following habitat categories (see Map II, Hardwoods in the Presettlement Landscape, to accompany the discussion below).

1. **Dry, fire-exposed uplands, largely free of hardwoods:**

SOIL SERIES	MAP CODES
Blanton sand	BaB
Dothan sand	DoA, DoB
Fuquay sand	FuA, FuB
Lakeland sand	LaB
Lucy sand	LuA, LuB
Neeses loamy sand	NeB
Norfolk loamy sand	NoA, NoB
Orangeburg loamy sand	OrA, OrB
Troup sand	TrB
Vaucluse sandy loam	VaB
Wagram sand	WaA

Mesic, dry-mesic and subxeric sands occupy the largest percentage of the SRS upland landscape. Such soils, under the presettlement fire regime were virtually free of hardwoods. On the driest sites, however, could be found longleaf/turkey oak scrub. Turkey oak exhibits a bimodal distribution in the landscape. When frequently burned, it occupies two specialized habitats, in high and low topographic settings. The lower setting is discussed under Dry Pyrophytic Woodland below. On the highest, driest sites, mostly on the elevated peaks and ridges within areas mapped Lakeland sand, turkey oak finds refugia from lethal fire in places where sand is so dry and sterile that the herb layer is too sparse to generate hot fire. Frequent fires reduce any fuel that does accumulate. Turkey oak may also find fire-safe microsites on bare patches of white sand, and, on the ridges, wind seems to sweep away flammable litter. The way that turkey oak leaves curl when on the ground may facilitate this wind effect. Mills (1825) described the high white sand habitat for turkey oak:

> "The sand hill region is about thirty miles wide, and includes the extremes of sterility and fertility. The high lands are composed of extensive ridges of barren sand, covered with small pitch pine [longleaf], and blackjacks [turkey oak]...."

As mentioned above, both turkey oak (*Quercus laevis*) and blackjack oak (*Quercus marylandica*) were called "blackjacks" until the 20th century.

The natural type on such sites was longleaf pine/turkey oak with a sparse layer of wiregrass. Most sites on Lakeland soils at SRS have succeeded to an unnatural density of scrub oaks, and wiregrass has been extirpated by a compact litter/duff layer composed of oak leaves and pine needles. While only a few inches thick, this layer can produce extreme fire behavior when very dry and generate heat intense enough to kill longleaf pine when fire finally does occur. This is one mechanism by which fire suppression can lead to an unnatural dominance of turkey oak. Paradoxically, frequent fire is cool fire, having only the herb layer and recent litter as fuel. In reintroducing fire to dry sites, it may be best first to conduct one or more cool-season burns for litter/duff reduction. Once this layer is gone growing season fire should be no threat to

trees.

2. Dry Pyrophytic Woodland. Turkey Oak (*Quercus laevis*), Blackjack Oak (*Q. marylandica*), Scrubby Post Oak (*Q. margarettiae*[4]), Post Oak (*Q. stellata*, often stunted), with scattered longleaf pine.

SOIL SERIES	MAP CODES
Ailey sand	AeB
Blanton sand	BaC
Lakeland sand	LaC
Lucy sand	LuC
Troup sand	TrC

While Mapping types 2 and 3 were heavily dominated by longleaf pine in the presettlement landscape, the species listed here for these two types include only the hardwoods. The purpose of Map 2 is to show where the different hardwood communities were to be found in the strongly fire-influenced original landscape. See Map 1 for dominant vegetation.

On presettlement uplands of SRS, there were at least three levels of fire influence in hardwoods. These varied along a gradient of fire intensity and fire effects ranging from those on dry, open, fire-exposed longleaf pine uplands, to cool, moist, fire-sheltered lower slopes adjacent to wetlands. Fire frequency and intensity were largely controlled by the position of the hardwood stand in the fire landscape.

Dry Pyrophytic Woodland is the driest and most fire-exposed of these three types, and it constitutes the lower landscape position of the bimodal habitat for turkey oak mentioned above. While the scrub oaks were excluded from the vast majority of longleaf pine lands by frequent fire, they found a niche in slightly fire-sheltered habitats within and around the margins of the pure longleaf savannas. Lightly fire-sheltered sites included gentle depressions and swales in

[4]The new spelling for the scientific name of scrubby Post Oak (*Q. margarettiae*) has been proposed by Weakley (1996) as a correction, to follow standard rules of botanical nomenclature.

upland flats, concave topographic areas where longleaf pine upland flats began to slope into the headwaters of a pineland drain, and sites on slopes adjacent to longleaf uplands. Longleaf pine is an integral member of this community, occurring as scattered individuals standing above the scrub oaks, in varying densities.

