United States
Department of
Agriculture

Forest Service

Southern
Research Station

General Technical
Report SRS-2

An Old-Growth Definition for Wet Pine Forests, Woodlands, and Savannas

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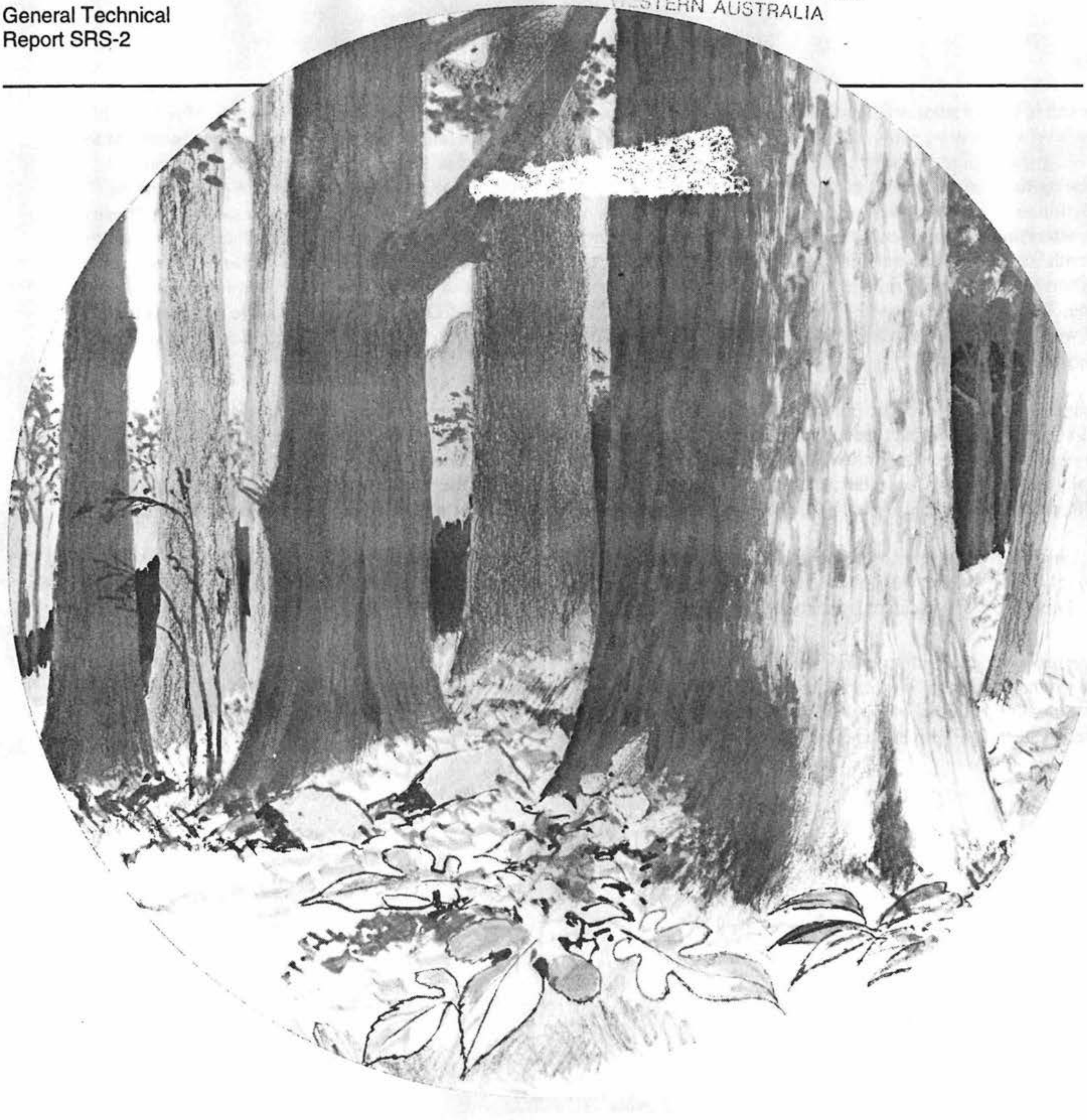

A Section of the Old-Growth Definition Series

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Preface

Old growth is widely acknowledged today as an essential part of managed forests, particularly on public lands. However, this concept is relatively new, evolving since the 1970's when a grassroots movement in the Pacific Northwest began in earnest to define old growth. In response to changes in public attitude, the U.S. Department of Agriculture, Forest Service began reevaluating its policy regarding old-growth forests in the 1980's. Indeed, the ecological significance of old growth and its contribution to biodiversity were apparent. It was also evident that definitions were needed to adequately assess and manage the old-growth resource. However, definitions of old growth varied widely among scientists. To address this discrepancy and other old-growth issues, the National Old-Growth Task Group was formed in 1988. At the recommendation of this committee, old growth was officially recognized as a distinct resource by the Forest Service, greatly enhancing its status in forest management planning. The committee devised "The Generic Definition and Description of Old-Growth Forests" to serve as a basis for further work and to ensure uniformity between Forest Service Stations and Regions. Emphasis was placed on the quantification of old-growth attributes.

At the urging of the Chief of the Forest Service, all Forest Service Stations and Regions began developing old-growth definitions for specific forest types. Because the Southern and Eastern Regions share many forest communities (together they encompass the entire Eastern United States), their efforts were combined, and a cooperative agreement was established with The Nature Conservancy for technical support. The resulting project represents the first large-scale effort to define old growth for all forests in the Eastern United States. This project helped bring the old-growth issue to public attention in the East.

Definitions will first be developed for broad forest types and based mainly on published information and so must be viewed accordingly. Refinements will be made by the Forest Service as new information becomes available. This document represents 1 of 35 forest types for which old-growth definitions will be drafted.

In preparing individual old-growth definitions, authors followed National Old-Growth Task Group guidelines, which differ from the standard General Technical Report format in two ways—the abstract (missing in this report) and the literature citations (listed in Southern Journal of Applied Forestry style). Allowing for these deviations will ensure consistency across organizational and geographic boundaries.

September 1996

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Introduction

Wet pine forests, woodlands, and savannas of the Southeastern United States are subtypes within the pine flatwoods forest region of the Atlantic and Gulf Coastal Plains. This review briefly describes the edaphic and vegetation characteristics of the dominant plant communities in this type group and provides a working definition that may be used to identify and evaluate stands for inclusion in an old-growth management program. The old-growth definitions offered below are based on available published information on the type group; no field investigations were made.

The distinction among the vegetation structure of forests, woodlands, and savannas is determined by the relative density of the dominant stand and the composition of the shrub and herb layers. Forests have closed stands of trees with touching crowns, well-developed understories of trees and shrubs (if not frequently burned), and little if any grass or herb ground cover. Woodlands have fewer trees per unit area than forests, crowns of the dominant stand do not generally touch, and the understory is dominated by woody shrubs, giving the woodland a two-layered structure. Savannas tend to have widely scattered trees and a predominantly grass-herb understory of high-species diversity (Christensen 1988, Harcombe et al. 1993, Peet and Allard 1993).

Forest Type Group Narrative

Wet pine forests, woodlands, and savannas (type no. 27) are classed as palustrine forests with frequent, low-intensity, widespread fires. They are found in the coastal plain physiographic province from Delaware south to Florida and west to eastern Texas, primarily in the flatwoods of the outer marine terraces. Representative sites include boggy nonriverine flatlands, poorly drained seasonally wet coastal flatlands, and lowlands adjacent to ponds, streams, and other wet areas. Soils range widely in texture from clay to sand. Moisture conditions are influenced by impermeable soil layers that restrict the downward movement of water. Poor drainage limits aeration of the soils on many sites and peat mats commonly develop over mineral surfaces. Acidic conditions prevail on most sites.

Three principal tree species are characteristic of the wet pine type group: longleaf pine (*Pinus palustris* Mill.), slash pine (*P. elliottii* Engelm), and pond pine (*P. serotina* Michx.). They define specific subtypes and occur either in pure stands or in mixtures, depending on geographical location, soil and hydrological conditions, and fire regime. For ease of reference, the subtypes are named according to the forest cover type classification system published by the Society of American Foresters (SAF) (Eyre 1980). The types are wet-site variants of longleaf pine (SAF 70), longleaf pine-slash pine (SAF 83), slash pine (SAF 84), and pond pine (SAF 98).

Species composition differs widely among subtypes and is shaped by fire frequency and intensity, soil characteristics, season and duration of flooding or soil waterlogging, and latitude. The subtypes are segregated on the landscape primarily on the basis of the soil moisture-hydroperiod gradient. On mineral soils where flooding is limited, longleaf pine is the predominate overstory tree. The stands tend to be pure with few if any trees in the midstory. Fires on longleaf sites occur at 2- to 5-year intervals. On wetter sites where fire is less frequent, both longleaf and slash pine dominate the overstory. On sites with growing-season hydroperiods, slash pine dominates. Fire usually restricts hardwood associates, such as sweetgum (*Liquidambar styraciflua* L.), red maple (*Acer rubrum* L.), blackgum (*Nyssa sylvatica* Marsh.), and cabbage palmetto [Sabal palmetto (Walt.) Lood. ex J.A. & J.H. Shult], to understory positions on sites where they occur. On organic soils subject to prolonged flooding, longleaf and slash pine are replaced by pond pine communities. Associates of pond pine include swamp tupelo [*N. sylvatica* var. *biflora* (Walt.) Sarg.], water oak (*Quercus nigra* L.), baldcypress [*Taxodium distichum* (L.) Rich.], pondcypress (*T. ascendens* Brongn.), sweetbay (*Magnolia virginiana* L.), live oak (*Q. virginiana* Mill.), loblolly-bay [*Gordonia lasianthus* (L.) Ellis], and redbay [*Persea borbonia* (L.) Spreng.].

Fire

All the communities in this type group are fire dominated and depend on fire for their continued existence (Christensen 1981). Although the frequency and intensity of fire vary among the different subtypes, it is a natural phenomenon in each one. Without continued disturbance from fire, it is likely that these vegetation types would dominate a particular site for a single generation, then gradually lose control to invading species and eventually disappear from the community (Wade 1983). The presettlement natural fire regimes for these ecosystems are not known, but studies of species life histories and patterns of fuel accumulation indicate that light-to-moderate intensity surface fires occurred every 2 to 8 years in the grass- and herb-dominated savannas (Wahlenberg 1946, Christensen 1981). In the wetter, shrub-dominated slash pine and pond pine woodlands, fire frequency was probably 10 to 30 years, less than in the savannas, because of the more moist conditions. Frequency in these types depends on occurrence of drought conditions sufficient to increase the flammability of the understory to where it will burn readily. Such fires are intense and usually burn all the aboveground vegetation, especially in pond pine woodlands (Christensen 1981, 1993). Fire is necessary for the establishment and maintenance of these ecosystems. In the longleaf types, grasses, such as wiregrass, are essential fuel components to ensure that fire will occur frequently (Noss 1989). The range of ecological processes and conditions that recurring fire initiates, terminates, and continues cannot be duplicated by any other disturbance (Volga 1979).

Forest Subtype Narratives

Longleaf Pine Type

Range—The natural range of longleaf pine covers most of the coastal plain from southeastern Virginia south to central Florida and west to Texas. It also occurs in areas of the piedmont and interior uplands of Georgia and Alabama (Wahlenberg 1946). Wet longleaf pine sites occur primarily in the flatwoods section of the Atlantic and east Gulf Coastal Plains and on seepage areas in the fall line section from central North Carolina south to Alabama (Peet and Allard 1993). In the west Gulf region, wet pine lands occur on poorly drained interstream areas of the outer coastal plain terraces in southwest Louisiana and southeast Texas (Harcombe et al. 1993).

Sites—Wet pine sites are seasonally wet, often saturated during the winter and droughty during the growing season. Most soils are sandy with low organic matter content and include predominantly Aquods (Spodosols) and Aquults (Ultisols). They are characterized by high and fluctuating water tables, often with a fine textured spodic (organic) or argillic (clay) horizon that restricts drainage (Boyer 1990).

Vegetation—High stand densities are not typical of longleaf pine in the natural state (Landers et al. 1990), virgin stands are described as mosaics of widely scattered trees intermingled with patches of seedlings, saplings, and pole-sized trees, and an understory of grasses and herbs (Schwartz 1907, Wahlenberg 1946). Longleaf pine communities, therefore, are typically woodlands or savannas. Longleaf is pure or is the dominant species on poorly to moderately drained soils. On wetter soils from southern South Carolina south and west along the Gulf, slash pine is a common associate or may dominate. In Florida and southeast Georgia, slash pine and/or pond pine replace longleaf pine on wet sites. Pond pine assumes dominance in Virginia and the Carolinas on the wettest sites and on organic soils.

In woodland stands, the understory is absent or may contain invading hardwoods such as blackgum, sweetgum, and water oak. A low shrub layer of varying density is usually present. Common species include gallberry [*Ilex glabra* (L.) Gray], redbay, sweetbay, and swamp cyrilla (*Cyrilla racemiflora* L.). On better drained sites, saw-palmetto [*Serenoa repens* (Bartr.) Small] may dominate the shrub layer. The herb layer is dominated by wiregrass (*Aristida stricta* L.). On wet savannas, the dominant pines occur in stands of widely scattered trees. Understory trees and shrubs are generally absent. Scattered gallberry, blueberry (*Vaccinium* spp.), waxmyrtle (*Myrica cerifera* L.), or other shrubs may be present. The herb layer is generally dense and is very diverse, with grasses, sedges, composites, orchids, and lilies particularly prominent. In the eastern part of its range and south to central Alabama and northwest Florida, wiregrass is the dominant species. In the western part of the range, bluestem (*Andropogon* L. spp.) and panic (*Panicum* spp.) grasses are dominant (Boyer 1980, Frost et al. 1986, Harcombe et al. 1993, Peet and Allard 1993).

Community dynamics—Longleaf pine is the longest lived species of this type group; Platt et al. (1988) reported trees older than 400 years. The longleaf pine types are fire maintained successional stages in the natural ecological progression to the southern mixed hardwood climax forest

(Quarterman and Keever 1962). The existence of pure pine stands in the virgin forest is attributed to frequent, naturally occurring, low-to-moderate intensity surface fires. Such fires create a favorable environment for seedling establishment and growth by keeping competing shrubs and herbs and invading hardwoods in check and controlling the brown-spot needle blight [*Scirrhia acicola* (Dern.) Siggers], which is a major cause of poor seedling growth and mortality (Boyer 1990). Frequent fire is essential for maintaining species diversity and community structure in the longleaf pine types (Landers et al. 1995). Without frequent fire, the fire-sensitive shrub and hardwood components already present in the stand, plus invaders from seed sources outside the stand, increase and eventually suppress the pines and dominate the site (Wahlenberg 1946, Quarterman and Keever 1962).

Slash Pine Type

Range—Slash pine has the most restricted natural range of the major southern pines. It is native only on a narrow strip of flatwoods along the southeast coastal plain from southern South Carolina into central Florida and westward along the Gulf Coastal Plain to eastern Louisiana. Its range has been extended by planting west through central Louisiana into eastern Texas, north in Alabama, Mississippi, and southern Arkansas, and in parts of North and South Carolina (Hodges 1980, Lohrey and Kossuth 1990).

Sites—Slash pine occupies wetter sites than longleaf. The original distribution of the species within its natural range was largely determined by its susceptibility to fire injury during its seedling stage, and its tolerance of wet soil conditions (Lohrey and Kossuth 1990, Stout and Marion 1993). It grows in irregular stands often mixed with longleaf or loblolly pine (*P. taeda* L.), pondcypress, swamp tupelo, and other wetland species. Historically, it was not noted for forming large forests, and extensive natural stands occurred only in central Florida (Mohr 1897, Schultz 1983). The sites where slash pine grows naturally include wet savannas and pitcher plant flats, poorly drained flatwoods, stream edges and pond margins, and seasonally flooded areas such as bays, ponds, and swamps where fires are rare (Mohr 1897, Hodges 1980, Schultz 1983). The soils range from Ochraquults and Albaquults (Ultisols) to Humaquents (Entisols), depending on the surface texture, color, and depth to a clay layer. They vary from loamy sands to sandy loams in surface texture. Because they are wet, they often accumulate organic matter (Pritchett and Comerford 1983).

Vegetation—The community has an open-to-closed tree canopy comprised predominantly of slash pine. On wet sites, associated species may include swamp tupelo, sweetbay, pondcypress, loblolly-bay, live oak, pond pine, southern redcedar [*Juniperus silicicola* (Small) Bailey], cabbage palmetto, red maple, and, less commonly, sweetgum, water oak, and swamp laurel oak (*Q. laurifolia* Michx.). Seasonally flooded bays dominated by slash pine will have sweetbay or loblolly-bay and sometimes swampbay [*P. borbonia* var. *pubescens* (Pursh) Little], pondcypress, and swamp tupelo in the canopy. The understory will often include swamp cyrilla, and buckwheat-tree [*Cliftonia monophylla* (Lam.) Britton ex Sarg.]. The herb layer is absent except in bays where sphagnum species are present. On boggy flatwoods sites, slash pine is commonly mixed with longleaf pine and a shrub layer of waxmyrtle, gallberry, buckwheat-tree, dahoon (*I. cassine* L.), and yaupon (*I. vomitoria* Ait.) is usually present. Species of pitcher plants occur in the herb layer (Hodges 1980).

Community dynamics—Slash pine is a relatively short lived species; mature trees more than 100 to 150 years old have seldom been reported (Mohr 1897, Pomeroy and Cooper 1956). The slash pine type is fire maintained but, because seedlings are less tolerant of fire than longleaf pine, it is generally restricted to wetter, less frequently burned sites (Abrahamson and Hartnett 1990). It is a transition species lying on a soil moisture gradient between seasonally wet longleaf pine sites and seasonally flooded ponds and bay swamps. With the elimination of fire, succession of wet-site slash pine tends toward the bay community type (Monk 1968) or swamp hardwoods (Abrahamson and Hartnett 1990).

Longleaf Pine—Slash Pine Type

Range—The geographic range of this cover type is determined by the natural range of slash pine. It extends in the coastal plain flatwoods from southern South Carolina to southeast Louisiana.

Sites—Fire history and moisture regime of the site are responsible for the occurrence of this type. It occurs on flatwoods and savanna sites where longleaf pine is adjacent to or in the vicinity of a slash pine seed source. In the prolonged absence of fire, slash pine will seed into neighboring longleaf stands to become established in the understory and, over time, grow into the overstory. Because slash pine seedlings are susceptible to fire damage, the site must be fire-free for 5 to 10 years to allow seedlings to reach fire-resistant size of approximately 9.8 feet (3 meters) tall (Grelen 1980).