Scrub oak woodlands on slopes were transitional communities between longleaf pine above and other vegetation below. Aspect and the degree of slope determined where the transition from longleaf to scrub oak took place. On slopes too gentle to have much effect on fire movement, scrub oak could sometimes be found on lower slopes. On steep slopes (>20%) Dry Pyrophytic Woodland might be confined to the upper slope shoulder. On slopes between 10 and 20% the transition might be midslope. On north aspects the whole vegetation sequence was shifted upslope. Where topographic breaks are abrupt, turkey oak may have been found only as single trees along the margin of longleaf pine savanna. Patches of Dry Pyrophytic Woodland make up one patch element of the Longleaf Pine-Pyrophytic Woodland Complex of Map 1.

3. Mesic Pyrophytic Woodland. Post Oak (*Quercus stellata*), Mockernut Hickory (*Carya tomentosa*) and any of the scrub oaks.

SOIL SERIES	MAP CODES
Fuquay sand	FuC
Ocilla loamy sand	OcA
Orangeburg loamy sand	OrC
Vaucluse sandy loam and	
Ailey sand complex	VeC, VeD
Wagram sand	WaB

Mesic Pyrophytic Woodlands experienced fire on almost the same frequency as on nearby longleaf pine uplands, but landscape factors moderated fire intensity and effect. These woodlands occur on sites that are cooler, moister or further downslope than Dry Pyrophytic Woodland. Stand structure differs from Dry Pyrophytic Woodland in that the canopy is most

often dominated by post oak or mockernut hickory, and these species may reach full canopy tree stature even with frequent understory fires (Figure C4.22). Scrub oaks range in importance from a major component to nearly absent.

Longleaf pine was a minor element in these stands, appearing only as a tree here and there in gaps, or on the upslope or marginal portions where the type intergraded with Dry Pyrophytic Woodland. Patches of Mesic Pyrophytic Woodland also make up a minor component of the Longleaf Pine-Pyrophytic Woodland Complex of Map 1.

Dynamics of regeneration in frequent-fire hardwood stands. The distribution of stems in diameter size classes in pyrophytic woodland is naturally top-heavy, with the great majority of woody stems being fire-resistant canopy trees. Vulnerable saplings and small stems on their way up to the canopy are rare, the vast majority being killed by fire before they develop enough bark to resist fire. This is the reverse of the stem size distribution in typical fire-suppressed woods, where the vast majority of stems may be in the smaller size classes. Fire-suppressed stands develop multistoried woody vegetation at the expense of the herb layer, longleaf pine, and certain species of hardwoods. Post oak, in particular, may not reproduce well without fire. As suggested above, the autecology of some oaks and hickories in relation to fire is largely unstudied.

It seems clearly a mistake to keep fire out of upland hardwoods. It doesn't matter if 99% of seedlings or shoots are killed by fire. Successful escape of a sapling into the canopy is a rare event, but once large enough to reach the canopy, a stem has enough bark to be reasonably safe from fire. Also, the canopy shade may naturally moderate fire intensity, permitting survival of the hardwoods. Except for the rare stem on its way to the canopy, such stands are bilayered, with only canopy and herb layer. Most plant species diversity, including certain rare species restricted to pyrophytic hardwood stands, such as *Astragalus michauxii* and *Echinacea laevigata*, are found in the herb layer. When fire is removed, such sites, being in more mesic parts of the landscape, succeed rapidly to thickets of multistoried shrubs and hardwoods. The grasses and forbs vanish within a few years (Figure C4.21).

See discussion of Map 1 for other varieties of pyrophytic woodland, such as the live oak-longleaf type on the Savannah River floodplain river scarp.

4*. Mesophytic Hardwood Flats with lightly Fire-Influenced understory. Post Oak (*Q. stellata*), Southern Red Oak (*Q. falcata*), Water Oak (*Q. nigra*), Willow Oak (*Q. phellos*), White Oak (*Q. alba*), Mockernut Hickory (*Carya tomentosa*), Pignut Hickory (*C. glabra*).

SOIL SERIES	MAP CODES
Albany loamy sand	AnB
Eunola fine sandy loam	EnA
Hornsville fine sandy loam	HoA
Smithboro loam	Sm

This river terrace flatwoods type corresponds to mapping unit 4 in Map I. They are dominated by oaks. Fire influence is light but sufficient to prevent establishment of beech. See vegetation type 4.4 in the preceding section for discussion.

5*. Mixed Mesophytic Hardwood Forest. Beech (in the most fire-sheltered sites), White Oak, Southern Red Oak, Black Oak (*Quercus velutina*), Mockernut Hickory, Pignut Hickory, Walnut (*Juglans nigra*).

SOIL SERIES	MAP CODES
Troup sand.	TrD
Troup and Lucy Sands	TuE, TuF

As mentioned in the discussion for Map 1, this type is found only on sites where slopes exceed 20% (slope classes E and F).

TABLE C4.11. SLOPE EFFECTS ON UPLAND HARDWOOD HABITATS ON SAVANNAH RIVER SOILS

Of the 29 soil series of the Savannah River Site, only 7 have slope class modifiers indicating slopes greater than 6% (slope classes C,D,E,F). The other 22 are relatively flat or gently rolling. Of these 7 series, the most steeply sloping sites are confined to only 3 series or combinations of series: the Troup (TrD), Troup and Lucy complex (TuE, TuF), and Vaucluse-Ailey complex (VeD). Of these, the TuE and TuF were steep enough to comprise fire-refugial habitat for mesophytic hardwoods, in all but a few instances. The soils in C and D slope classes were more likely to support fire-influenced pyrophytic hardwoods, in a sandy upland landscape otherwise dominated by longleaf pine.

SOIL SERIES		SLOPE CLASS
BaC	Blanton sand	6 to 10%
FuC	Fuquay sand	6 to 10%
LaC	Lakeland sand	6 to 10%
LuC	Lucy sand	6 to 10%
TrC	Troup sand	6 to 10%
TrD	Troup sand	10 to 15%
TuE	Troup and Lucy	15 to 25%
TuF	Troup and Lucy	25 to 40%
VeC	Vaucluse-Ailey	6 to 10%
VeD	Vaucluse-Ailey	10 to 15%

Vegetation on sloping soils is further complicated by aspect and degree of natural protection from fire. Not all steeply sloping soils constitute hardwood habitat. Frequent examples of longleaf pine can be found on steep soils in the C and D slope classes, where they occur in situations where fire can approach from below (Figure C4.23). Longleaf does not occur, however, where the slope toe is protected from fire by water or by non-pyrophytic wetland vegetation such as cypress-gum swamp. Aspect plays a part in that pyrophytic hardwoods may be found at higher elevations on north slopes in pinelands, and certain communities, such as mockernut hickory pyrophytic woodland seem to prefer such sites (Figure C4.22).

6*. Mesic Bottomland Hardwood Forest, Levee Forest, Oak Flats. Swamp Chestnut Oak (*Quercus michauxii*), Water Oak, Laurel Oak, Hackberry (*Celtis laevigata*), Sweetgum, American Elm (*Ulmus americana*), Red Maple, Swamp Black Gum (*Nyssa biflora*), Sycamore (*Platanus occidentalis*), Water Hickory (*Carya aquatica*).

SOIL SERIES	MAP CODES
Tawcaw silty clay	Ta
Toccoa loam	To
Shellbluff loam	Sh

These communities are covered in discussion of Map I, type 8.

7*. Wet Bottomland Hardwood Forest. Swamp Black Gum (Nyssa biflora), Water Oak (Quercus nigra), Swamp Chestnut Oak (Quercus michauxii), Laurel Oak (Q. laurifolia), willow oak (Quercus phellos), Sweetgum (Liquidambar styraciflua), American Elm (Ulmus americana), Red Maple (Acer rubrum). Swamp Forests (saturated sites): Swamp Black Gum, Sweetgum.

SOIL SERIES	MAP CODES
Fluvaquents, loamy sand	Fa
Pickney sand	Pk
Rembert sandy loam	Rm

In addition to the species mentioned, there are a few moist, fire-protected flats in the Upper Three Runs bottomland that serve as refugia for beech (Whipple et al. 1981). Bottomland hardwoods, as defined here, included the species above, on wet-mesic soils on low flats and

margins transitional to more mesic soils like levee forests, oak flats, pyrophytic woodlands, or mesophytic hardwood forests. On the Savannah River terraces, this community was found primarily on the wetter mineral soils like Rembert. In the interior small stream bottomlands, hardwoods of type 7 were found along the margins in fire-protected sites and in small interior patches in the small stream wetlands. See Map 1 discussion for further consideration of bottomland hardwoods.

8. Wetland communities with hardwoods largely lacking (canebrake and pocosin).

SOIL SERIES	MAP CODES
Ochlockonee loamy sand	Oa
Williman sand	Wm

Because of complex topography, patches of bottomland hardwoods and pyrophytic woodland are interspersed within these areas, but the Williman and Ochlockonee soils comprise some of the major presettlement habitat for canebrake and pocosin, types that are treeless or support only pond pine. Intense fire associated with cane and shrubs kept hardwoods out of these types (for an exception see the hardwood/canebrake community on Rembert soils, type 7.2 in the discussion of Map 1 and illustrated in Chapter 6, Figure 6.13). With fire exclusion, sandhills canebrake is ultimately replaced by red maple, loblolly pine, sweet gum and tulip poplar. Sandhills pocosin, under similar conditions of fire exclusion, succeeds to *Gordonia*, red maple, and swamp black gum.

9. Swamp forests (deep-water sites).

SOIL SERIES	MAP CODES
Chastain clay	Ch
Dorovan muck	Da
Kinston loam	Kn
Ogeechee sandy loam	Og

The hardwoods of these soils were tupelo in deepwater sites and swamp black gum in shallow-water localities. The swamp hardwoods were dominant in patches, but more typically

codominant with baldcypress. Taxodium was almost certainly more prominent in the presettlement wetland landscape. Neither tupelo (*Nyssa aquatica*) nor swamp black gum (*Nyssa biflora*) form a particularly dense canopy--almost never sufficiently dense to prevent cypress regeneration. I have seen sites where baldcypress was successfully reproducing beneath a *Nyssa* canopy and penetrating it to eventually overtop the *Nyssa*. This would have been the most common situation before commercial logging reached all the remaining virgin cypress in the early 20th century. In the absence of disturbance, emergent baldcypress in virgin stands rise up to 40 feet above the *Nyssa* canopy. Once in place, baldcypress can live to over 1,000 years, while the short-lived *Nyssa* cycles through several generations beneath it.