Vegetation—Slash and longleaf pines occur in the overstory in varying proportions. The most common shrub associates are gallberry and saw-palmetto. On wet sites, sweetbay, blackgum, buckwheat-tree, titi, greenbriers

(*Smilax* spp.), fetter-bush [*Lyonia lucida* (Lam.) K. Koch], sweet pepperbush (*Clethra alnifolia* L.), St. Andrew's Cross (*Ascyrum hypericoides* L.), and blueberries are common. Wiregrass is a major component of the herbaceous layer if fire is frequent enough to control the abundance of the shrub layer (Grelen 1980).

Community dynamics—With or without fire, this community is temporary. Fire destroys young slash pine; but where exclusion of fire allows slash pine to become established with longleaf pine, hardwoods and shrubs will invade and dominate the understory and eventually the overstory, eliminating subsequent regeneration of both pines (Grelen 1980). With frequent fire, the type will revert to longleaf pine.

Pond Pine Type

Range—Pond pine occurs in the coastal plain from southern New Jersey south to central Florida and west into southeastern Alabama (Bramlett 1990).

Sites—Pond pine occupies the wettest sites within this type group. It is found in swamps, pond borders, and pocosins, characterized by undrained peat soils and wet, sandy flats. It grows most extensively in the broad, poorly drained interstream areas of peaty soils in the lower coastal plain of North Carolina. Farther south, it is found on the wet pine flatwoods and savannas of the lower coastal marine terraces and in bays and ponds throughout the coastal plain. The species can make excellent growth on better drained mineral soils, but the faster earlier growth of slash and loblolly pine usually restricts it to a subordinate position on such sites (Johnson 1980, Bramlett 1990). The soils range from Ochraquults and Albaquults (Ultisols) to Humaquents (Entisols), depending on the surface texture, color, and depth to a clay layer. Organic soils include oligotrophic (nutrient-poor, rain-fed) mineral soils with shallow organic surface layers, represented by Haplaquods (Ultisols), and shallow-to-deep Humaquepts and Medisaprists (Histosols) (Schafale and Weakley 1990).

Vegetation—The dominant tree canopy of pond pine stands is open woodland to nearly closed forests. Associates include sweetbay, swampbay, red maple, loblolly pine, and Atlantic white-cedar [*Chamaecyparis thyoides* (L.) B.S P.] The shrub layer includes swamp cyrilla, fetter-bush, maleberry [*L. ligustrina* (L.) DC], gallberry, blue huckleberry [*Gaylussacia frondosa* (L.) T.&G.], saw-palmetto, sweet pepperbush, laurel-leaved greenbrier (*S. laurifolia* L.), and swampbay. Switch-cane (*Arundinaria* spp.) is often present and may dominate in Atlantic Coastal Plain sites. Saw-palmetto is the dominant shrub in Georgia and Florida. There is generally no herb layer (Edmisten 1965, Schafale and Weakley 1990).

Community dynamics—Pond pine communities are wet and nutrient-poor and are susceptible to fires during droughts that allow the organic soils to dry. The large amount of fuels produced by the understory make fires extremely intense. Pond pine has serotinous cones that require hot fires to release seed and produces epicormic sprouts when injured. Regeneration of new stands is therefore tied directly to fire (Woodwell 1958). All the dominant species sprout readily and the shrub layer regrows to its former height in just a few years. Stands persist indefinitely in the absence of fire but are readily regenerated after burning by sprouting, as well as from seeds (Schafale and Weakley 1990).

Old-Growth Definitions

Elimination of fire regimes of natural and Indian origin, indiscriminate logging, and conversion of forests to farms produced sweeping changes in the vegetation landscape that was present in the Southeast at the time of European settlement. As a result, few stands representative of the virgin or old-growth conditions of wet pine forests still exist. New old-growth forests will have to develop from existing stands with the help of an active management program and a set of old-growth definitions to guide it. Published data from examples of virgin or old-growth forests of this type group from which old-growth definitions can be constructed are limited. There are, however, descriptions of upland longleaf stands (Chapman 1907, Schwatrz 1907, Wahlenberg 1946, Platt et al. 1988) and a slash pine stand (Hebb and Clewell 1976) that provide limited guidance. No descriptions of old-growth pond pine have been found.

Provisional Definitions

These definitions are provisional in that they are based on limited information. They should be modified as new information from research and field study becomes available. There are five basic stand-selection criteria for the wet pine forests, woodlands, and savannas: (1) The environment must have seasonally wet soils. (2) It must include the fire regime appropriate to one of the subtypes described. (3) There must be a stand of trees of the required species composition and minimum age. The minimum age of most stands in all subtypes in this group will be 80 to 100 years, assuming that most of the oldest stands date from the late 1800's to the early 1900's, when the last of the old-growth southern pines were harvested (table 1). (4) There should be no evidence of recent soil disturbance or tree harvest. (5) Stand structures must be appropriate for forest, woodland, or savanna. Given these criteria, other characteristics and attributes of old-growth forests, such as snags, large and small woody debris in various stages of decay, herbaceous and woody undergrowth typical of the type, and regeneration of the dominant canopy species must be either present or the conditions necessary for their development evident.

Stand attributes used to identify old-growth wet pine forests are presented in table 1. Standards are defined for each of the forest subtypes except for longleaf pine-slash pine. Standards for this type are assumed to be the same as for the individual longleaf and slash pine types. Decadence in old, dominant trees, such as dead, broken, or deformed tops, and stem or root rot, also indicates old growth and should be evaluated. The minimum area for a stand to be considered viable for old growth is not defined. Acceptable size must be determined in the context of the landscape in which the stand occurs; some factors that should be considered when determining stand size include extent of edge effects from neighboring stands and ecosystems, and vulnerability to catastrophe.

Table 1—Provisional standards for old-growth wet pine forests, woodlands, and savannas in the southeastern coastal plain[a]

	Standard attributes[b]		
Species	Minimum no. trees/ha	Average stand d.b.h.	Minimum age
		cm	*yr*
Live canopy trees (forest structure):			
Longleaf pine	150	50	150 - 200
Slash pine	150	53	80 - 100
Pond pine	200	23	60 - 100
Stand structure[c]:			
Forest	Hardwood understory present		
Woodland	Shrub understory dominant		
Savanna	Grass-herb understory dominant		

[a] Forest = most crowns touching or nearly touching; woodland = trees widely scattered, shrub layer prominent; savanna = few scattered trees, herb layer prominent.

[b] Standards are for forest conditions and are extracted from various sources: longleaf pine (Chapman 1907, Wahlenberg 1946); slash pine (Hebb and Clewell 1976); pond pine—extrapolated from natural stand yield tables of Schumacher and Coile (1960) for age 80 and site index 70. Standard attributes for canopy trees in woodlands and savannas are not known—they can be set using the forest standards as a base.

[c] Stand structure will depend on the existing fire regime. Frequent fires favor a grass-herb understory, while less frequent fires favor a hardwood understory.

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United States
Department of
Agriculture

Forest Service

Southern
Research Station

General Technical
Report SRS-3

An Old-Growth Definition for Evergreen Bay Forests and Related Seral Communities

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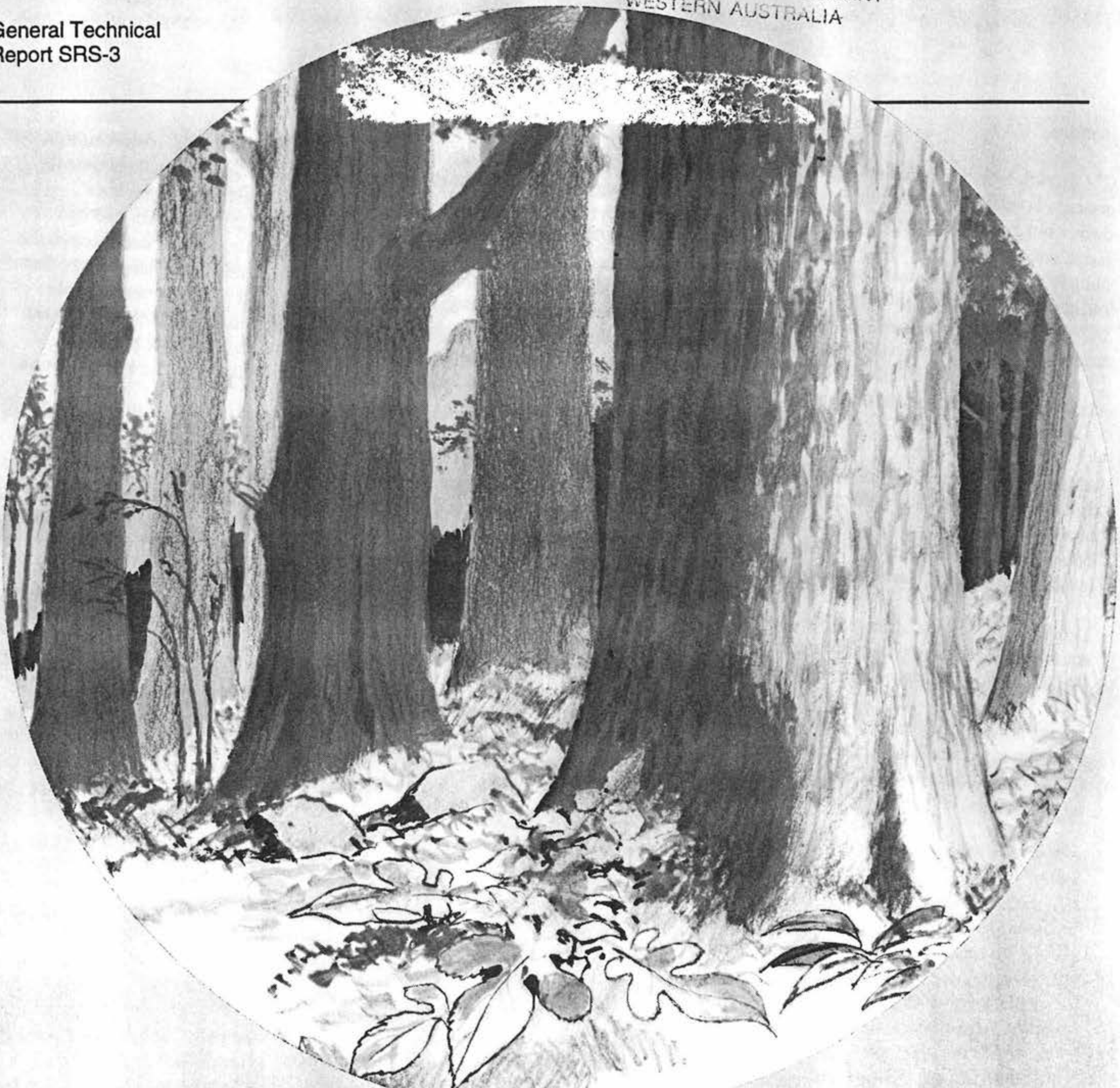

A Section of the Old-Growth Definition Series

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Preface

Old growth is widely acknowledged today as an essential part of managed forests, particularly on public lands. However, this concept is relatively new, evolving since the 1970's when a grassroots movement in the Pacific Northwest began in earnest to define old growth. In response to changes in public attitude, the U.S. Department of Agriculture, Forest Service began reevaluating its policy regarding old-growth forests in the 1980's. Indeed, the ecological significance of old growth and its contribution to biodiversity were apparent. It was also evident that definitions were needed to adequately assess and manage the old-growth resource. However, definitions of old growth varied widely among scientists. To address this discrepancy and other old-growth issues, the National Old-Growth Task Group was formed in 1988. At the recommendation of this committee, old growth was officially recognized as a distinct resource by the Forest Service, greatly enhancing its status in forest management planning. The committee devised "The Generic Definition and Description of Old-Growth Forests" to serve as a basis for further work and to ensure uniformity between Forest Service Stations and Regions. Emphasis was placed on the quantification of old-growth attributes.

At the urging of the Chief of the Forest Service, all Forest Service Stations and Regions began developing old-growth definitions for specific forest types. Because the Southern and Eastern Regions share many forest communities (together they encompass the entire Eastern United States), their efforts were combined, and a cooperative agreement was established with The Nature Conservancy for technical support. The resulting project represents the first large-scale effort to define old growth for all forests in the Eastern United States. This project helped bring the old-growth issue to public attention in the East.

Definitions will first be developed for broad forest types and based mainly on published information and so must be viewed accordingly. Refinements will be made by the Forest Service as new information becomes available. This document represents 1 of 35 forest types for which old-growth definitions will be drafted.

In preparing individual old-growth definitions, authors followed National Old-Growth Task Group guidelines, which differ from the standard General Technical Report format in two ways—the abstract (missing in this report) and the literature citations (listed in Southern Journal of Applied Forestry style). Allowing for these deviations will ensure consistency across organizational and geographic boundaries.

September 1996

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Introduction

Forests of the North American continent consist of diverse associations of woody and herbaceous plants. Within these forests, many species tend to occur as typical of various physiographic regions and topographic features. Historically, these communities have been viewed as pioneer, seral, or climax, relative to their persistence within the ecosystem. The popularized view of old-growth forests has been one of the plant communities in a climax equilibrium with individual trees hundreds of years old comprising most of the population of the dominant species. In cases where natural disturbances were rare or of limited intensity, community succession could proceed to its climactic condition and dominant individuals of long-lived species could attain ages of 500 to 1,000 years, such as occurs in the Douglas-fir forests of the Pacific Northwest. Sprugel (1991) refers to this concept as the "natural" ecosystem, which has been adhered to by many early ecologists. However, current views of community ecology suggest that nonequilibrium in plant communities is more common than not and that most natural ecosystems are dynamic, even in the absence of human activity (Davis 1984, Brubaker 1988, Sprugel 1991). Frequent and/or catastrophic disturbances, such as fire, can prevent plant communities from attaining a climax equilibrium and the associated characteristics considered common to old growth. Disturbances and changes in climate can influence species disproportionately, altering common community associations according to responses of the individual.

Considering the current focus within the U.S. Department of Agriculture, Forest Service on managing for healthy, sustainable forest ecosystems, more information is needed on the temporal dynamics of the many forest cover types found in the United States. In other words, what characteristics, other than age of specific individuals, make a forest ecosystem old? Pioneer and seral communities can persist over long periods provided that perturbations necessary to their initiation are frequent. Root stocks, rhizomes, and, in some cases, seed banks can be relatively old, although the aboveground shoots arising from these components may not themselves be old. Can these communities be considered ancient or old growth even if the longevity of the individuals is limited? What constitutes "old growth" in community types that may not ever achieve a climax equilibrium and are subject to frequent, natural disturbances? Should these systems be excluded from the consideration given to more traditional old-growth forests? Definitions including such systems should be developed so that the natural dynamics of the ecosystem as a whole can be sustained, not simply the existing collection of individuals.

Narrative Description

The bay forest type (41) falls under Disturbance Class 3 of the composite list prepared by the National Old-Growth Task Group; forests with infrequent, high intensity, widespread disturbances and the subcategory, palustrine forests. This forest type is similar to the Society of American Foresters forest type 84, slash pine; 85, slash pine-hardwood; and 104, sweetbay-swamp tupelo-redbay. A previously prepared narrative description of the forest type is as follows: "Bay forests occur exclusively in the Coastal Plain physiographic province, and range from Maryland to southeast Texas. These forests are restricted to coastal depressions or floodplains where saturated conditions prevail. Soils usually are organic, although mineral soils do occur in floodplains. Most are highly acidic and low in nutrient availability. Surface flooding is common, but usually is not persistent.

"In addition to loblolly bay (*Gordonia lasianthus*), sweet bay (*Magnolia virginiana*), and red bay (*Persea borbonia*), common species include swamp tupelo (*Nyssa sylvatica* var. *biflora*), sweetgum (*Liqidambar styraciflua*), red maple (*Acer rubrum*), slash pine (*Pinus elliottii*), pond pine (*P. serotina*), live oak (*Quercus virginiana*), bald cypress (*Taxodium distichum*), pond cypress (*T. ascendens*), and Atlantic white cedar (*Chamaecyparis thyoides*). Hydric conditions retard the invasion by flood-sensitive species and consequent succession to other forest types. Disturbance from fire and storm events plays an important role in the ecological development of these systems. This forest type frequently reverts to Atlantic white cedar or pond pine forests (forest types 40 and 29, respectively) after catastrophic fires."

The term "bay," used in this document, has a dual meaning. It refers to both a kind of site, e.g., Carolina bay, and a general grouping of tree species that may inhabit that site, e.g., bay trees.

Occurrence

Bay forests occur in several physiographic provinces with different geologic origins and topographic features. However, bay forests are considered rare and are found in scattered patches, often in a mosaic with other forest types in various stages of succession (Schafale and Harcombe 1983, Abrahamson and others 1984, Bennett and Nelson 1991). Pocosins, Carolina bays and sandhill seeps, stream heads, and stream margins will often support this forest type (Wells 1928, Monk 1966, Waggoner 1975, Christensen et al. 1981, Nelson 1986).

Pocosins

Pocosins occur on low, coastal-plain terraces of Virginia and the Carolinas. These physiographic features are nonalluvial, occurring on divides between rivers, in broad, shallow stream basins, drainage-basin heads, and on broad, flat uplands (Wells 1928, Kologiski 1977). Common synonyms for pocosin and pocosin-like areas include bay, bayland, bayhead, baygall, xeric shrub bog, and evergreen shrub bog (Kologiski 1977, Sharitz and Gibbons 1982, Schafale and Harcombe 1983). Pocosins have shallow to deep organic soils of sandy humus, muck, or peat and intermediate to long hydroperiods with temporary surface water (Kologiski 1977). Soils reported for North Carolina pocosins include Dare, Dorovan, Pamlico, and Ponzer (Kologiski 1977).

Pocosins are often further described as being either tall or short, depending on the average height of the canopy dominants, which can be up to 32.8 feet [10 meters (m)] (Christensen et al. 1981). Bay forests are more closely associated with tall pocosins; evergreen shrub bogs are associated with short pocosins. Kologiski (1977) described the bay forest canopy as only 9.84- to 32.8-feet (3- to 10-m) high with the shrub stratum blending into the canopy layer. Greater fertility and productivity are also generally characteristic of tall pocosins and bay forests (Christensen et al. 1981, Richardson and Gibbons 1993). Evergreen shrub bogs are believed by some to represent an earlier successional stage to the evergreen bay forest and are the result of fire disturbance within the past 10 to 20 years (Buell 1946, Duever et al. 1982). The shrub species found in shrub bogs often occur as understory in bay forests and stunted individuals of sweetbay (*Magnolia virginana* L.), loblolly-bay [*Gordonia lasianthus* (L.) Ellis], and redbay [*Persea borbonia* (L.) Spreng.] often occur in shrub bogs (Richardson and Gibbons 1993). However, Otte (1981) and Christensen et al. (1981) have different views on the successional relationships between shrub bogs and bay forests.