10. Carolina Bays

Hardwoods are generally absent from true Carolina bays, other than an occasional *Nyssa*. The majority of cypress, Nyssa, sweetgum and loblolly pine stems commonly seen in Carolina bays appear to be the result of elimination of fire. See discussion for Map I.

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regime in the Savannah River landscape. Acknowledgement is also due to Steve Simon of the U.S. Forest Service, Asheville, North Carolina, and Lauren Hillman and staff of the Croatan National Forest, where background was provided by work in valuable examples of fire-maintained vegetation in various stages of succession not available at Savannah River.

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APPENDIX 1: GLOSSARY OF TERMS AND CONCEPTS OF LANDSCAPE FIRE ECOLOGY[5]

Landscape fire ecology – the study of the interactions between fire, landscape factors and organisms.

Adversity habitat – marginal habitat in which a fire-dependent species may survive a period of fire exclusion: the last habitat in which a species is found before it dies out. With Venus flytrap this is the dry margin of its preferred wet habitat. With *Hudsonia montana* it is the thinnest soils on rock ledges where a few plants may eke out an existence while 99% of the population is overgrown and eliminated by shrubs.

Area fire frequency – the fire-return interval for a large area such as a natural forest. This is the incidence of fire within the area, even though only parts of the area may burn, so fire frequency may be reported as multiple fires per year (compare site fire frequency).

Backing fire - fire moving slowly, against the wind (assumed rate of spread of backing fires is relatively constant regardless of wind velocity.

Bay forest - fire-infrequent forest type dominated by evergreen trees like red bay, sweet bay and Gordonia, found in fire tension zones between pocosin, or other frequent-fire type, and more fire-protected vegetation.

Canebrake - wetland plant community with 50% or more cover of Arundinaria spp. (canebrake was called reeds, cane, marsh or even pocosin in Colonial Era literature). Canebrake reaches its best development on shallow to medium deep peat soils and wet mineral soils of fluvial bottomlands.

Canopy thinning fires – fires which kill some canopy trees but fail to initiate crown fire or to kill all trees from below.

Charcoalization – preservation of flowers, seeds and other fossils by being charred by wildfires

[5] Prairie, savanna and woodland definitions from Frost, Walker and Peet (1987).

shortly before being covered by water and sediment.

Ecological fire effects – effects of fire on vegetation structure, species composition, and physical characteristics of habitat.

Effective windspeed – A way to account for slope effects in determining rate of fire spread. For example, midflame windspeed is adjusted upward in relation to the degree of slope for a fire moving uphill with the wind.

Facultative pyrophyte - a plant species not dependent upon fire but which reaches its best development in fire communities or exhibits adaptations that permit it to survive under a natural fire regime.

Fire adaptations - characteristics like thickened bark, rapid resprouting, specialized responses to increased light after a burn, production of litter which decomposes rapidly and decreases flammability, production of litter which decomposes slowly and promotes flammability. There are two suites of fire adaptations, those with characteristics that decrease frequency and intensity of fire, and those that increase frequency and intensity.

Fire barriers or firebreaks – natural landscape features which prevent or resist the spread of fire, such as rivers, other bodies of water, steep slopes and non-pyrophytic vegetation. Boundaries between fire compartments, such as rivers or streams, that stop the flow of fire under average burning conditions. Other barriers are steep-sided, wet ravines and unvegetated sand and rock. Fire barriers are rarely absolute, under severe burning conditions fires have been known to spot across bodies of water over a mile wide. By definition, a fire barrier stops most fires that occur under average wildfire conditions. (Any fire barrier that stops even a few fires automatically reduces the local fire frequency; the more fire barriers and fire filters in the landscape, the lower the fire frequency).

Fire behavior - variation in rate of spread and intensity of fire moving through the landscape. Rate of spread and intensity respond to changes in fuel, vegetation structure, topography, wind, and diurnal changes in temperature and humidity.

Firebreak – synonym for fire barrier (as opposed to fire filter).

Fire compartment - a unit of the landscape with continuous fuel and no natural firebreaks, such that a lightning ignition in one part would be likely to burn the whole unless there were a change in weather or fuel moisture.

Fire corridor - pathway for fire flow between fire compartments.

Fire-dependent species – a species that depends upon fire to maintain or prepare its habitat, or to

facilitate completion of some phase of its life cycle, such as scarification of seeds or opening of cones.

Fire effects - changes in fuel load and vegetation structure (what about effects oon fauna, mineral nutrients, soil composition and structure). See ecological fire effects Effects range from simple litter removal and herb layer reduction to shrub reduction, understory thinning, understory reduction, stand thinning or canopy destruction.

Fire effects gradient - distribution of plant communities based on differential effects of fire on different community types.

Fire ephemeral species – plants that persist as seeds or spores, in the seed bank, appearing in large numbers after a fire. Most are annuals, plants with seeds or spores widely dispersed by wind, that may persist for decades before fire prepares a site for germination. Examples: Erectites hieracifolia and Funaria hygrometrica, a moss.

Fire-exposed - referring to portions of the landscape lacking natural firebreaks or environmental factors to slow the spread of fire, especially broad flats, south slopes and ridges. Site exposure grades from fire-exposed to fire-sheltered to fire-protected.

Fire facilitator species - species with adaptations in litter, plant growth form, or plant part structure or chemistry which facilitate spread of fire or enhancement of fire intensity.

Fire filter - topographic or vegetation features that temporarily reduce fire intensity or rate of spread (examples: steep north slopes, areas with complex or rugged topography where all the land is in slope, moist ravines, bottomlands with oligopyrophytic vegetation or having vegetation with poor fuel connectivity). Fire filters reduce fire frequency in two ways. First, a certain percentage of fires will be detained long enough for rainfall or cool, moist nocturnal conditions to extinguish the fire. Second, even fires that pass through the filter will have been delayed. A certain number will not spread as far as they would have before being extinguished by rain or other events. The density of fire filters and fire barriers, along with fuel type and fire compartment size determine the fire frequency in a region.

Fire flow - the movement of fire over the landscape. Characterized by rate of spread and relation to wind direction (backing fire, flanking fire and heardfire).

Fire frequency – see fire return interval, area frequency, point frequency, site frequency.

Fire frequency classes – partitioning the fire frequency gradient into classes. Those I have found useful approximate a 2x geometric progression: 1-3 year fire-return interval, 4-6 years, 7-12 years, 13-25, 26-50, 51-100, 101 to >300 and nonpyrophytic.

Fire frequency indicator community - plant community limited to a specific fire frequency regime (such as canebrake, which reached its best development with fire-return intervals of 2-5 years). Can be used to map original landscape fire regime where remnants or historic records exist.

Fire frequency indicator species - plant species limited to a specific fire regime (as 1-3 years, 4-6 years, etc.). Can be used to map original landscape fire regime where the indicator species remain, or where herbarium or other historic records exist.

Fire frequency gradient - change in fire frequency across a fire-tension zone, where a gradient of topography, soil texture, or soil moisture, reduces intensity of fire as the fire moves along the gradient. Fires originating from the frequent-fire end of the gradient will penetrate different distances into the gradient toward its fire-sheltered end before going out (see fire effects gradient, which subsumes effects of both frequency and intensity).

Fire inhibitor species - species with adaptations in litter, plant growth form, or plant part structure or chemistry which inhibit spread of fire or enhancement of fire intensity.

Fire-refugial species - species like beech, which, in a frequent-fire landscape, are confined to naturally fire-infrequent or fire-free sites.

Fire regime types – classification of fire regimes using parameters of fire behavior such as periodicity (nonrandom or predictable, irregular, polycyclic), fire-return interval, season of burn, ecological fire effects, and typical rate of spread.

Fire resistant community - community with collective characteristics which offer little fuel for spread or intensity of fire (high canopy, lack of shrub and herb layers, rapidly flattening and decomposing litter.

Fire resistant species - species like most pines and oaks with adaptations like thick bark and rapid self-pruning that resist damage from understory fires.

Fire-return interval – time between fires on a specific site or in a specific community type. Usually expressed as the mean fire-return interval (MFRI).

Fire severity – fire behavior characterized by probability of ignition, rate of fire spread, and potential for fire to spread up bark of trees, spot ahead and crown.

Fire shadow - area on the downwind side of a body of water or other natural firebreak, with fire-infrequent vegetation in an otherwise frequent-fire landscape.

Fire sheltered - a site in a pyrophytic landscape where topographic or other factors do not eliminate fire but reduce fire frequency or fire intensity below that of the surrounding landscape. An

example would be an upland on the downwind side of a ravine containing wetland vegetation that slowed or sometimes topped the passage of fire.

Fire spread - the rate of fire flow.

Fire tension zone - the regions between fire-exposed and naturally fire-protected parts of the landscape. Local fire-tension zones may separate disparate vegetation types only a few meters apart. In regional fire tension zones, fire frequency may decline gradually over several kilometers in a flat landscape where fire can only approach from one direction.

Fireline intensity – amount of heat released at head of fire, expressed in BTUs/ft/sec.

Fireshed – region around a natural area having vegetation that may lead fires into the natural area. (Proposed by Andrew G. Windisch at Tall Timbers Fire Ecology Conference No. 17, 1989. He proposed protecting the contiguous vegetation for its ability to promote burning.)