Carolina Bays

Carolina bays are floristically similar to many pocosin sites and may also support evergreen bay forests (Buell 1946, Porcher 1966, Sharitz and Gibbons 1982, Bennett and Nelson 1991), although, when present in Carolina bays, sweetbay and redbay most often occur as shrubs (Schalles et al. 1989). The general term "bay" refers to the dense growth of bay trees found on many upland sites having histic soils with poor drainage; Carolina bays are the most abundant of these types of sites in the Southeast (Schalles 1979).

Carolina bays are unusual topographic features common to the Atlantic Coastal Plain. They are natural, elliptical depressions oriented northwest to southeast often having a pronounced sand rim along the southeastern edge. These depressions are isolated wetlands with no natural drainage outlets and are usually ombrotrophic. Typically, the central zone of a Carolina bay remains more or less inundated, depending upon weather patterns and local hydrology (Bennett and Nelson 1991). This perched, surface water is maintained by an impervious clay lens or a sand-iron-humate complex (Schalles 1979). Soil types within Carolina bays may vary but are usually composed of an organic surface layer of peat varying in depth and underlain by a layer of sand, which usually forms part of the impervious humate complex. However, clay-based bays generally have a mineral soil overlying the clay layer with little or no peat accumulation in the basin (Bennett and Nelson 1991). Bay forests are generally peat-based as opposed to clay-based.

Sandhill Seeps and Drainages

Sandhill seeps are found in the upper Atlantic Coastal Plain. They are usually located at the bases of hills and ridges in depressions where there is groundwater seepage from the adjacent slopes. The soils are histic due to constant saturation, although the seeps are seldom flooded. Stream margins and heads of stream branches along the Gulf Coastal Plain may also develop peaty soils and support bay forests (Monk 1966). These bayheads are visually distinguishable from cypress ponds by the absence of cypress trees and standing water, and the presence of an irregular surface with exposed, highly convoluted roots (Wharton 1978). The Pickney series is representative of the soils found in seeps and stream margins supporting evergreen bay forests. Soils of bayheads are less fertile than those of alluvial swamps with lower concentrations of cations and a lower pH; however, they are more fertile than soils associated with cypress ponds (Monk 1966, 1968).

Fire Ecology

Frequent disturbance across the landscape often results in a mosaic of vegetative cover types (Hamilton 1984). The patchwork nature of evergreen bay forests is related to their extreme susceptibility to fire, after which they may revert back to any one of several freshwater, hydric vegetative cover types depending on the intensity of the burn and depth to the water table during and following the burn (Monk 1968, Wells and Whitford 1976, Kologiski 1977, Duever et al. 1982, Hamilton 1984, Bennett and Nelson 1991). Fire intensity determines the amount or depth of peat burned away. Up to 6 feet (1.8 m) of peat were consumed by a severe fire in the Okefenokee Swamp, removing the base of support for the cypress (*Taxodium*) and tupelo (*Nyssa*) trees present on the site and causing them to collapse (Wharton 1978). Catastrophic fires also destroy seed banks and kill root systems and stumps that might survive less severe burns. Water-table depth during a fire influences fire intensity and depth of the burn; after a fire, water-table depth determines which of the available species will be able to recolonize the site. With shallow burns, as may occur when water tables are high, bay swamps may revert to pine swamps; with deeper burns, they may revert to cypress-gum ponds (Penfound 1952, Monk 1968). With a devastating surface fire, bay swamps may be replaced by Atlantic white-cedar [*Chamaecyparis thyoides* (L.) B.S.P.]; and with recurrent fire, the bay swamp, pond pine-slash pine wetlands, and Atlantic white-cedar bogs may revert to shrub bogs (Monk 1968). After a fire, pocosins may return to a pre-fire pocosin condition or develop into an Atlantic white-cedar bog, a sedge bog, an evergreen bay forest, or a deciduous bay forest (Monk 1968, Wells and Whitford 1976, Kologiski 1977, Duever et al. 1982, Bennett and Nelson 1991).

Most ecologists studying these systems agree that a successional relationship exists between sedge bogs, shrub bogs, pocosins, Atlantic white-cedar bogs, pine swamps, cypress-gum ponds, and bay forests (Penfound 1952, Hamilton 1984). However, there is disagreement on the direction and driving forces of succession. Wells (1928) suggested that the pocosin or shrub bog was a seral stage within a successional sequence, of which the evergreen bay forest is considered to be climax (Monk 1968). The succession process requires a few hundred years without disturbance. In the more fertile shrub bog communities, fire appears to be a major influence in succession (Christensen 1981). Kologiski (1977) used the term "fire disclimax" to describe the successional stage commonly known as pocosin and also suggested that the evergreen bay forest would eventually dominate.

On the other hand, Christensen et al. (1981) also noted that in the absence of fire, many ombrotrophic shrub bogs show little signs of succeeding to swamp forests and that some shrub bogs have been relatively stable for several thousand years. Otte (1981) proposed a succession sequence driven by nutrient levels, with the bay forest as a seral stage and the short-pocosin as the equilibrium stage. Richardson and Gibbons (1993) observed gradients in phosphorus (P) availability and the nitrogen:phosphorus (N:P) ratio associated with differences in cover type, i.e., short pocosin versus bay forest. The nutrient-driven theory of succession is also supported by pollen analysis. This form of succession occurs in conjunction with paludification (Richardson and Gibbons 1993).

Depth of peat or, more precisely, depth to the mineral soil below the peat layer appears to be the major fertility factor influencing succession and community types (Christensen et al. 1988 as cited by Richardson and Gibbons 1993). Many shrub bogs and shrub pocosins have a deeper layer of peat than do bay forests and only a minor canopy component of stunted tree species (Buell 1946, Bennett and Nelson 1991, Richardson and Gibbons 1993). Fire reduces peat accumulation and releases nutrients tied up in organic matter, suggesting that fire and fertility are intimately related and both may play a role in succession and stability.

Plant composition of these systems is also determined by frequency of fire as well as fire intensity (Monk 1968, Christensen 1981, Taggart 1981). Fire cycles of 50 to 150 years are required for the development of mature evergreen bay forests (Wharton 1978). Buell (1946) and Monk (1966) believed that the climax vegetation community of a Carolina bay shrub bog was the broadleaf bay forest and also considered this forest type successor to Atlantic white-cedar stands and pine pocosins when fire was absent from the ecosystem for long intervals. Buell (1946) went so far as to suggest that the dominant climax tree species would be swampbay (also known as redbay) [*P. pubescens (borbonia)*] due to its extreme shade tolerance. In an 80-year-old, declining Atlantic white-cedar stand in Brunswick

County, North Carolina, Buell and Cain (1943) noted that swampbay was the most abundant tree species in the understory, with 3,967 individuals per acre (98 individuals 100 m^{-2}). Sweetbay had 810 individuals per acre (20 individuals 100 m^{-2}). No Atlantic white-cedar seedlings were found and 90 percent of all seedlings present were swampbay. Kologiski (1977) also stated that the most common seedling in many of the evergreen bay forest stands of the Green Swamp in North Carolina was swampbay.

In addition to fire frequency and intensity, plant composition is also influenced by site hydrology. Short pocosins have been associated with high summer water tables and anaerobic conditions throughout the year, whereas tall pocosins and bay swamps have a highly seasonal water table (Bridgham and Richardson 1993). In areas with a defined moisture gradient, shrub bogs gradually give way to swamp forests as moisture increases. The spatial progression is characterized by decreasing shrub diversity and increasing tree diversity, in association with decreasing peat depth and increasing nutrient availability and productivity (Christensen et al. 1981).

Site hydrology, i.e., duration and depth of flooding, and climatic factors, i.e., precipitation and lightning strikes, also influence fire frequency and intensity in shrub bog/bay forest systems. Slightly elevated areas dry out more frequently, and periodic droughts increase the possibility of intense fires. However, bay swamps associated with seeps and streamheads seldom dry out due to the constant seepage of groundwater into the peat substratum, which is capable of absorbing and retaining large quantities of water (Wharton 1978).

Alteration of the water table by agricultural and silvicultural drainage practices over the past years has increased the frequency of dry periods and subsequently the possibility of fires in the Coastal Plain. Such management practices may have inadvertently interrupted the succession of shrub bogs to bay forests and severely reduced in size or damaged mature bay forests (Buell 1946, Monk 1966, Christensen 1981). However, a high frequency of fire in the Southeast before 1800 has been documented by early explorers and attributed to the activity of Native Americans (Christensen 1981). Even with the disturbance of the natural hydrology, fires may be less frequent today than they were 200 years ago.

Fire is necessary to the cycling of nutrients in the shrub bog/bay forest system. Shrub bogs may stagnate if nutrients remain tied up in the slowly decomposing litter, especially on inherently poor sites with deep peat accumulations (Christensen 1981). However, Monk (1968) indicated that soil fertility was more important in controlling the direction of succession than in limiting the advancement of succession. Many pocosin plants seem to require fire to complete their life cycle, and the absence of fire may be more of a disturbance than a very intense wildfire (Christensen 1981, Christensen et al. 1981). Prescribed fire has not been an acceptable substitute for wildfire and does not provide conditions necessary for regeneration. Gresham and Lipscomb (1985) reported that *Gordonia* required a high degree of soil disturbance, such as would occur from a very intense wildfire, for successful seedling recruitment.

In summary, plant composition in shrub bog/bay forest systems is determined by fire frequency and intensity, climate, hydrology, and site fertility. Fire frequency and intensity are influenced by climate and hydrology, and site fertility is influenced by hydrology and fire frequency and intensity. Regenerative capacity, i.e., potential seed banks and living rootstocks, is also determined in part by fire intensity and frequency. The complex web of interactions controlling succession within these depressional wetlands ensures myriad possible alternatives in vegetative cover types, one of which is the evergreen bay forest. Due to the long fire cycle required to achieve this cover type and the longevity of the regenerative components of a bay forest, the mere existence of an evergreen bay forest suggests it is indeed both climax and "ancient" relative to surrounding cover types occurring within depressional wetlands.

Life History and Community Associates

The floristic richness and species diversity of bay forests are relatively low compared with other southeastern forest types (Buell 1946, Monk 1968, Abrahamson et al. 1984). As stated in the narrative description, bay forests are usually dominated by the three bay species: loblolly-bay, sweetbay, and redbay.

According to *Silvics of North America*, loblolly-bay is a small-to-medium-sized tree or shrub (Gresham and Lipscomb 1990). At 10 years of age, specimens averaged 21.3 feet (6.5 m) in height and 2.2 inches [5.6 centimeters (cm)] in diameter at breast height (d.b.h.). Measurements of older specimens were not reported, although individuals at least 25 years old were noted. Elias (1980) reports the species to be short-lived with a maximum height of 65.6 feet (20 m) and diameter of 19.7 inches (50 cm). The National Champion, located on the Ocala National Forest, has a circumference of 13.4 feet (4.09 m) a diameter of 4.3 feet (1.31 m), a height of 95.2 feet (29 m), and a crown spread of

52.5 feet (16 m).[1] Loblolly-bay rarely occurs in pure stands (Gresham and Lipscomb 1985). The species is considered shade tolerant and is a strong competitor, but it is extremely sensitive to fire. Seedlings seem to require relatively open conditions and exposed soil for establishment. Few seedlings have been observed in the field. Stump and root-collar sprouts appear to be the most common form of regeneration for this species.

Sweetbay is also listed as a slow-growing, small-to-medium-sized tree (Priester 1990). It is considered a shrub in the northern reaches of its range (New Jersey), where it attains a height of 23.6 to 59.1 inches (60 to 150 cm). In the southern portion of its range (Florida), it varies in height from 49.2 to 98.4 feet (15 to 30 m) and in d.b.h. from 3.9 to 35.4 inches (10 to 90 cm). A record specimen measuring 50.4 inches (128 cm) d.b.h. and 91.9 feet (28 m) tall has been recorded in Florida; however, the age of this individual was not given. Individuals up to 70 years old were reported in the understory of a declining 80-year-old, Atlantic white-cedar stand in North Carolina (Buell and Cain 1943). Early growth of the sweetbays was slow, but their growth rate increased as the growth rate of the cedars declined. Regeneration is best in natural openings or clearcuts, although seedlings are fairly tolerant of shade and competing vegetation (Priester 1990). However, Buell and Cain (1943) found no seedlings of sweetbay in the cedar stand mentioned above. Like loblolly-bay, sweetbay also produces stump sprouts. Sweetbay is considered resistant to fire but will succumb after repeated burning.

Redbay is also listed as a tree or a shrub with size and growth habit varying over its range. Heights up to 68.9 feet (21 m) have been reported along with diameters of 35.8 inches (91 cm) (Brendemuehl 1990). Redbay occurring in pocosins has been described as a shrub. Ages associated with these dimensions were not reported. Redbay is tolerant of shade but also grows well in the open. As previously mentioned, redbay seedlings were abundant under a mature Atlantic white-cedar canopy (Buell and Cain 1943). However, reproduction may be erratic, and poor growth forms often occur under overstory competition (Brendemuehl 1990). Fire damage to redbay is severe and may interfere with reproduction.

Bay forest communities usually have a dense understory. Shrub, vine, and herbaceous species include the following: fetter-bush (*Leucothoe racemosa* D. Don), tetter-bush [*Lyonia lucida* (Lam.) K. Kosh], swamp cyrilla (*Cyrilla racemiflora* L.), buckwheat-tree or titi [*Cliftonia monophylla* (Lam.) Britton ex Sarg.], maleberry [*L. ligustrina* (L.) DC], sweet pepperbush (*Clethra alnifolia* L.), inkberry [*Ilex glabra* (L.) Gray], gallberry (*I. lucida*), sweet gallberry [*I. coriacea* (Pursh) Chapm.], American holly (*I. opaca* Ait.), dahoon holly (*I. cassine* L.), possumhaw (*I. decidua* Walt), wax-myrtle (*Myrica cerifera* L.), Virginia willow (*Itea virginica* L. Virginian), greenbrier (*Smilax* spp.), zenobia [*Zenobia pulverulenta* (Bartr.)], leather leaf [*Cassandra calyculata* (L.) Moench], sheepkill (*Kalmia augustifolia* L.), and cane [*Arundinaria gigantea* (Walt.) Chapm.] (Buell 1946, Porcher 1966, Monk 1968, Waggoner 1975, Abrahamson et al. 1984). *Cassandra calyculata* is listed on the rare/threatened/endangered plant list (Bennett and Nelson 1991). Several ferns and mosses have also been listed in the literature as commonly occurring in bay forests. These include *Osmunda cinnamomea*, *O. regalis*, *Woodwardia virginica*, *W. areolata*, and *Sphagnum spp.* (Porcher 1966, Kologiski 1977, Wharton 1978, Barry 1980). The herbaceous component is usually sparse (Nelson 1986) but may include partridge berry (*Mitchella repens* L.) and wild ginger (*Hexastylis arifolia*) (Barry 1980).

Age Structure

There is little information in the literature on age structure for the dominant tree species in evergreen bay forests. They are all described as moderately slow growing, and yet specimens have achieved heights of 98.4 feet (30 m) and diameters of 36.2 inches (92 cm). Loblolly-bay averaged 9.1 and 14.2 inches (23 and 36 cm) per year in height growth and 0.2 inches (0.58 cm) per year in diameter growth for two separate sites on the Coastal Plain of South Carolina (Gresham and Lipscomb 1985). At these growth rates, it would require about 100 years to achieve dimensions of 75.5 feet (23 m) tall and 22.8 inches (58 cm) d.b.h. One bay tree located on the Hofmann Forest in North Carolina was reportedly 85 years old.[2] However, specimens 50 to 150 years old do not meet the popular concept of "old growth" or "ancient forest."

The absence of relatively "old" individuals of the dominant tree species in a bay forest stand does not necessarily indicate the natural longevity of those species but may indicate frequent fires that prevent aboveground components from reaching old age. However, stumps and rootstocks partially protected from severe fire damage may be old.

[1] Personal communication. 1994. Laura Lowery, Ocala National Forest, Lake George Ranger District, 17147 East Highway 40, Silver Springs, FL 34488-5849.

[2] Personal communication. 1994. Richard Braham, Professor, North Carolina State University, Raleigh, NC 27695.

Both loblolly-bay and sweetbay commonly regenerate by means of stump and root-collar sprouts (Gresham and Lipscomb 1985). Wharton (1978) considered the bay swamp one of Florida's oldest and most stable environments because of the bay's ability to stump sprout following fire. Therefore, it may be appropriate to assign old-growth status to those plant communities with individuals whose propagating parts are long-lived, whether the aboveground shoot is old by currently accepted standards. With temporally dynamic systems, such as the bay forest/Atlantic white-cedar bog/evergreen shrub bog, it may be more important to recognize the longevity of the nonequilibrium ecosystem rather than that of the current stand of individual aboveground stems.

Stand Structure

There are few quantitative data in the literature on stand structure for evergreen bay forests of any age, much less those considered mature. Gresham and Lipscomb (1985) detailed 50 sites on the South Carolina Coastal Plain supporting loblolly-bay (table 1). For their purposes, these sites had only to include one loblolly-bay specimen larger than 1.2 inches (3 cm) d.b.h. and, therefore, the sites studied cannot all be considered bay forest stands. Redbay was also a dominant tree species on these sites with sweetbay occurring as well. The three other major tree species were blackgum [*Nyssa sylvatica* var *biflora* (Walt.) Sarg.], loblolly pine (*Pinus taeda* L.), and pond pine (*P. serotina* Michx.), together with the two dominant bay species, they comprised over 60 percent of the average site composition and 84 percent of the basal area. The three bay species alone averaged 299 stems per acre [740 stems per hectare (ha^{-1})] (39 percent of the total) and a basal area of 30.7 square feet per acre (7.05 m^2 ha^{-1}) (28 percent of the total). Shrub densities averaged 18,728 stems per acre (46,278 stems ha^{-1}), with *L. lucida* and *C. alnifolia* comprising 73 percent of the shrub composition.