Forest - community with a closed or nearly closed tree canopy. Usually applies to naturally fire-protected communities, or communities that experience only light surface fires, or vegetation like jack pine, sand pine and white cedar, that experience catastrophic fires, but with a fire-return interval of 25-300 years.

Flame length – length of flames at head of fire. Can vary from a few inches in a grass fire to 40 feet in canbrake, to 1,000 feet in an upslope crown fire.

Frequency-dependent species or communities – plants that require fire at a particular frequency for survival or full expression. Examples are Venus flytrap, which requires fire at 1-3 year interval for survival, and canebrake which requires fire at 2-5 years intervals for maximum stem density.

Fuel models – Fuels characterized by the fire carrier type, such as short grass, tall grass, forest litter, or chaparral, and the expected fire behavior in each. The National Wildfire Coordinating Group currently recognizes 12 fuel models.

Fuel species - principal species in a community which contribute to fire spread.

Fuel structure – arrangement of fuels in relation to flammability. The spatial arrangement affects fire intensity: fuels that lie compactly will be less flammable than cross-stacked limbs and twigs and light airy fuels such as pine needles draped over vegetation or dead limbs.

Fusain - fossil plant fragments charcoalized by fire at time of preservation. A component of coal and sedimentary rocks characterized by black color, silky luster and fibrous texture. Fusain is considered evidence of natural wildfires in the primeval forest (Calder et al. 1993, Jones and Rowe 1999).

Grass reduction fires – surface fires in light, airy fuel, predominantly grasses. Intensity varies with density and length of grass.

Ground fire – fires in organic substrates such as peat (as opposed to surface fire in litter and other fine fuel). Fire may burn down to expose mineral soil or may burn deeper than the seasonal high water table during dry spells, initiating ponding later.

Ignition source – most fires in the presettlement landscape were intitiated by lightning or Native Americans. Rare instances of spontaneous ignition (in dead marsh grasses) have been reported, as well as fires ignited by volcanoes and sparks from fallling rocks.

Ladder fuels – fuels such as vines, dead twigs and dead pine needles draped on understory hardwood limbs that may carry surface fire upward into the canopy.

Landscape fire ecology - is the study of physical and biological factors that control the frequency of fire, the movement of fire in a landscape, and the effects of fire on vegetation and other organisms.

Land surface form – a classification of topographic features according to 1) the percent of the landscape that is flat or only gently sloping, 2) amount of local relief from the stream bottoms to the ridge tops, and 3) whether the flat or only gently sloping parts are located on uplands or in bottoms (Hammond (1964). This gives a way to draw boundaries between parts of the landscape that have similarities in fire compartment size, density of fire filters, and density of firebreaks. This permits mapping fire regimes of major geographic regions.

Marsh - wetlands dominated by emergent herbaceous vegetation, either grasses or broad-leaved herbs. Only a few types will not burn.

Mean Fire-Return Interval (MFRI) – the mean of the time between fires on a specific site or in a specific community type, averaged over a long enough time to give the typical fire frequency regime.

Mesophytic succession - the change, after removal of fire, from communities with only one or two vegetation layers to multistoried woody vegetation with few herbs.

Mixed pine savanna - bilayered community with 2 or more pine species over a savanna herb layer maintained by frequent fire. (Tree mixtures include any combination of Pinus palustris, P. echinata, P. serotina and P. taeda, often with a minor component of oaks and hickories).

Nonpyrophytic communities – relatively fireproof vegetation such as tupelo swamps (*Nyssa aquatica*), with standing water, isolated vegetation clumps above treeline, talus slopes, rock outcrops, lava flows in the pioneer stages of succession, and barren deserts, playas and salt

flats. This category also includes some arid land vegetation lacking sufficient fuel to carry fire.

Obligate fire frequency – the fire frequency range upon which a plant species is dependent for its survival.

Obligate pyrophyte - Plant species dependent upon fire for completion of its life cycle.

Oligopyric communities – Sites that ordinarily do not burn because of wetness or lack of fuel continuity, but which may carry a fire under extraordinary conditions of wind or drought.

Pine marsh - bilayered fire community type of estuarine regions, usually dominated by loblolly pine over a graminoid layer, commonly Carex hyalinolepis or Chasmanthium laxum, or pond pine over a variety on marsh species, commonly including sawgrass.

Point fire frequency – the fire-return interval for a specific point in the landscape. Usually obtained from a point sample—the number of fire scars on a particular tree. Point samples are usually underestimates of fire frequency because it is unlikely that every fire will scar a particular tree.

Pocosin - evergreen shrub bog. May occur on organic or wet mineral soils under a wide range of fire-return intervals. Historically, and as used by Algonquian Indians, the term meant any open, relatively treeless plant communities, especially those in wetlands.

Prairie - community consisting of an herb layer only, maintained free of trees and most other woody vegetation by fire, soils with severe wet/drought cycle or a combination of the two (carries implication of extensive area but is sometimes applied to treeless areas as small as 1 hectare in the southeastern U.S.).

Presettlement fire frequency – In the western hemisphere, the prevailing fire return intervals at time of European settlement. Presettlement fire frequency was a composite of fires resulting from ignitions by Native Americans, against a background of lightning ignitions, which varied greatly in different parts oif the presettlement landscape. Portions of the original landscape can be identified where either ignition source was dominant.

Presettlement vegetation – in the western hemisphere, the natural vegetation which existed, under natural fire regimes, at time of European settlement (ranging from 1565 in Florida to around 1890 in remote parts of the western U.S.).

Probability of ignition – the probability that a fire will continue to burn if an ignition source, such as lightning, occurs. Calculated from fine fuel moisture, temperature and degree of shading.

Pyrogenic, pyrogenicity - influence of vegetation on fire behavior, acting through factors like ignitability of living vegetation, and characteristics of dead fuel produced by vegetation.

Pyrographic - relating to environmental and biotic factors contributing to fire flow, fire frequency and fire intensity in the landscape.

Pyrographic map - a map depicting isopleths of fire frequency for the most fire-exposed parts of the landscape. Based on soil maps or land surface form maps (Hammond 1964), taking into account historical records, remnant fire vegetation, fire-frequency indicator species, fire frequency indicator communities and natural firebreaks in the landscape.

Pyrographic method – (landscape fire ecology method) creating approximate presettlement vegetation maps by first reconstructing presettlement fire regime and then reconstructing natural vegetation on each soil series as it occurred under a fire regime like the original.

Pyrography - mapping fire frequency, fire behavior or fire vegetation in a landscape.

Pyromosaic - Shifting or stable mosaic of plant communities in which the dominant species in any one patch depends upon conditions at time of last fire. For example, in southeastern peatlands the same site may have had, in different decades or centuries, white cedar, pond pine, bay forest, swamp black gum, baldcypress, or pond cypress, depending on whether the level of the water table at time of fire caused the fire to remain on the surface, burn shallowly into the peat, destroying the seed bank, or burn deeply, pooling water.

Pyrophoric – tendency of a fuel type to spontaneous combustion. Some materials like coal have a temperature at which they will continue to heat spontaneously until combustion occurs (if oxygen is present).

Pyrophytic landscape - landscape dominated by vegetation that owes its structure or species composition to fire.

Pyrophytic species - plant species dependent on fire for completion of their life cycles (obligate) or adapted to survival under natural fire regimes (facultative).

Pyrophytic woodland - (eastern U.S.) bilayered community with the tree canopy and herb layer being the principal layers, the understory being kept clear of woody species by fire. Tree cover may be up to 75%. Trees may be mixtures of oaks (especially post oak and blackjack), hickories (especially Carya tomentosa, C. pallida, C. cordiformis) and pines (especially shortleaf pine).

Pyrotone – the fire-tension zone between flammable upland vegetation and less flammable wetland vegetation (term coined by Geoff Babb).

Rate of spread – fire behavior, traditionally expressed as fire spread in chains per hour (66 feet/chain).

Savanna - (southeastern U.S.) bilayered community maintained by fire, with an open tree canopy and an almost continuous herb layer. Tree cover may be up to 50%.

Shrub reduction fires – intense fires in shrub-dominated communities that reduce all stems to the ground.

Site fire-return interval – the mean fire-return interval for a particular fire compartment. Usually derived from a composite fire scar chronology of fire scar dates from several trees within the fire compartment. This is the most ecologically useful estimate of fire frequency since it is the actual rate of fire experienced by vegetation in a particular fire compartment (compare point samples and area samples of fire frequency).

Stand-replacing fire – fires which kill trees to the ground. There are two types: crown fires and lethal understory fires. Some camopy species are killed outright while others may resprout.

Surface fire – light fires in hardwood leaf litter, conifer litter, light grass and some forb communities.

Understory reduction fires – fires in multistoried stands, intense enough to clear out everything in the understory, including any subcanopy trees, but leave most canopy trees intact.

Understory thining fires – fires in multistoried stands which thin the shrub and subcanopy layers without killing everything beneath the canopy.

Within-compartment fire effects – variation in fire frequency within a single compartment may be predicted from comparing fire exposed points in the compartment with partially fire sheltered points. Fire frequency and intensity can be expected to be higher on dry south slopes and ridges, at points downwind from the prevailing fire season wind direction, and points in the vicinity of a connector or window into another fire compartment—an additional source of ignition. Fire frequency can be expected to be lower upwind, in bottoms, in the fire shadow downwind from a stream or other firebreak, and in other places accessible only to slower moving, backing fire.

APPENDIX 2. FIRE FREQUENCY INDICATOR SPECIES AND FIRE REGIMES OF SELECTED RARE AND COMMON FIRE DEPENDENT SPECIES OF THE SOUTHEASTERN U.S.