Braham (see footnote 2) collected data in a bay forest at the Horticulture Crops Research Station, Clinton, NC. Loblolly-bay made up 58 percent of the total basal area and had the largest number of stems per ha (table 1). Red maple (*Acer rubrum* L.) was second with 16 percent of the total basal area and 130 stems per acre (321 stems ha^{-1}). Swamp tupelo, sweetgum (*Liquidambar styraciflua* L.), redbay, and sweetbay were the other major tree species in the community.

In a study describing the influence of fire on a typical "blackgum bay" in the Okefenokee Swamp in Georgia, the three bay species made up 24 percent and 54 percent of the total number of tree stems counted along two 50-chain transects (Cypert 1961) (table 1). Sweetbay was second only to blackgum in total number of stems for both transects. Basal areas for the three bay species combined were 28.5 and 77.2 square feet per acre (6.54 and 17.7 m^2 ha^{-1}), and total basal area averaged 202.6 square feet per acre (46.47 m^2 ha^{-1}) for the two transects. Basal area of sweetbay was second only to blackgum for both transects. Fire-induced mortality along the two transects averaged 5 and 50 percent for the bay species. Fire damage in this section of the swamp was considered typical.

In three other areas of the swamp that were severely burned, bay species made up 80 percent of 117 stems per acre (290 stems ha^{-1}), 71 percent of 21 stems per acre (52 stems ha^{-1}), and 8 percent of 203 stems per acre (501 stems ha^{-1}) before the fire. All stems of the bay species were killed by the fire; however, 17, 6, and 15 bay sprouts per acre (43, 15, and 37 bay sprouts ha^{-1}) were present several years after the fire. Pre-fire basal areas for the bay species were as follows for the three study areas: 80.7, 2.9, and 1.4 square feet per acre (18.5, 0.67, and 0.32 m^2 ha^{-1}), and for all tree species combined were 121.6, 11.8, and 95.1 square feet per acre (27.9, 2.7, and 21.8 m^2 ha^{-1}), respectively. These values represent a wide range of stand conditions on sites supporting typical bay forest vegetation.

In a typical South Carolina pocosin, tree densities and basal areas were lower than in other wetland forest types (Jones 1981) (table 1). Pond pine was most numerous, with loblolly-bay second in number. However, pondcypress [*Taxodium distichum* var. *nutans* (Ait.) Sweet] had greater basal area than loblolly-bay. Redbay and sweetbay densities combined had 10 stems per acre (25 stems ha^{-1}) with a combined basal area of 0.4 square feet per acre (0.08 m^2 ha^{-1}). Other tree and large shrub species on the site included swamp tupelo, red maple, wax-myrtle, and dahoon holly.

Jones (1981) also provides some additional information on diversity and community structure of six bay forest sites located in South Carolina. These sites averaged 11 tree species and 14 shrub species, a tree basal area of 145.2 square feet per acre (33.3 m^2 ha^{-1}) and a shrub cover of 10.7 inches per foot (88.9 cm m^{-1}).

Richardson and Gibbons (1993) summarized stand characteristics of short pocosins, tall pocosins, and bay/gum forests showing results similar to those reported above (table 1). Only tall pocosins had tree-size (loblolly) bay trees, but numbers and basal areas were low. Pond pine, red maple, and Atlantic white-cedar were the only other tree species present in the tall pocosin. The three bay species made up

Table 1—Stand structure characteristics in old-growth evergreen bay forests and related seral communities

Species	Gordonia sites[a]		Transect A[b]		Transect B[b]		SC pocosin[c]		Short pocosin[d]		Tall pocosin[d]		Bay/gum forest[d]		Hoffmann forest[e]		Bay forest community[e,f]	
	Basal area	Density	Basal area	Density	Basal area	Density	Basal area	Density	Basal area	Density	Basal area	Density	Basal area	Density	Basal area	Density	Basal area	Density
	m²/ha	*stems/ha*	*m²/ha*	*stems/ha*	*m²/ha*	*stems/ha*	*m²/ha*	*stems/ha*	*m²/ha*	*stems/ha*	*m²/ha*	*stems/ha*	*m²/ha*	*stems/ha*	*m²/ha*	*stems/ha*	*m²/ha*	*stems/ha*
Gordonia lasianthus	4.64	322	0.54	11	1.87	24	0.88	125	--	--	0.04	13	.98	233	14.51	93	17.26	482
Persea borbonia	2.15	343	.11	4	3.57	42	.06	18	--	--	--	--	4.74	308	--	--	1.04	68
Magnolia virginiana	.26	75	5.90	53	12.25	114	.02	7	--	--	--	--	.37	75	--	--	.28	99
Nyssa sylvatica	3.91	211	33.95	156	23.73	123	.42	77	--	--	--	--	7.13	33	--	--	--	--
N. biflora	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2.88	68
Pinus taeda	5.32	134	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.28	6
P. serotina	4.93	134	--	--	--	--	8.70	538	3.89	395	2.93	156	5.10	166	11.92	30	--	--
P. elliotti	--	--	--	--	.04	2	--	--	--	--	--	--	--	--	--	--	--	--
Taxodium ascendens	--	--	--	--	--	--	1.34	103	--	--	--	--	--	--	--	--	--	--
T. distichum	--	--	2.43	12	1.28	--	--	--	--	--	--	--	--	--	--	--	--	--
Quercus nigra	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.29	31
Acer rubrum	--	--	1.60	53	1.69	23	.07	7	--	--	.04	13	15.07	133	--	--	4.80	321
Chamaecyparis thyoides	--	--	--	--	--	--	--	--	--	--	2.08	75	--	--	--	--	--	--
Liquidambar styraciflua	.77	102	--	--	--	--	--	--	--	--	--	--	18.88	175	--	--	.81	6
Ilex cassine	--	--	1.59	98	.24	6	.01	4	--	--	--	--	--	--	--	--	--	--
I. opaca	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.59	86
Myrica cerifera	.46	156	--	--	--	--	.04	11	--	--	--	--	--	--	--	--	--	--
Symplocos tinctoria	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.23	3
Miscellaneous	2.37	435	.21	7	1.95	74	--	--	--	--	--	--	.43	108	--	--	.40	216
Total	24.81	1912	46.33	394	46.62	408	11.54	890	3.89	395	5.09	257	52.7	1231	26.43	123	29.86	1386

[a] Gresham and Lipscomb 1985.
[b] Cypert 1961.
[c] Jones 1981.
[d] Richardson and Gibbons 1993.
[e] Personal communication. 1994. Richard Braham, Professor, North Carolina State University, Raleigh, NC 27695.
[f] Located in Sampson County, North Carolina.

49 percent of the stems per acre and 12 percent of the basal area in the bay/gum forest. Other dominant tree species in that stand included red maple, sweetgum, blackgum, and pond pine. Sweetgum and red maple accounted for 36 percent and 27 percent of the basal area, respectively, and only 14 percent and 11 percent of the stems per acre.

Soils

Soils of bay forests are typically histosols, organic soils whose fertility depends on the hydrologic conditions. However, bay forest species can also be found on spodosols, inceptisols, ultisols, and to a lesser degree entisols and mollisols (Gresham and Lipscomb 1990). Variations in size and growth habit reported for the dominant tree species are probably related to differences in soil-site characteristics of the different soil orders. Elevated areas that depend on precipitation for nutrients and water (ombrotrophic) have the poorest productivity (Bridgham and Richardson 1993). However, poor sites may have greater species diversity due to the inability of any one species to dominate (Christensen 1981). Richardson and Gibbons (1993) suggest that the ecosystem gradient from short to tall pocosin to bay forest represents a natural gradient of increasing P availability and decreasing N:P ratio.

Accumulation of peat in the substrate is a common attribute of bay forests. Buell (1946) described in detail the soil profile in a typical Carolina bay—Jerome Bog in North Carolina. This particular bay had a small bay forest stand along its western edge. Peat accumulations ranged in depth from 4 to 11 feet (1.2 to 3.4 m) and consisted of a surface black peat and an underlying brown peat. In the deepest section of the bay, an underlying clay lens was also present over a sand layer. The surface of the bay was described as a "continuous thick, coarse, tough mat of tree roots and the roots and rhizomes of shrubs," indicating a shallow, surface-rooting habit in the peat substrate. The surface black peat was described as fine, soft, and sticky when wet, drying to a hard, brittle mass when dry, containing charred plant fragments and fine charcoal throughout, with pollen in the lower portion. The layer of black peat was thinnest under the bay forest. The underlying brown peat contained partially decomposed plant fragments, charcoal, numerous logs, and an abundance of pollen. Both the logs and the pollen were in a well-preserved state. The abundance of charcoal in the peat substrate, particularly its presence in the deepest sections of the underlying layer of brown peat, confirms the historical importance of fire in the shrub bog/bay forest ecosystem.

In North Carolina, Bridgham and Richardson (1993) studied the soil chemistry along a hydrology gradient in a freshwater peatland comprised of short pocosin, tall pocosin, and gum swamp. Bay species were not listed as major vegetation components of these communities; however, it is likely that soil chemistry is similar between these communities and evergreen bay forest sites, given the relationships between bay forests and pocosins. Both short and tall pocosins were nutrient-deficient with low levels of total and available P, N, and basic cations and a low pH. They differed primarily in seasonal hydrology and peat depth. Gum swamps had high levels of N and P but low levels of exchangeable calcium (Ca) and magnesium (Mg) and a low percent base saturation.

Richardson and Gibbons (1993) summarized Walbridge's (1986) soil chemistry work on pocosins and bay forests in North Carolina and found results similar to those of Bridgham and Richardson (1993) described above. Although pH values were similar among the three site types (3.7 to 3.9), exchangeable and total P as well as total N levels were higher in the bay forest than in the short and tall pocosins. Exchangeable P values ranged from 5.5 to 30.9 pounds per acre [6.2 to 34.6 kilograms (kg) ha^{-1}] and total P values ranged from 17.5 to 105.3 pounds per acre (19.6 to 118 kg ha^{-1}) for short and tall pocosin and bay forests. Total N values were 1,002.8, 847.6, and 1,993.2 pounds per acre (1124, 950, and 2234 kg ha^{-1}) for short pocosin, tall pocosin, and bay forests, respectively.

Christensen et al. (1988) also studied plant communities on peat and hydric mineral soils in the Croatan National Forest in North Carolina and found that pocosin soils had greater peat depth, exchangeable Mg and potassium (K), and cation exchange capacity and lower bulk density, extractable P, Ca:Mg ratios, and pH than the other plant communities studied.

Gresham and Lipscomb (1985) described soils associated with loblolly-bay and redbay on the South Carolina Coastal Plain. These included Leon sand, Lynn Haven fine sand, Rutledge loamy sand, Pickney loamy fine sand, and Chipley fine sand. The surface peat layer of these soils ranged from 1.2 to 5.6 inches (3 to 14 cm) thick. All soils were low in pH, ranging from 3.2 to 4.8. Also in South Carolina, Jones (1981 as cited by Sharitz and Gibbons 1982) described soils supporting bay forest stands as having more than 15.8 inches (40 cm) of organic substrate, 54 percent organic matter, 59 percent sand, 31 percent silt, and 10 percent clay.

In a typical Florida bayhead dominated by loblolly, sweet, and redbay, Monk (1966, 1968) described soil as being lower in Ca, Mg, K, Ca:Mg ratio, Ca:K ratio, milliequivalents of cations, P, and pH compared with mixed deciduous hardwood swamps found in Florida. These edaphic features were strongly related to the dominant tree species present in each of the swamp types studied. The greater longevity of evergreen foliage and high nutrient-use efficiency may give bay species an advantage over deciduous species on infertile sites (Christensen et al. 1981).

Also in Florida, Abrahamson et al. (1984) listed the soil series Sanibel and Pompano depressional, very poorly drained and poorly drained, respectively, as common to bayheads located on the Archbold Biological Station, a 3,904.2-acre (1580-ha) biological preserve located on the Lake Wales Ridge in Highlands County. The three bayheads found on the station occupied only 13.6 acres (5.52 ha) or 0.35 percent of the total land area of the station. Both soil types had a surface layer of muck; however, the layer was thinner on the Pompano depressional soil series. Nutrient analysis of the soil found it similar to other soil series supporting bay forests. Major nutrients averaged 2.1, 51.2, 42.2, and 57.2 pounds per acre (2.3, 57.4, 47.3, and 64.1 kg ha^{-1}) of P, K, Ca, and Mg, respectively, and pH averaged 4.7. Phosphorus and Ca values were lower than on other sites on the station and K and Mg values were high to intermediate compared to other forested sites.

Snags and Downed Woody Debris

No quantitative information was available in the literature on numbers of snags per acre or the amount of downed woody debris found in bay forest stands.

Threats to Existence

Many sites inhabited by bay species are so unproductive as to have limited usefulness in silviculture or agriculture. However, the use of phosphorus fertilization and bedding with minor drainage by timber companies has resulted in the establishment of pine plantations on many acres of pocosins. For example, in the 17-year period after 1962, pocosin acreage in North Carolina was decreased by 69 percent (Ash et al. 1983). Nevertheless, some timber companies are beginning to recognize the value of the rare bay forest type and are designating these small patches as natural preserves.[3] Peat mining is another threat to pocosins and bay forests. Interest in bioenergy fuels resulted in an increase in the number of permits to mine peat from North Carolina pocosins during the early 1980's (Ash et al. 1983).

Carolina bays are also subject to disturbance; half of all bays in South Carolina identified by Bennett and Nelson (1991) had one-fifth or more of their ellipse disturbed. Types of disturbance included ditches, row cropping, pine plantations, logging, development, roads, rights-of-way, and farm ponds. Eighty percent of all disturbed bays had multiple disturbances. However, as with some of the pocosins, State heritage trust programs are attempting to identify and protect as many relatively undisturbed Carolina bays as possible.

Aside from conversion, the greatest threat to "old-growth" bay forests is wildfire. Silvicultural practices, such as minor drainage, and agricultural use of adjacent upland areas could indirectly influence both the frequency and intensity of wildfire in shrub bogs and mature bay forests. A lowering of the water table could result in more frequent and deeper burns. On the other hand, prescribed fire and fire suppression, as practiced in forest management, could decrease the occurrence of wildfire, thus allowing the succession of shrub bogs to mature bay forests. For that reason, current forest management practices may promote the development of mature bay forests. At the same time, intense wildfires may be required for seedling recruitment, and lack thereof may prevent regeneration of many bay forest species. Drainage of these systems is also a form of disturbance, stimulating productivity and reducing species diversity (Christensen 1981).

The very existence of mature bay forests today is the result of a series of stochastic events that provided an exposed mineral-soil seedbed (probably the result of catastrophic wildfire) and yet an extended period free from wildfire. This had the combined effect of seedling establishment and uninterrupted succession to the climax condition—mature, evergreen bay forest. Management that will produce such a fortuitous chain of events might be difficult, if not impossible, in light of unpredictable weather patterns, land-use planning for adjacent areas, and public health concerns. It is probably more feasible to maintain current sites with adequate fire suppression and conservation easements than to attempt to create new mature bay forests. Fire suppression during the seral stages of bay ecosystem succession may lead to the eventual development of a mature bay forest, but may not be economically feasible or desirable in some circumstances.

[3] Personal communication. 1994. Mac Baughman, Westvaco Corporation, P.O. Box 1950, Summerville, SC 29484.

Representative Stands

Several representative stands of evergreen bay forests still exist throughout the Southeastern United States and can be found associated with each of the physiographic features described above. However, because little information is available on the ages of these stands, it is inappropriate to assume that they are "old-growth" bay forests. The individuals suggesting their inclusion in this list believed that these stands came closest to what might be considered "old growth" for this forest type. Further research in these areas would provide additional information regarding (1) age distributions of perennating parts, as well as aboveground stems; (2) successional relationships between pocosins, bay forests, and Atlantic white-cedar bogs; and (3) the influence of hydrology on peat accumulation, fire frequency and intensity, and nutrient cycling in these dynamic, interrelated systems.

North Carolina

The Hofmann Forest owned by the North Carolina Forestry Foundation has approximately 622.7 acres (252 ha) of bay forest in two forest-management units (FMU 218 and 404). These areas have reportedly not burned for over 40 years. In 1992, the average age of the stands was 56 years with one loblolly-bay 85 years old. Loblolly-bay was the dominant species followed by pond pine (table 1). This area is slowly succeeding from a pond pine stand to a bay forest in the absence of fire, and stands dominated by both species are interspersed in a patchwork mosaic (see footnote 2).

Dr. Braham (see footnote 2) also described a bay community in Sampson County, North Carolina, that he visited in 1988 (table 1). The stand contained some large specimens of loblolly-bay, one of which until recently had been on record as the North Carolina State Champion. Several trees in the stand exceeded 20.9-inches (53-cm) d.b.h.

Several other areas in North Carolina, classified as pocosins, are reported to have some bay forest intact. These include Angola Bay, Holly Shelter, and Green Swamp, all located in the southeastern corner of North Carolina. Angola Bay and Holly Shelter were classified by Wells (1946) as estuary bays, the elevated flat bottoms of ancient estuaries when sea levels were higher than those at present. Angola Bay has about 20,015.1 acres (8100 ha) of pocosin, Holly Shelter about 29,899.1 acres (12,100 ha), and Green Swamp about 13,837.6 acres (5600 ha) (Taggart 1981). The acreage of mature bay forest is unknown and is intermixed with more typical pocosin vegetation. Angola Bay and Holly Shelter are owned by the State of North Carolina and a portion of Green Swamp is owned by The Nature Conservancy. Kologiski (1977) described community structure in the Green Swamp and noted that in 1977, bay forest existed in areas that did not burn in 1955 and 1969, years of large fires in the swamp. The most recent fire previous to those fires was in 1932, suggesting that the bay forest areas were at least 45 years old in 1977. Little recent information was available for these sites.

South Carolina

River's Bridge State Park, located off Highway 641 in Bamberg County, has been reported to have a stand of old evergreen bay forest.[4] It fits the description of bay forests associated with stream margins.

Pigeon Pond (also known as Pigeon Bay) has also been reported to have a stand of loblolly-bay trees.[5] Pigeon Pond, a 808-acre (327-ha) Carolina bay located off State Road 135 between Highways 311 and 176 in Berkeley County, is owned by the Westvaco Corporation. It has been placed in the company's "unique stand category" and current plans are to preserve the bay as a natural area (see footnote 3). Bay trees in this Carolina bay are reported to be 11.9 to 14.2 inches (30 to 36 cm) in diameter.

Snuggedy Swamp, accessible only by boat, has also been reported to have an old-growth evergreen bay forest. Snuggedy Swamp is located on the Ashepoo River of the ACE Basin in Colleton County. Additional information concerning Snuggedy Swamp may be obtained from Mike Prevost with The Nature Conservancy or Dr. Bert Pittman of the South Carolina Heritage Trust Program.

Barry (1980) also mentions the existence of "a well-developed bay forest" as well as an Atlantic white-cedar bog in Lexington County, South Carolina. Attempts to verify their continued existence and to gain additional information as to their locations were not successful.

Georgia

Seventeen Mile Creek in Coffee County has an excellent example of a mature bay swamp, according to Wharton (1978). There are about 98.8 acres (40 ha) of bay swamp located along a 1.5-mile [2.4-kilometer (km)] stretch on the

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[4] Personal communication. 1994. Richard Porcher, Professor, The Citadel, 171 Moultrie Street, Charleston, SC 29409.

[5] Personal communication. 1994. Steve Bennet, The South Carolina Heritage Trust Program, Columbia, SC 29631.

eastern side of the stream. This bay swamp occurs at the base of sandhills that are present only on the eastern side of the stream. Other cover types (according to Wharton 1978) associated with the bay swamp include evergreen shrub bog, creek swamp, and upland, broadleaf, evergreen forest. Wharton states there is little evidence to suggest that the mature evergreen shrub bog is in succession toward bay forest; the shrub bog appears to be a stable community. Together, these plant communities occupy 200.2 acres (81 ha) of lowland along this creek bottom. The bay swamp is made up of mature loblolly-bay with lesser amounts of sweetbay and redbay. Dominant trees were up to 15 inches (38 cm) in d.b.h. In a personal communication during the summer of 1994, Wharton indicated that most of the stand was still intact, to the best of his knowledge.

Wharton also recommends two other locations in Georgia as examples of bay swamps—Ohoopee Sandhills in Emanuel County and Whitewater Creek, where it crosses Highway 137 in Taylor County. The Whitewater Creek community also contains Atlantic white-cedar in addition to the typical bay species and shrubs.

The Okefenokee Swamp ecosystem also has areas mapped as bay forests by McCaffrey and Hamilton (1984) with 80 percent of the canopy cover made up of "broad-leaved evergreen trees of medium height." Wharton (1978) classified the Okefenokee as a bog swamp but acknowledged the presence of many related communities made up of bay species along with others typical of bay swamps, e.g., cypress, blackgum, and red maple. Crew members of the USDA Forest Service, Forest Inventory and Analysis unit, reported pure stands of sweetbay in bays of the Okefenokee with an average d.b.h. of 16.1 inches (41 cm) and some individuals as large as 24 inches (61 cm) d.b.h. in 1980 to 1981.[6] The largest individuals appeared to be in decline and may have been representative of "old-growth" at that time.

Florida

The Bradwell Bay Wilderness Area, located in the Wakulla Ranger District of the Apalachicola National Forest, has been reported to have a stand typical of the bay forest type.[7]

The National Champion Loblolly-Bay tree is also located in Florida on the Ocala National Forest; however, it does not occur in a typical bay forest. According to Laura Lowery with the USDA Forest Service (see footnote 1), it is located in a rather unusual topographic setting—a 56.8-acre (23-ha) limestone sink with an underlying clay pan that occurs in a 882.2-acre (357-ha) longleaf pine "island" surrounded by sand pine scrub.

The Ocala National Forest does, however, have a representative bay swamp in the area known as Rocky Point. This site has been described as being an extensive, dry, pineland grading into a floodplain forest toward Lake George[8] and possesses many of the species considered typical of the evergreen bay forest type. The age of this stand was not given.

Alabama

Patches of bay forest are reported in the Conecuh National Forest, located in southern Alabama on the Florida border in Escambia and Covington Counties. These areas extend across the border into the northern Florida panhandle. The patches of bay forest occur as inclusions in other cover types. These areas include (1) Bear Bay, located in Covington County in Bradley Quad T2NR24W Sector 27, 26, 34; (2) Wolf Thicket Bay, also located in Covington County in Wing Quad T1NR14E Sector 11, 12, 1; and (3) Blackwater Bay and Falco Bay located in Wing Quad T1NR15E Sector 6, 5, 7, 8 and T1NR14E Sector 13, 18, respectively. Loblolly-bay has been found in only two locations, although redbay and sweetbay are present throughout. (This information was obtained through Jarel Hilton and Chris Oberholster of the Alabama Natural Heritage Program and through Suzanne Oberholster of the USDA Forest Service.)

Grand Bay Savannah Bioreserve is located on the border between Alabama and Mississippi on the coast below Interstate 10 in Mobile and Jackson Counties. This natural preserve has been reported to have patches of evergreen bay

[6] Personal communication. 1994. Mike Lick, USDA Forest Service, De Soto National Forest, Black Creek Ranger District, Wiggins, MS 39577.

[7] Personal communication. 1994. Donna Streng, Tall Timbers Research Station, Route 1, Box 678, Tallahassee, FL 32312.

[8] Personal communication. 1994. Gerald Guala II, Florida Museum of Natural History, University of Florida, Gainesville, FL 32611.

forest in a mosaic with other wetland cover types, such as titi-dominated shrub bogs and pond cypress strands.[9] [10] [11]

Mississippi

Grand Bay Savannah Bioreserve (described above for Alabama) also extends into Mississippi and may have scattered patches of evergreen shrub bog and bay forest.

Loblolly-bay is considered rare in Mississippi and bay forests in this State are composed primarily of the bay species sweetbay with some redbay. However, five or six sites have been reported to contain loblolly-bay, one of which is located on the DeSoto National Forest. This area is located on the Black Creek Ranger District in Compartment 47 along Turkey Branch. The 148.3-acre (60-ha) site includes a loblolly-bay forest and associated uplands and has been nominated as a Research Natural Area. The classification of this area as such should assure its preservation for future study.[12]

Most of the other drainheads supporting bay forests are mainly made up of sweetbay and were cutover in the 1930's and 1940's. These areas, which support almost pure stands of sweetbay, are small, some being only 5 to 7.4 acres (2 to 3 ha). The existence of mature bay trees on these sites is questionable[13] (see also footnote 6). In the future, some of these areas will be managed by the national forest as "lands unsuitable for timber" and may develop into mature bay forests.

Louisiana

Baygalls with sweetbay and redbay exist in the form of stream heads and drains, but currently loblolly-bay has not been located in the State of Louisiana.[14] The Kisatchie National Forest is the site of many such baygalls, supporting stands of large sweetbay; however, these stands may not be very old nor do they contain some of the largest sweetbay trees. Charter Oak Baygall, located in southeast Louisiana in St. Tammany Parish and owned by The Nature Conservancy, is one of the best representatives of the bay forest type in this State. Overstory dominants include swamp blackgum, sweetbay, and red maple. Redbay exists in the shrub understory along with *Cyrilla* and *Cliftonia*, which is rare for Louisiana. Swamp blackgum individuals as large as 35.4-inches (90-cm) d.b.h. and sweetbay individuals 29.9- to 35.4-inches (76- to 90-cm) d.b.h. have been reported.[15]

Summary

The evergreen bay forest cover type can occur on a variety of habitat types (abiotic features of the landscape based on land form and soil type) throughout the Atlantic and Gulf Coastal Plains. A common characteristic among the diverse landforms is the development of histic soils. Although duration, frequency, and seasonality vary, periods of soil saturation or soil inundation are common to sites supporting bay forests. Hydrologic and nutrient input for such sites can range from ombrotrophic to spring-fed, depending on the local topography and hydrology. These differences in hydrology, along with differences in soil type, lead to differences in fertility. The depth of the peat or histic horizon and the presence or absence of underlying mineral soil also influence site fertility, and these taken together strongly influence the successional relationships among sedge bogs, shrub bogs, and bay forests. Fire also plays a major role in the development of these systems, but its importance depends on the local topography and hydrology. All these site characteristics can vary significantly among pocosins, Carolina bays, and intermittent drainage heads. Although each of these landforms may support bay forest plant communities, the direction of succession and the position of each community type along the successional sere may vary from location to location. Hence, a single description of features indicative of old growth in these bay forest systems is not necessarily appropriate nor ecologically sound. Until these successional relationships are better

[9] Personal communication. 1994. Jarel Hilton, Alabama Natural Heritage Program, Department of Conservation and Natural Resources, Division of Lands, Folsom Administrative Building, 64 N. Union Street, Room 752, Montgomery, AL 36130.

[10] Personal communication. 1994. Ron Wieland, Mississippi Natural Heritage Program, Museum of Natural Science, 111 N. Jefferson Street, Jackson, MS 39201-2897.

[11] Personal communication. 1994. Will McDearman, Department of Fish and Wildlife, 6578 Dogwood View Parkway, Suite. A, Jackson, MS 39213.

[12] Personal communication. 1994. Steve Lee, USDA Forest Service, DeSoto National Forest, Black Creek Ranger District, Wiggins, MS 39577.

[13] Personal communication. 1994. Tom Cruise, USDA Forest Service, DeSoto National Forest, Black Creek Ranger District, Wiggins, MS 39577.

[14] Personal communication. 1994. Julia Larke, Louisiana State Heritage Program, Department of Wildlife and Fish, P.O. Box 98000, Baton Rouge, LA 70898-9000.

[15] Personal communication. 1994. Latimore Smith, Louisiana State Heritage Program, Department of Wildlife and Fish, P.O. Box 98000, Baton Rouge, LA 70898-9000.

understood, it may be more appropriate to consider preservation of representative systems with examples of the full mosaic of the successional sere on a variety of landforms.

The evergreen bay forest community is a rare and unique system regardless of the age of individuals. As previously discussed, the bay forest system as a whole, made up of the various successional stages associated with this cover type, is considered to be stable. Due to the susceptibility of some of these systems to fire, aboveground components may not be particularly old. However, belowground components, including root stocks and seed banks involved in regeneration, may be very old. Hence, old growth should be evaluated in terms of both aboveground and belowground components and community stability over time within the natural cycles of disturbance. Obviously, more information than is currently available in the literature is necessary to make ecologically sound descriptions of these systems. Recognizing that they are indeed rare, State and Federal agencies, along with conservation groups, are making an effort to set aside these bay forest systems. With further study, more ecologically appropriate descriptions will be possible.

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General Technical
Report SRS-4

An Old-Growth Definition for Eastern Riverfront Forests

James S. Meadows and Gregory J. Nowacki

A Section of the Old-Growth Definition Series

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Preface

Old growth is widely acknowledged today as an essential part of managed forests, particularly on public lands. However, this concept is relatively new, evolving since the 1970's when a grassroots movement in the Pacific Northwest began in earnest to define old growth. In response to changes in public attitude, the USDA Forest Service began reevaluating its policy regarding old-growth forests in the 1980's. Indeed, the ecological significance of old growth and its contribution to biodiversity were apparent. It was also evident that definitions were needed to adequately assess and manage the old-growth resource. However, definitions of old growth varied widely among scientists. To address this discrepancy and other old-growth issues, the National Old-Growth Task Group was formed in 1988. At the recommendation of this committee, old growth was officially recognized as a distinct resource by the Forest Service, greatly enhancing its status in forest management planning. The committee devised "The Generic Definition and Description of Old-Growth Forests" to serve as a basis for further work and to ensure uniformity between Forest Service Stations and Regions. Emphasis was placed on the quantification of old-growth attributes.

At the urging of the Chief of the Forest Service, all Forest Service Stations and Regions began developing old-growth definitions for specific forest types. Because the Southern and Eastern Regions share many forest communities (together they encompass the entire Eastern United States), their efforts were combined, and a cooperative agreement was established with The Nature Conservancy for technical support. The resulting project represents the first large-scale effort to define old growth for all forests in the Eastern United States. This project helped bring the old-growth issue to public attention in the East.

Definitions will first be developed for broad forest types and based mainly on published information and so must be viewed accordingly. Refinements will be made by the Forest Service as new information becomes available. This document represents 1 of 35 forest types for which old-growth definitions will be drafted.

In preparing individual old-growth definitions, authors followed National Old-Growth Task Group guidelines, which differ from the standard General Technical Report format in two ways—the abstract (missing in this report) and the literature citations (listed in Southern Journal of Applied Forestry style). Allowing for these deviations will ensure consistency across organizational and geographic boundaries.

September 1996

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An Old-Growth Definition for Eastern Riverfront Forests

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Introduction

Eastern riverfront forests fall into one of three types: (1) nearly pure eastern cottonwood (*Populus deltoides* Bartr. ex Marsh.) stands, (2) nearly pure black willow (*Salix nigra* Marsh.) stands, and (3) typical riverfront hardwood stands containing many species, but generally dominated by sycamore (*Platanus occidentalis* L.), pecan [*Carya illinoensis* (Wangenh.) K. Koch], green ash (*Fraxinus pennsylvanica* Marsh.), sugarberry (*Celtis laevigata* Willd.), and American elm (*Ulmus americana* L.). Both eastern cottonwood and black willow are temporary, pioneer forest types that become established on newly exposed river margins. Both species are short-lived and individuals rarely exceed 85 to 120 years of age. The eastern riverfront forest generally succeeds both eastern cottonwood and black willow forests, and represents an intermediate successional stage between these pioneer types and the sweetgum (*Liquidambar styraciflua* L.)-water oaks (*Quercus nigra* L., *Q. phellos* L., and *Q. nuttallii* Palmer) type on drier sites and the overcup oak (*Q. lyrata* Walt.)-water hickory [*Carya aquatica* (Michx. f.) Nutt.] type on wetter sites. Some evidence indicates that cottonwood/willow forests begin to break up at about 35 years of age and are replaced by eastern riverfront forests by 85 years of age. The eastern riverfront type lives for about 80 years before being gradually invaded by sweetgum and water oaks. However, repeated disturbances may allow eastern riverfront forests to persist on a site for several generations.

Description of Eastern Riverfront Forests

Description

Eastern riverfront forests occur over a large portion of the Eastern United States, essentially from the forest-prairie margin eastward to the Atlantic coastline and from Massachusetts to northeast Florida. These forests are most abundant within the Mississippi River watershed and along the East Coast, and are least common in the Appalachians. As the name implies, the forest type is predominant on sites immediately adjacent to large rivers and streams (i.e., river banks and first bottoms, natural levees, sandbars, and islands). Soils are alluvial and range widely in texture from sand to clay. Soils are generally moist year-round due to their topographic position and proximity to open water. Flooding occurs seasonally on most sites and often damages the vegetation. Because of flooding and rapid decomposition rates, litter accumulation on the forest floor is negligible except in depressions.

The principal species in eastern riverfront forests include river birch (*Betula nigra* L.), sycamore, silver maple (*Acer saccharinum* L.), American elm, eastern cottonwood, swamp cottonwood (*P. heterophylla* L.), sweetgum, and black willow. Live oak (*Quercus virginiana* Mill.) is an important component in southern forests. Common associates are red maple (*A. rubrum* L.), boxelder (*A. negundo* L.), hackberry (*Celtis occidentalis* L.), slippery elm (*U. rubra* Muhl.), black walnut (*Juglans nigra* L.), pin oak (*Q. palustris* Muenchh.), swamp white oak (*Q. bicolor* Willd.), green ash, sugarberry, water oak, and pecan. These pioneer forests are restricted to riparian zones where intense flooding, accompanied by ice and water scouring, routinely occur. These naturally occurring perturbations expose mineral soil, reduce competing undergrowth, and increase surface light—conditions required by the shade-intolerant species of this type. In this sense, flooding is considered a rejuvenating force. Within a dynamic river system, the location of these forests will shift as the river course changes, remaining adjacent to the active channel. In the absence of major flooding, these forests are susceptible to encroachments by shade-tolerant species. Indeed, many present-day stands are in jeopardy of successional change because hydrologic alterations by humans (e.g., dam and dike construction) have largely controlled this force in many locations.

Associated Society of American Foresters Forest Cover Types

One or more principal species in eastern riverfront forests is an associate species in the following Society of American Foresters forest cover types:

61—river birch-sycamore
62—silver maple-American elm
63—cottonwood
89—live oak
94—sycamore-sweetgum-American elm
95—black willow.

Physiographic Provinces (after Fenneman 1938)

Eastern riverfront forests are found in all physiographic provinces except for New England (White Mountain, Green Mountain, and Taconic sections), Adirondack Mountains, and Superior Upland.

Old-Growth Conditions

Living Tree Component

Eastern riverfront forests generally fall into one of three types: (1) nearly pure eastern cottonwood stands; (2) nearly pure black willow stands; and (3) typical riverfront hardwood stands containing many species but generally dominated by sycamore, pecan, green ash, sugarberry, and American elm.

Eastern cottonwood establishes itself on newly formed sandbars or newly exposed river margins. It forms nearly pure stands and is regarded as a temporary, pioneer forest type. Old-growth stands contain many large eastern cottonwood trees up to 72 inches [183 centimeters (cm)] in diameter at breast height (d.b.h.) and up to 175 feet [53 meters (m)] in height (Williamson 1913, Putnam and Bull 1932). Tree age at maturity ranges from 60 to 125 years; most stands begin to break up at around 85 years of age as significant mortality occurs (Williamson 1913, Putnam and Bull 1932). Openings created by dead trees or windthrow in old-growth eastern cottonwood stands are generally occupied by sycamore, American elm, sugarberry, pecan, and green ash (Putnam and others 1960). Because eastern cottonwood is intolerant of shade, stand density is generally low and may not exceed 32 trees per acre [79 trees per hectare (ha)] at stand maturity (Williamson 1913).

Black willow becomes established on newly exposed mud flats along rivers. It forms nearly pure stands and is also regarded as a temporary, pioneer forest type. Old-growth stands contain many large black willow trees up to 44 inches (112 cm) in d.b.h. and up to 130 feet (40 m) in height (Lamb 1915, Putnam and Bull 1932). Black willow is a short-lived species and rarely exceeds 85 years of age. In fact, most stands begin to break up at around 30 to 55 years of age as significant mortality occurs (Lamb 1915, Putnam and others 1960). Openings in old-growth black willow stands generally support wet-site species and are typically occupied by green ash, sugarberry, American elm, red maple, and baldcypress [*Taxodium distichum* (L.) Rich.] (Putnam and others 1960).

Typical eastern riverfront forests generally succeed both eastern cottonwood and black willow forests. These stands contain many species but are usually dominated by sycamore, pecan, green ash, American elm, and sugarberry and may also contain silver maple, river birch, boxelder, red maple, and baldcypress (Putnam 1951, Putnam and others 1960, Wiseman 1982). Sweetgum and various water oaks, such as water, willow (*Q. phellos* L.), and Nuttall (*Q. nuttallii* Palmer) oaks, may be found in the later stages of stand development (Putnam and others 1960, Sharitz and Mitsch 1993).