The fire regimes below are a tentative classification for species with which I have experience in the field. Frequencies are based on recent fire history determined in 116 1/10 hectare plots and 352 stands of vegetation on particular soil series in an area ranging from the James River in Virginia, south to the White Oak River in North Carolina. Estimates of presettlement fire frequency were made in the field for each, based on local fire compartment size and other landscape factors. Occasionally, historical references to fire frequency were available. Also used were species lists and recent fire history for about 30 stands on the Savannah River Site in South Carolina, as well as the plots cited above in the Green Swamp, and studies of endangered and threatened plant species carried out by the staff and contractors of the NC Plant Conservation Program. Frequencies reported for MacBridea alba (Florida) and Iliamna corei (Virginia) are based on discussions with others. Species' fire frequency requirements vary with soil texture, site moisture and fertility status. The following estimates are for the most typical habitats observed for each.

KEY:

R* – Rare species (for status refer to Walker 1993).

S – May require a combination of special, usually circumneutral, substrate as well as fire.

L – classification based on study by Lemon (1949).

N – not fire dependent.

Presettlement – Most common presettlement fire frequency range.

Tolerated – Range of frequencies tolerated (some only on certain soils such as dry sands).

Persists – Time that a species may persist after elimination of fire. This corresponds in part to the extreme fire-infrequent range that a species may tolerate (some only on certain soils).

COASTAL PLAIN AND SANDHILLS

SPECIES	Presettlement Fire Frequency Range	Tolerated Fire Frequency Range	May Persist After Last Fire
Aristida beyrichiana N	1-3	1-20	40
Aristida stricta N	1-3	1-20	40
Astragalus michauxii R*	1-3	1-6	15
Carex lutea R*	1-3	1-3	20
Carphephorus bellidifolius N	1-3	1-20	50+
Cnidoscolus stimulosus N	1-3	1-20	25
Dionaea muscipula R*	1-3	1-4	7
Ilex glabra N	1-300+	1-300+	300+
Lespedeza hirta N	1-6	1-20	50+
Lysimachia asperulifolia R*	1-3	1-7	10
MacBridea alba R*	1-3	1-7	10
MacBridea caroliniana R*	1-3	1-7	10
Oxypolis canbyi R*, S	1-3	1-10	15
Parnassia caroliniana R*	1-3	1-7	12
Pinguicula pumila R*	1-3	1-6	10
Pinus palustris N	1-6	1-50	75
Pleea tenuifolia R*	1-3	1-15	25
Pyxidanthera barbulata N	1-3	1-20	50
Sarracenia flava N	1-3	1-10	20
Sarracenia minor R*	1-3	1-7	15
Schwalbea americana R*	1-3	1-6	10

Solidago odora N	1-12	1-25	50+
Sporobolus curtissii L N	1-3	1-20	40
Sporobolus teretifolius	1-3	1-10	20
Tephrosia virginiana N	1-6	1-35	50+
Thalictrum cooleyi R*, S	1-3	1-10	15

PIEDMONT

Aster depauperatus R*, S	4-6	1-20	50
Aster georgianus R*	4-6	1-15	25
Echinacea laevigata R*, S	2-6	1-20	40
Eryngium yuccifolium N	1-6	1-7	20
Helianthus schweinitzii R*	4-6	1-15	35
Liatris graminifolia N	4-6	1-15	40
Liatris squarrulosa R* (L. earlei)	4-6	1-15	25
Lithospermum canescens R*	4-6	1-15	25
Parthenium integrifolium var. auriculatum R*	4-6	1-15	20
Quercus ilicifolia R*	4-6	4-20	60
Rhus michauxii R*	4-6	1-7	10
Silphium terebinthinaceum R*	4-6	1-15	20
Solidago ptarmicoidesR*	4-6	1-10	15
Solidago rigida ssp. glabrata R*	4-6	1-15	30

SOUTHERN APPALACHIANS

Andropogon gerardii (rock outcrops) N	5-10	3-20	30
Aster laevis R*, S	5-10	3-20	30
Comptonia peregrina N	5-12	3-15	20
Elymus trachycaulis R*, S	5-10	3-20	30

Geum radiatum R*	10-15	5-20	60
Houstonia purpurea var. montana R*	10-15	5-20	40
Hudsonia montana R*	5-12	3-15	40
Iliamna corei R*	5-7	3-15	20
Leiophyllum buxifolium N	5-7	5-50	75
Liatris helleri R*	5-12	3-15	40
Melampyrum lineare N	5-12	3-50	75
Muhlenbergia glomerata R*,S	5-12	3-15	30
Robinia hispida N (also persists in the seed bank)	5-12	3-20	30
Poa saultensis R*, S	5-10	3-15	20
Sarracenia oreophila R*	5-10	4-12	20
Senecio pratensis R*, S	5-10	3-20	30
Solidago spithamea R*	10-15	5-12	60
Sporobolus heterolepis R*, S	7-12	3-15	30
Xerophyllum asphodeloides N	5-12	3-25	45
Zygadenus glaberrimus R*	5-12	3-15	50