Wiseman (1982) described an old-growth eastern riverfront forest in the Mississippi Delta that may be regarded as representative of this forest type. The site is a heavy clay flat that typically floods to a depth of 3 to 4 feet (0.9 to 1.2 m) for 1 to 3 weeks each year. The overstory is dense and averages 220 square feet of basal area per acre (50.4 $m^2 ha^{-1}$) across the area. The overstory is dominated by green ash but also contains significant quantities of American elm, water hickory, baldcypress, and Nuttall oak. The stand appears to be in the transition phase between old-growth eastern riverfront forest and immature Nuttall oak-sweetgum. Evidence for this observation lies in the fact that the green ash component of the stand has steadily declined since 1935. Johnson and Price[1] reported that green ash comprised 39 percent of the basal area in 1935 and 34 percent in 1959; Wiseman (1982) found that the green ash component had dropped to only 31 percent of the basal area by 1981. Although no ranges of data were given by Wiseman (1982), average d.b.h. of green ash in the stand in 1981 was 25.8 inches (65.5 cm); average d.b.h. of apparently younger Nuttall oak found in canopy gaps was 16.1 inches (40.9 cm), thus supporting the notion that this old-growth stand is gradually breaking up and will eventually be replaced by a younger stand dominated by Nuttall oak.

Dead Tree Component

The number of standing snags and the volume of downed logs in the old-growth stage of eastern riverfront forests probably vary depending on the specific type of stand and its location. In general, downed logs likely decompose rapidly because decay organisms are active under the prevailing conditions of both high temperature and high relative humidity. Moreover, frequent flooding probably

[1] Johnson, R.L., Price, T.L. 1959. Final report—resumé of 20 years of hardwood management on the Delta Purchase Unit. Unpublished report. On file with: Southern Research Station, Southern Hardwoods Laboratory, P.O. Box 227, Stoneville, MS 38776.

removes much of the downed woody debris from these stands. Although Martin and Smith (1991) reported "several" standing snags and "many" downed logs in an old-growth eastern riverfront forest in Louisiana, no other information was found in the literature that quantified the dead tree component in the old-growth stage of this forest type.

Understory Characteristics

The understory in old-growth eastern riverfront forests is a diverse mixture of small trees, shrubs, seedlings, vines, and herbaceous vegetation. It may range from sparse to dense, particularly in openings created by dead trees or windthrow. Species composition of the understory also varies with the type of old-growth forest.

For example, McKnight (1969) reported that the understory in old-growth eastern cottonwood forests is generally extremely dense and may be composed of several tree species, typically dominated by boxelder, red maple, sugarberry, red mulberry (*Morus rubra* L.), and American elm. Woody vines are also abundant in old-growth eastern cottonwood forests and may restrict tree regeneration, especially in gaps. The most common woody vines and other vegetation found in the ground cover in old-growth eastern cottonwood forests are poison-ivy [*Toxicodendron radicans* (L.) O. Kuntze], grape (*Vitis* sp.), Virginia creeper [*Parthenocissus quinquefolia* (L.) Planch.], peppervine [*Ampelopsis arborea* (L.) Koehne], blackberry (*Rubus* sp.), common greenbrier (*Smilax rotundifolia* L.), and stinging nettle [*Laportea canadensis* (L.) Wedd.], also known as Canada woodnettle (McKnight 1969).

In the old-growth green ash stand in the Mississippi Delta, Wiseman (1982) found that the sapling and seedling component of the stand was dominated primarily by sugarberry, American elm, Nuttall oak, and possumhaw (*Ilex decidua* Walt.). Ground cover was sparse, except in the larger openings where woody vines, especially cat greenbrier (*S. glauca* Walter), common greenbrier, and trumpetcreeper [*Campsis radicans* (L.) Seem.], were abundant. Other woody vines and herbs found in the old-growth tract included peppervine, smallspike false-nettle [*Boehmeria cylindrica* (L.) Swartz], buckwheat vine (*Brunnichia cirrhosa* Gaertn.), sedge (*Carex* sp.), snailseed [*Cocculus carolinsis* (L.) DC.], rice cutgrass [*Leersia oryzoides* (L.) Swartz], Japanese honeysuckle (*Lonicera japonica* L.), Virginia creeper, blackberry, poison-ivy, starjasmine [*Trachelospermum difforme* (Walter) Gray], and grape.

Martin and Smith (1991) described the understory of an old-growth eastern riverfront forest in Louisiana as dominated primarily by American hornbeam (*Carpinus caroliniana* Walt.) but with lesser quantities of winged elm (*U. alata* Michx.), silverbell (*Halesia diptera* Ellis), American holly (*Ilex opaca* Ait.), yaupon (*I. vomitoria* Ait.), pawpaw [*Asimina triloba* (L.) Dunal], blueberry (*Vaccinium elliottii* Chapm.), giant cane [*Arundinaria gigantea* (Walter) Muhl.], and grape. Other woody plants and the major herbs found in the understory included poison-ivy, common greenbrier, elephant's foot (*Elephantopus carolinianus* Raeusch.), panicum (*Panicum* sp.), sedge, violet (*Viola* sp.), and grapefern (*Botrychium* sp.). In general, Martin and Smith (1991) described the understory as sparse except under canopy gaps.

Soils and Microtopography

Eastern riverfront forests occur along the margins of both major rivers and minor streams on sites that are seasonally flooded for short periods. Flooding may be deep, as much as 6 to 8 feet (1.8 to 2.4 m) during atypical years, but generally lasts only 1 to 3 weeks. Soils are young and generally have little or no profile development.

Both eastern cottonwood and black willow become established on newly formed sandbars or mud flats and on newly exposed river margins. Soils range from coarse sand to fine clay, with eastern cottonwood generally found on coarse sediments and black willow found on fine sediments. As further deposition of silt and other sediments occurs on these sites and the substrate develops, the cottonwood/willow type is replaced by the riverfront hardwood type, dominated by sycamore, pecan, and American elm on the drier sites and by green ash, sugarberry, and American elm on the wetter sites (Sharitz and Mitsch 1993).

Topography is generally the ridge and swale type commonly found adjacent to rivers and streams. Both low and high flats separate the ridges. Eastern riverfront forests occur on all these topographic features; species occurrence depends greatly upon landscape position, soil texture, and soil moisture regime.

Other Important Features

Although species diversity and other measures of richness are generally expected to increase as forests approach the old-growth stage of stand development, Wiseman (1982) reported only moderate diversity and evenness ($H'=1.79$; $J'=0.86$) in an old-growth eastern riverfront forest in the Mississippi Delta.

Forest Dynamics and Ecosystem Function

The cottonwood/willow forest types represent temporary, pioneer stages of forest succession. Because both of these species require bare mineral soil for establishment, their natural development is generally restricted to newly exposed sandbars and mud flats along the margins of rivers and streams. They both attain their best development along major rivers in the Lower Mississippi Valley. Because of their extreme intolerance to shade, neither species is capable of succeeding itself on these newly formed lands. Continued natural establishment of these species depends upon continued formation of new land along major rivers. However, because many of the rivers within the Lower Mississippi Valley have been channelized and leveed, formation of new land has dramatically declined in the recent past. Natural establishment of new eastern cottonwood and black willow forests has declined concomitantly during this same period. Although never abundant, due to premature logging of these commercially valuable timber species, old-growth eastern cottonwood and black willow forests will likely decline in number because human-caused alterations in the hydrology of major river systems within the Lower Mississippi Valley prevent establishment.

The eastern riverfront forest represents an intermediate successional stage between the pioneer cottonwood/willow types and the sweetgum-water oaks (water, willow, and Nuttall) type on drier sites and the overcup oak-water hickory type on wetter sites (Putnam and others 1960). Shelford (1954, 1974) speculated that cottonwood/willow forests begin to break up at about 35 years of age and are replaced by eastern riverfront forests by 85 years of age. The eastern riverfront type lives for about 80 years before being gradually invaded by sweetgum and water oaks. This begins about 165 years after initial establishment of the cottonwood/willow forests on new land and generally lasts for about 85 years, so that the sweetgum-water oaks type has replaced the eastern riverfront forest about 250 years after initial invasion of the site by eastern cottonwood and black willow. However, Sharitz and Mitsch (1993) pointed out that repeated disturbances, such as severe flooding or logging, may allow the eastern riverfront forest type to persist on the site for several generations over long periods of time. In the absence of such severe disturbances, the eastern riverfront forest will soon be replaced by the sweetgum-water oaks type.

Representative Old-Growth Stands

Representative old-growth eastern riverfront forests occur at the following two locations:

- Green Ash Natural Area, Delta National Forest, near Rolling Fork, MS—60 acres (24 ha)
- River Birch Bottom, Kisatchie National Forest, near Alexandria, LA—9 acres (3.6 ha)

Areas where representative old-growth eastern riverfront forests may occur include:

- Dardenne Creek, August A. Busch Memorial Wildlife Area, near Weldon Spring, MO
- Big Oak Tree State Park, Mississippi County, Missouri
- Westport Island Natural Area, near Elsberry, MO—480 acres (194 ha)
- Cow Shoals, Cleburne County, Arkansas
- Sulphur River Wildlife Management Area, Miller County, Arkansas
- Broad River, Chester County, South Carolina

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Table 1 (English units)—Standardized table of old-growth attributes for eastern riverfront forests

Quantifiable attribute	Value		Number of stands[a]	References
	Range	Mean		
Stand density (no.acre^{-1})				
—trees ≥4 in. d.b.h.	32-179	112	3	Williamson 1913 Winters et al. 1938 Wiseman 1982
Stand basal area (ft^2 acre^{-1})				
—trees ≥ 4 in. d.b.h.	160-220	190	2	Robertson et al. 1978 Wiseman 1982
Age of large trees (yrs)[b]				
—all species	58-120	84	9	Hardin et al. 1989 Lamb 1915 Martin and Smith 1991 Putnam and Bull 1932 Williamson 1913
Number of 4-in. size classes				
—starting at 4 in. d.b.h.	6-10	8	3	Martin and Smith 1991 Winters et al. 1938 Wiseman 1982
D.b.h. (or maximum d.b.h.) of largest trees (in)[b]				
—all species	25-72	39	6	Lamb 1915 Martin and Smith 1991 Putnam and Bull 1932 Williamson 1913
Standing snags (no.acre^{-1})				
—snags ≥ 4 in. d.b.h.	Several		1	Martin and Smith 1991
Downed logs (ft^3 acre^{-1})	Many	Many	1	Martin and Smith 1991
Decadent trees (no.acre^{-1})[c]				
—trees ≥ 4 in. d.b.h.	62	62	1	Winters et al. 1938
Number of canopy layers	3+	3+	5	Martin and Smith 1991 Putnam and Bull 1932 Wiseman 1982
Percent canopy in gaps[d]				
Other features	H'=1.79 J'=0.86		1	Wiseman 1982

[a] Number of stands may not equal the number of citations.

[b] Includes dominant and codominant trees that comprise the upper canopy.

[c] Includes deformed, bole-scarred, spike-topped, and wind-damaged trees.

[d] Data unavailable.

Table 1 (metric units)—Standardized table of old-growth attributes for eastern riverfront forests

Quantifiable attribute	Value: Range	Value: Mean	Number of stands[a]	References
Stand density (no.ha^{-1}) —trees ≥10 cm d.b.h.	79-442	277	3	Williamson 1913 Winters et al. 1938 Wiseman 1982
Stand basal area (m^2 ha^{-1}) —trees ≥10 cm d.b.h	37-50	44	2	Robertson et al. 1978 Wiseman 1982
Age of large trees (yrs)[b] —all species	58-120	84	9	Hardin et al. 1989 Lamb 1915 Martin and Smith 1991 Putnam and Bull 1932 Williamson 1913
Number of 10-cm size classes —starting at 10 cm d.b.h.	6-10	8	3	Martin and Smith 1991 Winters et al. 1938 Wiseman 1982
D.b.h. (or maximum d.b.h.) of largest trees (cm)[b] —all species	64-183	99	6	Lamb 1915 Martin and Smith 1991 Putnam and Bull 1932 Williamson 1913
Standing snags (no.ha^{-1}) —snags ≥10 cm d.b.h.	Several		1	Martin and Smith 1991
Downed logs (m^3 ha^{-1})	Many	Many	1	Martin and Smith 1991
Decadent trees (no.ha^{-1})[c] —trees ≥10 cm d.b.h.	153	153	1	Winters et al. 1938
Number of canopy layers	3+	3+	5	Martin and Smith 1991 Putnam and Bull 1932 Wiseman 1982
Percent canopy in gaps[d]				
Other features	H'=1.79 J'=0.86		1	Wiseman 1982

[a] Number of stands may not equal the number of citations.
[b] Includes dominant and codominant trees that comprise the upper canopy.
[c] Includes deformed, bole-scarred, spike-topped, and wind-damaged trees.
[d] Data unavailable.

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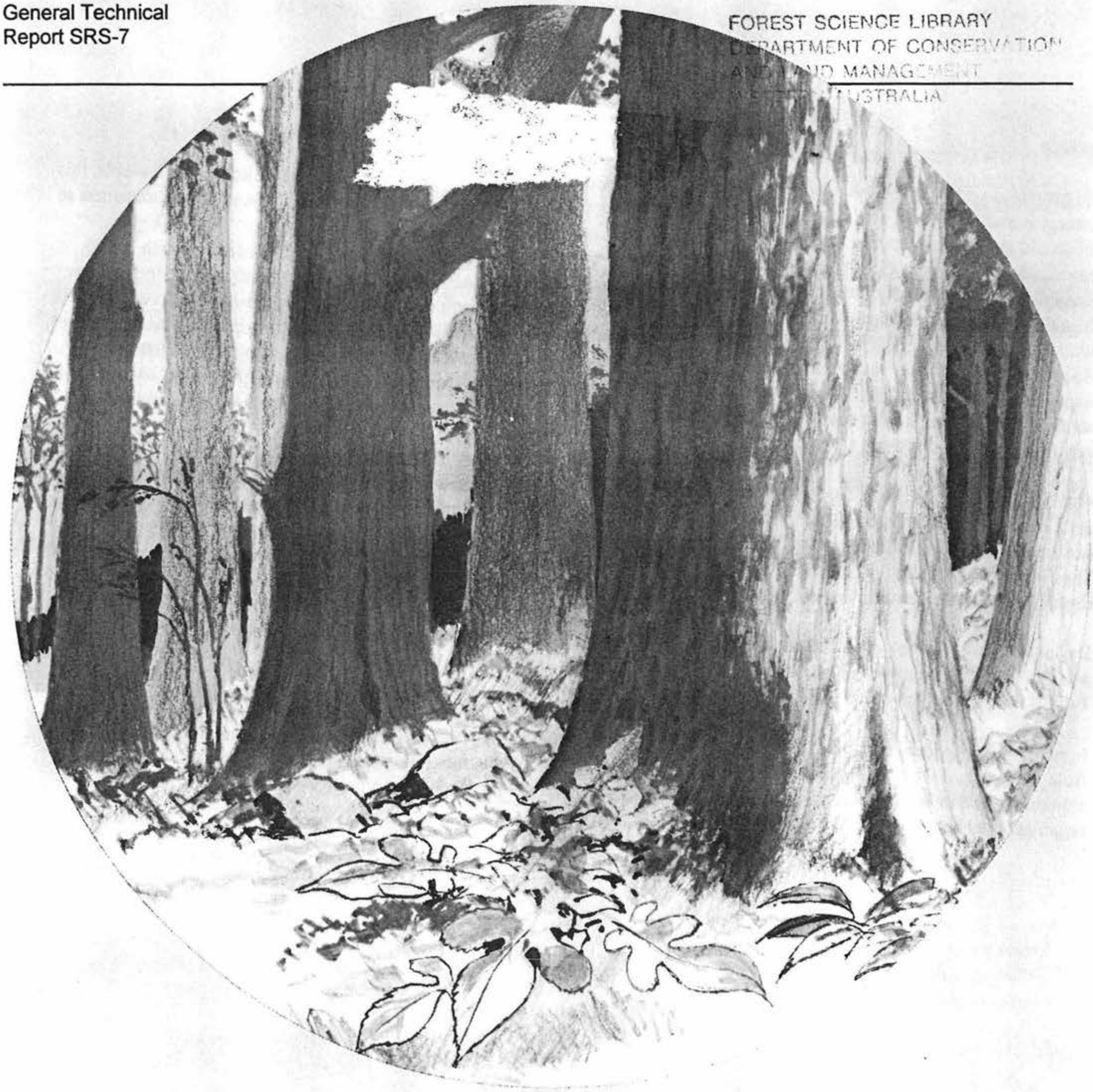
General Technical
Report SRS-7

An Old-Growth Definition for Xeric Pine and Pine-Oak Woodlands

Paul A. Murphy and Gregory J. Nowacki



A Section of the Old-Growth Definition Series

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Preface

Old growth is widely acknowledged today as an essential part of managed forests, particularly on public lands. However, this concept is relatively new, evolving since the 1970's when a grassroots movement in the Pacific Northwest began in earnest to define old growth. In response to changes in public attitude, the U.S. Department of Agriculture, Forest Service, began reevaluating its policy regarding old-growth forests in the 1980's. Indeed, the ecological significance of old growth and its contribution to biodiversity were apparent. It was also evident that definitions were needed to adequately assess and manage the old-growth resource. However, definitions of old growth varied widely among scientists. To address this discrepancy and other old-growth issues, the National Old-Growth Task Group was formed in 1988. At the recommendation of this committee, old growth was officially recognized as a distinct resource by the Forest Service, greatly enhancing its status in forest management planning. The committee devised "The Generic Definition and Description of Old-Growth Forests" to serve as a basis for further work and to ensure uniformity among Forest Service Stations and Regions. Emphasis was placed on the quantification of old-growth attributes.

At the urging of the Chief of the Forest Service, all Forest Service Stations and Regions began developing old-growth definitions for specific forest types. Because the Southern and Eastern Regions share many forest communities (together they encompass the entire Eastern United States), their efforts were combined, and a cooperative agreement was established with The Nature Conservancy for technical support. The resulting project represents the first large-scale effort to define old growth for all forests in the Eastern United States. This project helped bring the old-growth issue to public attention in the East.

Definitions will first be developed for broad forest types and based mainly on published information and so must be viewed accordingly. Refinements will be made by the Forest Service as new information becomes available. This document represents 1 of 35 forest types for which old-growth definitions will be drafted.

In preparing individual old-growth definitions, authors followed National Old-Growth Task Group guidelines, which differ from the standard General Technical Report format in two ways—the abstract (missing in this report) and the literature citations (listed in Southern Journal of Applied Forestry style). Allowing for these deviations will ensure consistency across organizational and geographic boundaries.

April 1997

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P.O. Box 2680
Asheville, NC 28802

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Paul A. Murphy and Gregory J. Nowacki

Introduction

This old-growth type differs from the general concept of old growth, which is generally viewed as multicanopied and with a luxuriant understory. This type occurs in more hostile environments, such as exposed ridges and southern slopes, and often the midcanopy layers below the overstory are missing. This type often occurs as relatively small, isolated fragments because it is usually restricted to minor topographic features. These differences make the xeric pine and pine-oak woodlands unique among the old-growth types.

Description of Forest Type Group

General Location

Xeric pine and pine-oak forests and woodlands are found throughout most of the Eastern United States, from southern Missouri to northeast Texas eastward to the Atlantic coastline from southern Maine to South Carolina. The chief physiographic provinces containing these forests and woodlands are the Ozark Plateau, Ouachita Mountains, Interior Low Plateau, Appalachian Plateau, Ridge and Valley, Blue Ridge, Piedmont, West Gulf Coastal Plain, Embayed Coastal Plain, and southern New England.

Site Characteristics

These communities normally exist on dry, infertile sites with strongly acidic soils. Xeric site conditions result from (1) low precipitation, (2) limited moisture absorption/ retention (exposed bedrock, steep slopes, coarse-textured soils, rocky soils, shallow soils), and/or (3) high evapotranspiration rates (southern exposures). Most xeric pine and pine-oak forests and woodlands occur on ridgetops and south-facing upper slopes in the mountains or on excessively drained, sandy uplands in gentle terrain (e.g., Piedmont).

Species

Principal species of these xerophytic communities include pitch pine (*Pinus rigida* Mill.), Virginia pine (*P. virginiana* Mill.), shortleaf pine (*P. echinata* Mill.), Table Mountain pine (*P. pungens* Lamb.), and chestnut oak (*Quercus prinus* L.). Associated species are scarlet oak (*Q. coccinea* Muenchh.), black oak (*Q. velutina* Lam.), blackjack oak (*Q. marilandica* Muenchh.), post oak (*Q. stellata* Wangenh.), northern red oak (*Q. rubra* L.), southern red oak (*Q. falcata* Michx.), white oak (*Q. alba* L.), and pignut hickory (*Carya glabra* Mill.). Understories consist predominantly of ericaceous shrubs, and within its range, bear oak (*Q. ilicifolia* Wangenh.).

Site Disturbances

Due to the prevailing xeric conditions, these forests and woodlands have had frequent fires. Before European settlement, most fires were probably low-intensity, surface burns, although occasional catastrophic canopy fires undoubtedly occurred in some stands. On sites where nutrients and moisture are not extremely limiting, periodic burns are usually necessary to maintain these early successional forests, especially the pines (*Pinus* spp.). Over many decades, accumulation of dead biomass can predispose these forests to catastrophic fire. However, even in the absence of fire, successional changes are normally restricted (possibly ending with oak domination) because most sites are infertile and dry.

Distinguishing Features

Distinctive differences exist in this group east and west of the Mississippi River. All the principal species are found east of the river; shortleaf pine is the only pine species occurring west of the river; and chestnut oak is confined to east of the river.

The occurrence of pines in the Appalachian Highlands is influenced by elevation, aspect, and exposure, even on xeric sites. In the Great Smoky Mountains, Whittaker (1956) found that Virginia and shortleaf pines were concentrated at low elevations and were scarce above 2,500 feet [762 meters (m)]; pitch pine dominated between 2,200 and 3,200 feet (671 and 975 m); and Table Mountain pine was the most abundant pine at higher elevations. Table Mountain pine occurred most commonly between elevations of 1,000 and 4,000 feet (305 and 1219 m); occurrences above 4,000 feet (1219 m) were confined to its southern range in North Carolina and Tennessee (Zobel 1969). Golden (1981) found that communities of pitch pine and Table Mountain pine tended to occur on exposed ridges, upper slopes, or steep south-southwest slopes at middle to low elevations, less than 4,100 feet (1250 m), in the central Great Smoky Mountains. Racine (1966) observed that the most important factor affecting the dominance of these pine species in the Blue Ridge escarpment was ridge width; however, pine dominance was also influenced by ridge prominence in relation to surrounding topography and a southern exposure. Racine (1966) reported that ridge orientation was also important; on east-west ridges pine communities would extend down the south slopes almost to cove forests, but on north-south ridges the pines were confined to a narrow strip on the crest. Hack and Goodlett (1960) reported that pitch pine and Table Mountain pine in the upper Shenandoah Valley were restricted to noses, ridges, and convex slopes. In the Interior Highlands of Arkansas, Oklahoma, and Missouri, xeric communities of shortleaf pine are found up to 2,000 feet (610 m) on south-facing slopes and ridges that are harsh, refractory sites (Eyre 1980).

Associated Society of American Foresters Cover Types:

43—bear oak (in part)
45—pitch pine (in part)
75—shortleaf pine
76—shortleaf pine-oak
78—Virginia pine-oak
79—Virginia pine

Old-Growth Conditions

Living Tree Component

Because of the poor growing conditions, tree size and other old-growth characteristics of xeric pine and pine-oak woodlands are vastly different from other old-growth types; e.g., mixed mesophytic (Martin 1991). For instance, Stahle and others (1985) described the vegetation on a steep, xeric, south-facing slope of the Roaring Branch Research Natural Area in Arkansas as open with few overstory trees and many canopy gaps. Most shortleaf pines on this site were large, scattered trees. Stahle and others (1985) also characterized a xeric shortleaf pine forest in Hot Springs National Park as rather open with shortleaf the most common species but with abundant white oak, various hickories (*Carya* spp.), and other hardwoods. Whittaker (1956) portrayed Table Mountain pine stands in the Great Smoky Mountains as having an open pine canopy above a dense, low, ericaceous shrub layer.

Because this forest type group includes several species and covers a wide geographic area, stand characteristics also differ. Tree density runs from about 45 trees per acre [11 per hectare (ha)] for Table Mountain pine to more than 300 per acre (741 per ha) for shortleaf pine in the Ouachita Mountains (table 1). Martin (1991) stated that old-growth basal areas on dry sites would probably be less than 109 square feet per acre (25 m^2/ha).

The average age of large trees in table 1 was taken as the midpoint between the mature age and maximum age given by Hepting (1971) for each species; values range from 140 to 200 years. Pitch pine, Table Mountain pine, and Virginia pine will usually grow to no more than about 15 inches [38 centimeters (cm)] in diameter at breast height (d.b.h.) on xeric sites in the Great Smoky Mountains (Whittaker 1956). But shortleaf pine in the Interior Highlands may reach 25 inches (64 cm) in d.b.h. on these sites (Fountain and Sweeney 1985).

Limited information is available on the number of 4-inch (10-cm) diameter classes. Whittaker (1956) showed four 4-inch (10-cm) diameter classes in a stand table for Table Mountain pine in the Great Smoky Mountains. A sample of south-facing midslopes in the Roaring Branch Research Natural Area (Fountain and Sweeney 1985) revealed six classes for shortleaf pine and four classes for hardwoods.

Dead Tree Component

The only information available about dead tree components involves glade and decadent stands in the Hot Springs National Park (Johnson and Schnell 1985). The glade type occurs as narrow strips on ridgetops and steep, south-facing slopes with thin, rocky soils and rock outcrops. The overstory is composed of pines, oaks, and hickories; the understory is primarily grass with some herbaceous cover. The decadent stands have medium-to-heavy fuel loads and are composed of large, old, shortleaf pine trees scattered among smaller pines and hardwoods. Most of the large downed and dead woody material and snags are pine. Some stands have a large amount of dead material, probably because they accumulated more biomass than the glades and went longer without fire.

Other Components

In the Great Smoky Mountains, Whittaker (1956) observed that common associates of Virginia pine at lower elevations were chestnut oak, scarlet oak, white pine (*P. strobus* L.), blackgum (*Nyssa sylvatica* Marsh.), black oak, and white oak. Shrub-layer coverage ranges from 10 to 40 percent; common species are *Kalmia latifolia* L., *Vaccinium vacillans* Torr., *V. stamineum* L., *Ilex montana* var. *beadlei* Ashe, and *Smilax* spp. The herb-layer coverage is only 2 to 10 percent with *Andropogon scoparius* Michx. being the most prevalent species. Chestnut oak is a common associate of pitch pine along with other species. Shrub coverage is greater, from 40 to 70 percent, and the dominant species are *K. latifolia*, *V. vacillans*, and *V. hirsutum* Buckl. Herb coverage is 5 to 20 percent with *A. scoparius* Michx., *Pteridium aquilinum* var. *latisculum* Desvaux, *Epigaea repens* L., and *Gaultheria procumbens* L. the most common species. At high elevations, pitch pine, scarlet oak, chestnut oak, and blackgum are associates of Table Mountain pine. *Kalmia latifolia* and *Vaccinium* spp. dominate the shrub layer, which ranges from 60 to 90 percent coverage. *Galax aphylla* L., *E. repens* L., and *G. procumbens* L. are the important species of the herb layer, which ranges from 5 to 20 percent coverage.

In addition to shortleaf pine, the south-facing slopes at Hot Springs National Park (Dale and Watts 1980) support post oak, blackjack oak, and black hickory (*C. texana* Buckl.). Ground cover is sparse but comprises a variety of species; dominants are *Tephrosia virginiana* (L.) Persoon and *Brachyelytrum erectum* (Schreb.) Beauv.

In Le Flore County, Oklahoma, Johnson (1986) found several species characteristic of xeric sites associated with shortleaf pine on south-facing slopes. *Vaccinium vacillans* Torr. dominated the shrub layer.

On the Roaring Branch Research Natural Area in Arkansas, Fountain and Sweeney (1985) found that white oak, northern red oak, black oak, and mockernut hickory [*C. tomentosa* (Poir.) Nutt.] were common associates of shortleaf pine on a south-facing midslope. The shrub layer was dominated by *V. arboreum* Marsh., *V. vacillans*, and *Q. alba*. Typical herbaceous species were *Panicum* spp. L., *Danthonia spicata* (L.) Beauv., and *Desmodium* spp. Desvaux.

Forest Dynamics and Succession

Xeric pine and pine-oak woodlands occur primarily in small patches that have survived settlement, mining, logging, farming, grazing, and other activities that have greatly affected the more fertile and accessible forest land. Typically, they occur on steep slopes, ridgetops, and less fertile sites, thus discouraging human exploitation. Confined to these rugged locations, most old-growth xeric pine and pine-oak woodlands are small and scattered rather than in large contiguous blocks. Stahle and others (1985) stated that some of the old growth still found in the Eastern United States occurs on these sites as small pockets of relict stands.

Because of greater productivity and easier access, forests in the Piedmont and Coastal Plain have been so extensively logged and cleared that old-growth forests, including xeric pine and pine-oak woodlands, are rare. Jones (1988) described the xeric sites in the South Carolina Piedmont where this old-growth type could occur as high-landscape positions, southerly and westerly aspects, and heavy clay-textured soils or rocks close to the soil surface. The driest sites were on exposed ridge flats and upper slopes of any aspect with soils that had a heavy clay subsurface within 1.0 feet (0.3 m) of the surface or bedrock within 2.0 to 2.3 feet (0.6 to 0.7 m) of the surface. Ward (1984) described xeric sites in the east Texas Coastal Plain as rounded to flat-topped hills with sandy, porous soils.

Whether this forest type group is self-sustaining or is a seral stage is debatable. Even the historic role of fire is not completely understood. Whittaker (1956) suggested that intense fires on xeric sites in the Great Smoky Mountains might produce an even-aged pine stand. As this pine stand ages, mortality creates small openings where a new generation of pine becomes established. Whittaker (1956) speculated that these successive waves of new seedlings might be the reason for bimodal distributions in these stands. He also stated that fire alone does not produce these pine stands. Barden and Woods' (1976) results indicate that not every lightning fire is intense enough to eliminate the existing forest canopy in the Great Smoky Mountains; thus, most lightning fires would not necessarily initiate new pine reproduction. Harmon and others (1983) found in the Great Smoky Mountains National Park that occurrence of both natural and anthropogenic fires increased with elevation, but most of the lightning fires occurred on xeric sites. Barden (1977) found that Table Mountain pine maintained itself for 87 years without fire on Looking Glass Mountain in North Carolina. Zobel (1969) suggested that Table Mountain pine might be self-sustaining on rock outcrops or shale slopes where hardwood species grow poorly. The pines might

Table 1 (English units)[a]—Old-growth attributes for xeric pine and pine-oak forests and woodlands

Quantifiable attribute	Value		No. of stands[b]	References
	Range	Mean		
Stand density (no./acre; ≥4-in d.b.h.)				
Hot Springs National Park				Dale and Watts 1980
Shortleaf pine	234-434	340.0	NA	
Hardwoods	84-167	112.0	NA	
Oklahoma				Johnson 1986
Shortleaf pine and hardwoods (>2-in d.b.h.)	NA	253.0	NA	
Roaring Branch RNA				Fountain and Sweeney 1985
Shortleaf pine	NA	56.0	1	
Hardwoods	NA	169.0	1	
Great Smoky Mountains				Whittaker 1956
Table Mountain pine	NA	45.0	NA	
Stand basal area (ft^2/acre; ≥4-in d.b.h.)				
Hot Springs National Park				Dale and Watts 1980
Shortleaf pine	36.7-76.7	56.7	NA	
Hardwoods	18.4-21.7	20.0	NA	
Oklahoma				Johnson 1986
Shortleaf pine and hardwoods (>2-in d.b.h.)	NA	94.0	NA	
Roaring Branch RNA				Fountain and Sweeney 1985
Shortleaf pine	NA	30.0	1	
Hardwoods	NA	51.0	1	
Great Smoky Mountains				Whittaker 1956
Table Mountain pine	NA	24.4	NA	
Age of large trees (years)				Hepting 1971
Shortleaf pine	NA	200.0	NA	
Pitch pine	NA	150.0	NA	
Table Mountain pine	NA	200.0	NA	
Virginia pine	NA	140.0	NA	
Number of 4-in size classes (≥4-in d.b.h.)				
Roaring Branch RNA				Fountain and Sweeney 1985
Shortleaf pine	NA	6.0	1	
Hardwoods	NA	4.0	1	
D.b.h. (or maximum d.b.h.) of largest trees (inches)[c]				
Shortleaf pine	22-25	23.0	1	Fountain and Sweeney 1985
Pitch pine	12-15	NA	NA	Whittaker 1956
Table Mountain pine	10-15	NA	NA	Whittaker 1956
Virginia pine	10-15	NA	NA	Whittaker 1956
Standing snags (tons/acre; ≥3-in d.b.h.)				
Hot Springs National Park				Johnson and Schnell 1985
Glade	NA	3.5	NA	
Decadent stand	NA	13.1	NA	
Downed logs (tons/acre)				
Hot Springs National Park				Johnson and Schnell 1985
Glade	NA	.1	NA	
Decadent stand	NA	4.2	NA	
Decadent trees[d] (no./acre; ≥4-in d.b.h.)	NA	NA	NA	NA
Canopy layers (no.)[e]	NA	NA	NA	NA
Canopy in gaps (percent)	NA	NA	NA	NA
Other features	NA	NA	NA	NA

[a] NA in the table denotes that information is not available.
[b] Number of stands may not equal the number of citations.
[c] Includes dominant and codominant trees that make up the upper canopy.
[d] Includes deformed, bole-scarred, spike-topped, and wind-damaged trees.
[e] May be bimodal.

Table 1 (metric units)[a]—Old-growth attributes for xeric pine and pine-oak forests and woodlands

Quantifiable attribute	Value: Range	Value: Mean	No. of stands[b]	References
Stand density (no./acre; ≥10-cm d.b.h.)				
Hot Springs National Park				Dale and Watts 1980
Shortleaf pine	578-1072	840.0	NA	
Hardwoods	208- 413	277.0	NA	
Oklahoma				Johnson 1986
Shortleaf pine and hardwoods (>5-cm d.b.h.)	NA	625.0	NA	
Roaring Branch RNA				Fountain and Sweeney 1985
Shortleaf pine	NA	138.0	1	
Hardwoods	NA	418.0	1	
Great Smoky Mountains				Whittaker 1956
Table Mountain pine	NA	111.0	NA	
Stand basal area (m^2/ha; ≥10-cm d.b.h.)				
Hot Springs National Park				Dale and Watts 1980
Shortleaf pine	8.4-17.6	13.0	NA	
Hardwoods	4.2- 5.0	4.6	NA	
Oklahoma				Johnson 1986
Shortleaf pine and hardwoods (>5-cm d.b.h.)	NA	21.6	NA	
Roaring Branch RNA				Fountain and Sweeney 1985
Shortleaf pine	NA	6.9	1	
Hardwoods	NA	11.7	1	
Great Smoky Mountains				Whittaker 1956
Table Mountain pine	NA	5.6	NA	
Age of large trees (years)				Hepting 1971
Shortleaf pine	NA	200.0	NA	
Pitch pine	NA	150.0	NA	
Table Mountain pine	NA	200.0	NA	
Virginia pine	NA	140.0	NA	
Number of 10-cm size classes (≥10-cm d.b.h.)				
Roaring Branch RNA				Fountain and Sweeney 1985
Shortleaf pine	NA	6.0	1	
Hardwoods	NA	4.0	1	
D.b.h. (or maximum d.b.h.) of largest trees (cm)[c]				
Shortleaf pine	56-64	58.0	1	Fountain and Sweeney 1985
Pitch pine	30-38	NA	NA	Whittaker 1956
Table Mountain pine	25-38	NA	NA	Whittaker 1956
Virginia pine	25-38	NA	NA	Whittaker 1956
Standing snags (tons/ha; ≥7.6-cm d.b.h.)				
Hot Springs National Park				Johnson and Schnell 1985
Glade	NA	7.8	NA	
Decadent stand	NA	29.5	NA	
Downed logs (tons/ha)				
Hot Springs National Park				Johnson and Schnell 1985
Glade	NA	.3	NA	
Decadent stand	NA	9.4	NA	
Decadent trees[d] (no./ha; ≥10-cm d.b.h.)	NA	NA	NA	NA
Canopy layers (no.)[e]	NA	NA	NA	NA
Canopy in gaps (percent)	NA	NA	NA	NA
Other features	NA	NA	NA	NA

[a] NA in the table denotes that information is not available.
[b] Number of stands may not equal the number of citations.
[c] Includes dominant and codominant trees that make up the upper canopy.
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maintain themselves best where understory hardwoods and shrubs do not prevent the establishment and development of pine reproduction. Indeed, fires help keep competition in check. So it may not be necessary for the sparse pine overstory to be eliminated for pine reproduction to develop, particularly with understory burning. Tornadoes and wind storms may also create openings in certain regions (Turner 1935). Ward (1984) described xeric forests (not necessarily old growth) in hilly, dry uplands in east Texas as open and two-storied and speculated that dense understories might prevent establishment of seedlings of overstory species. In the past, fire may have kept understory densities lower.

The limited, scattered occurrence of this type probably precludes setting aside an area exclusively for old growth. Rather, old-growth xeric pine and pine-hardwood forests and woodlands will probably be managed in areas that have more than one type, especially where oak dominates. Because it occurs in small tracts in large areas, setting a minimum area for management may not be appropriate.

Representative Old-Growth Stands

Areas where representative old-growth stands may appear include:

- Hot Springs National Park, Arkansas
- Lake Winona Research Natural Area, Ouachita National Forest, Arkansas
- Magazine Mountain, Ozark National Forest, Arkansas
- Roaring Branch Research Natural Area, Ouachita National Forest, Arkansas
- Marshall Forest Preserve, near Rome, Georgia
- Alley Spring Hollow, Shannon County, Missouri—50 acres (20.3 ha)
- Big Spring Towering Pines, Carter County, Missouri—150 acres (60.8 ha)
- Botkins Pine Woods, Ste. Genevieve County, Missouri—30 acres (12.2 ha)
- Hawe's Recreation Area, Carter County, Missouri—15 acres (6.1 ha)
- Hickory Canyons, Ste. Genevieve County, Missouri—30 acres (12.2 ha)
- Highway T Forest, Phelps County, Missouri—20 acres (8.1 ha)
- Johnson Tract, Wayne County, Missouri—30 acres (12.2 ha)
- Kaintuck Hollow, Phelps County, Missouri—15 acres (6.1 ha)
- Lovers Leap, Howell County, Missouri—15 acres (6.1 ha)
- Paddy Creek Wilderness Area, Texas County, Missouri— 50 acres (20.3 ha)
- Peter A. Eck Tract, Texas County, Missouri—230 acres (93.2 ha)
- Prairie Hollow, Shannon County, Missouri—13 acres (5.3 ha)
- Rocky Falls, Shannon County, Missouri—30 acres (12.2 ha)
- Spring Valley Branch, Carter County, Missouri—15 acres (6.1 ha)
- Twin Springs Woods, Ripley County, Missouri—30 acres (12.2 ha)
- Virgin Pine Forest, Shannon County, Missouri—47 acres (19.0 ha)
- Great Smoky Mountains National Park, North Carolina and Tennessee
- Linville Gorge, Pisgah National Forest, North Carolina.

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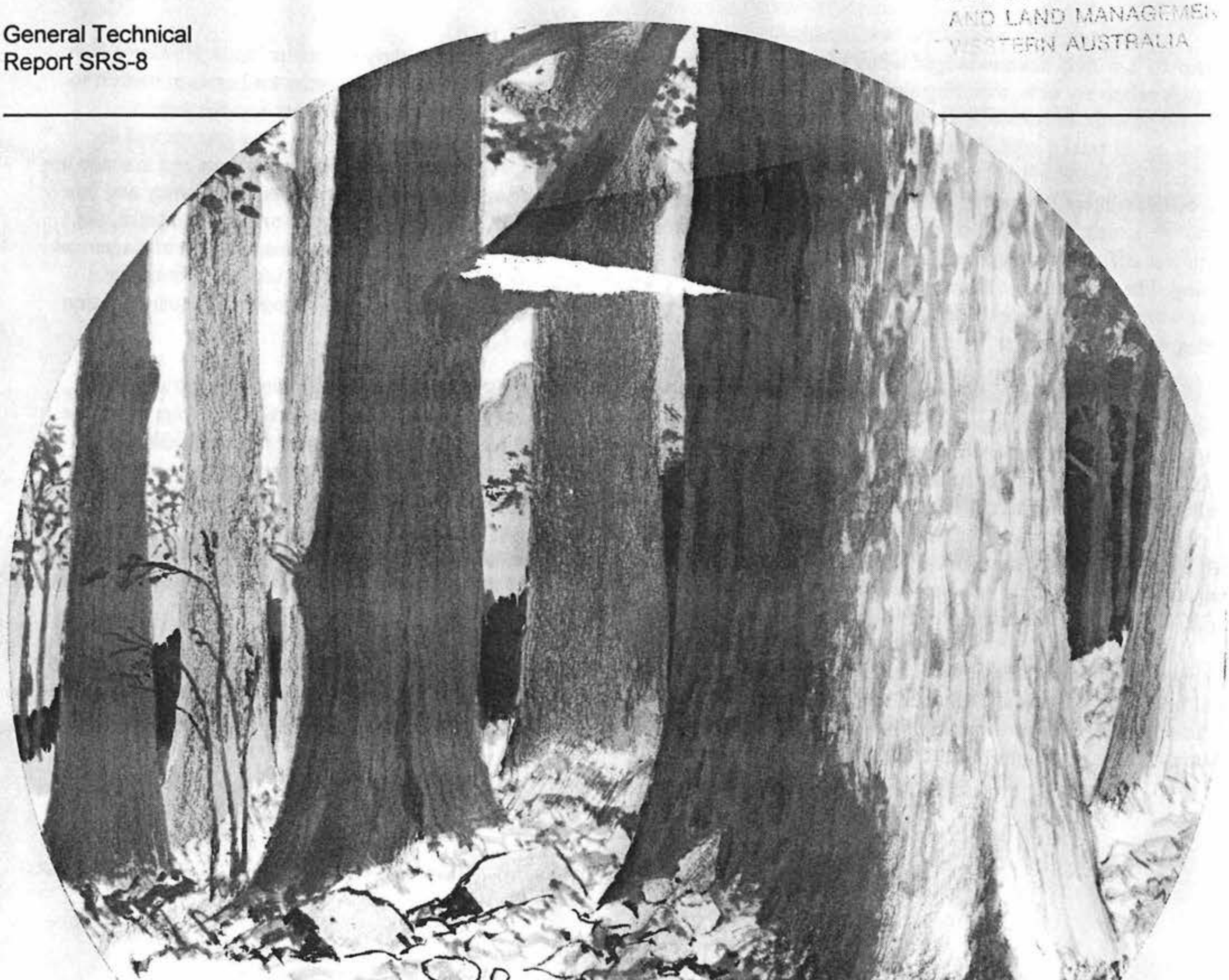

A Section of the Old-Growth Definition Series

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Preface

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In preparing individual old-growth definitions, authors followed the National Old-Growth Task Group guidelines, which differ from the standard General Technical Report format in two ways—the abstract (missing in this report) and the literature citations are listed in the Southern Journal of Applied Forestry style. Allowing these deviations will ensure consistency across organizational and geographic boundaries.

April 1997

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An Old-Growth Definition for Seasonally Wet Oak-Hardwood Woodlands

Harvey E. Kennedy and Gregory J. Nowacki

Introduction

Southern bottomland hardwoods occur on approximately 32 million acres [13 million hectares (ha)] of forest land in river bottoms, minor stream bottoms, and swamps from Virginia to east Texas (McKnight and Johnson 1980). These ecosystems support a wide variety of tree species and communities (Meadows and Stanturf 1996), one of which is seasonally wet oak-hardwood woodlands. Past geologic events led to the formation of broad stream valleys in these areas because of the erodable, sedimentary geologic materials. Although the stream valleys of the Coastal Plain may be quite old, most of the floodplain sediments were formed in recent geologic times (Wharton et al. 1982).

An active river in an alluvial valley constantly cuts its banks on one side and deposits the soil downstream on the opposite side to form new land. Spring floods gradually raise the land by depositing coarser sediments near the riverbanks to build natural levees, and by dropping finer sediments farther back, to form low, broad, poorly drained "slackwater" areas. Complex but recognizable species associations characterize these sites. Cottonwood (*Populus deltoides* Bartr. ex Marsh.) and willow (*Salix nigra* Marsh.) are pioneer species on natural levees and are succeeded by riverfront species, then by oaks (*Quercus* spp.) and other species. A similar succession occurs in the backlands as sloughs, swamps, and oxbow lakes fill with sediment. Seasonally wet oak-hardwood woodlands can eventually occur on any of these sites (Putnam et al. 1960).

Seasonally Wet Oak-Hardwood Woodlands

Description of Forest Type Group

General Location—Seasonally wet oak-hardwood woodlands are scattered throughout the Eastern United States, ranging primarily from the Midwest south to eastern Oklahoma and Texas and eastward to Virginia. Commonly referred to as oak glades or flatwoods, these open woodlands develop best within the Ohio, Arkansas, and southern Mississippi River valleys.

Site Characteristics—These woodlands occur principally on river bottom lands and isolated depressions seasonally flooded for short periods. Soils are clayey; many have clay layers, deposited during river flooding, that may be mistaken for hardpans. Although soil drainage is poor, moisture conditions in these forests fluctuate dramatically. In summer, soil moisture deficits may occur if clay layers limit the rooting space available for trees and prevent the upward movement of water from lower wet zones.

Species—Principal species are pin oak (*Quercus palustris* Muenchh.), willow oak (*Q. phellos* L.), white oak (*Q. alba* L.), water oak (*Q. nigra* L.), diamondleaf oak (*Q. laurifolia* Michx.), and Nuttall oak (*Q. nuttallii* Palmer). Post oak (*Q. stellata* Wang.) predominates the Cross Timbers area of Texas and Oklahoma. Common associates include overcup oak (*Q. lyrata* Walt.), red maple (*Acer rubrum* L.), sweetgum (*Liquidambar styraciflua* L.), water hickory [*Carya aquatica* (Michx. f.) Nutt.], and waterlocust (*Gleditsia aquatica* Marsh.)

Site Disturbance—If, in presettlement times, surfaces dried out during summer, low-intensity fires could have occurred. Although such burns would probably have been confined primarily to the litter layer, they would have helped maintain the open conditions of these woodlands by checking woody regeneration. Large oaks are fire tolerant and were largely unaffected by surface burns, whereas fire-sensitive species such as red maple, American elm (*Ulmus americana* L.), and green ash (*Fraxinus pennsylvanica* Marsh.) were adversely affected. Even though fires have been largely controlled over the last century, the open condition of these woodlands is usually maintained due to the unusual hydrologic constraints of the sites.

Associated Society of American Foresters Forest Cover Types

One or more principal species in the seasonally wet oak-hardwood woodlands are associate species in the following Society of American Foresters forest cover types:

40—post oak-blackjack oak (in part)
53—white oak (in part)
65—pin oak-sweetgum (in part)
88—willow oak-water oak-diamondleaf (laurel) oak (in part)

Physiographic Provinces (after Fenneman 1938)

- Coastal Plain (all sections except Floridian)
- Appalachian plateaus (unglaciated Allegheny Plateau section)
- Interior low plateaus (all sections)
- Central lowland (till plains, dissected till plains, and Osage Plains sections)
- Ozark plateaus (all sections)
- Ouachita (all sections)

Old-Growth Conditions

Living Tree Component

Old-growth, seasonally wet oak-hardwood woodlands is usually a mixture of tree species, chiefly oaks, of many sizes and ages. The canopy is typically multilayered (table 1), and tree age varies accordingly, from young reproduction (Winters et al. 1938, Arkansas Department of Planning 1974) occurring in openings created by dead trees or windthrow, to mature trees 150 years old or more.[1] Large canopy trees may reach 110 feet [33.5 meters (m)] in height (see footnote 1).

Winters et al. (1938) describe a typical old-growth stand. The woodland contained 174 trees per acre (70.5 trees per ha) ranging in size from 2 to 40 inches (5 to 102 centimeters [cm]) in diameter at breast height (d.b.h.). Fifty-nine percent of the trees were 2 to 4 inches (5 to 10 cm) in d.b.h., 24 percent were 6 to 12 inches (15 to 30 cm) in d.b.h., 8.5 percent were 14 to 18 inches (36 to 46 cm) in d.b.h., 6 percent were 20 to 28 inches (51 to 71 cm) in d.b.h., 2 percent were 30 to 38 inches (76 to 97 cm) in d.b.h., and less than 1 percent were 40 inches (102 cm) or larger in d.b.h. Sixty-two percent of the trees were classified as good (potentially usable sawtimber). Thirty-four percent were sound culls, that is, trees with no rot, but having poorly formed, excessively limby boles, or other defects. Three percent were classified as rotten culls; trees that would eventually become snags or fall. Winters et al. (1938) defined rotten cull trees as (1) sawlog-size trees containing at least half their board-foot volume in logs culled because of rot and (2) smaller trees containing at least half their cubic foot volume in rotten material. These trees represented about 3 percent of all diameter classes or 5.6 trees per acre (13.8 trees per ha).

Dead Tree Component

Meadows (see footnote 1) found an average of 16 to 20 dead trees per acre (40 to 49 trees per ha), representing 12 to 14 percent of the total number of trees. Most of these were Nuttall oak, sweetgum, and elm.

Woody debris is difficult to quantify for this forest type group. Because of prevailing high temperature and relative humidity, decay organisms are very active, resulting in rapid decomposition (3 to 4 years) of downed woody debris. Consequently, woody debris is scarce and composed almost exclusively of recently fallen tree limbs and boles. No literature defined or quantified the amount of downed wood in this forest type.

Understory Characteristics

Understory vegetation is commonly a diverse mixture of young trees, vines, and shrubs that range from sparse to very thick (Putnam et al. 1960, Arkansas Department of Planning 1974). Small woody species, such as planertree (*Planera aquatica* J.F. Gmelin), buttonbush (*Cephalanthus occidentalis* L.), wild grape (*Vitis* spp.), pepper-vine [*Ampelopsis arborea* (L.) Koehne], trumpet-creeper [*Campsis radicans* (L.) Seeman], poison-ivy [*Toxicodendron radicans* (L.) Kuntze], and honeysuckle (*Lonicera* spp.) usually originate ahead of tree reproduction and, at times, may form virtually impenetrable thickets (Putnam et al. 1960, Arkansas Department of Planning 1974). Tree regeneration is thus largely excluded. Small trees are common in the understory and include American hornbeam (*Carpinus caroliniana* Walt.), eastern hophornbeam [*Ostyra virginiana* (Miller) K. Koch], flowering dogwood (*Cornus florida* L.), and hawthorn (*Crataegus* spp.).

Young seedlings of canopy-tree species develop either from seed or sprouts and are typically most abundant beneath canopy gaps. During unfavorable periods (e.g., intense competition/shade), tree seedlings frequently die back and resprout. Where a thick mat of underbrush is present, it may take 20 years for tree seedlings to grow through this layer. Seedling and sapling development is most rapid in openings, which, in old growth, can be 300 feet (91.4 m) in diameter (Arkansas Department of Planning 1974). Chief obstacles to old-growth regeneration include shade, flooding, and fire. Together these factors largely control seedling and sapling composition.

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[1] Meadows, J.S. February 1990. Study on long-term timber growth and quality following an improvement cutting in an uneven-aged stand vs. clearcutting to produce an even-aged stand. Unpublished report. On file with: Southern Research Station, Southern Hardwoods Laboratory, P.O. Box 227, Stoneville, MS 38776.

Table 1 (English units)—Standardized table of old-growth attributes for seasonally wet oak-hardwood woodlands

Quantifiable attribute	Value: Range	Value: Mean	Number of stands[a]	References
Stand density (no./acre) —trees ≥4 in d.b.h.	40-215	125.0	3	Meadows, unpublished data[b] Putnam and Bull 1932 Society of American Foresters 1980
Stand basal area (ft^2 /acre) —trees ≥4 in d.b.h.	44.3-214.1	90.9	3	Meadows, unpublished data[b] Putnam and Bull 1932 Society of American Foresters 1980
Age of large trees (yrs)[c] —all species	80-150	85.0	3	Meadows, unpublished data[b] Putnam and Bull 1932 Society of American Foresters 1980
Number of 4-in. size classes —4 in d.b.h.	9	9.0	1	Society of American Foresters 1980
D.b.h. (or maximum d.b.h.) of largest trees (in) —all species	45	45.0	1	Meadows, unpublished data[b] Society of American Foresters 1980
Standing snags (no./acre) —snags ≥4 in d.b.h.	0-75	20.0	2	Meadows, unpublished data[b] Society of American Foresters 1980
Downed logs (ft^3/acre)[d]	–	–	–	
Decadent trees (no./acre)[e] —≥4 in d.b.h.	0-60	44.0	3	Meadows, unpublished data[b] Putnam and Bull 1932 Society of American Foresters 1980
Number of canopy layers	Multilayered	--[d]	5	Arkansas Dept. of Planning 1974 Meadows, unpublished data[b] Putnam and Bull 1932 Putnam et al. 1960 Society of American Foresters 1980
Percent canopy in gaps[d]	–	–	–	
Other features[d]	–	–	–	

[a] Number of stands may not equal the number of citations.
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[c] Includes dominant and codominant trees that make up the upper canopy.
[d] Data not available.
[e] Includes deformed, bole-scarred, spike-topped, and wind-damaged trees.

Table 1 (metric units)—Standardized table of old-growth attributes for seasonally wet oak-hardwood woodlands

Quantifiable attribute	Value		Number of stands[a]	References
	Range	Mean		
Stand density (no./ha) —trees ≥10-cm d.b.h.	100-506	308.0	3	Meadows, unpublished data[b] Putnam and Bull 1932 Society of American Foresters 1980
Stand basal area (m^2/ha) —trees ≥10-cm d.b.h.	110-528	225.0	3	Meadows, unpublished data[b] Putnam and Bull 1932 Society of American Foresters 1980
Age of large trees (yrs)[c] —all species	80-150	85.0	3	Meadows, unpublished data[b] Putnam and Bull 1932 Society of American Foresters 1980
Number of 10-cm size classes —starting at 10-cm d.b.h.	9	9.0	1	Society of American Foresters 1980
D.b.h. (or maximum d.b.h.) of largest trees (cm) —all species	114	114.0	1	Meadows, unpublished data[b] Society of American Foresters 1980
Standing snags (no./ha) —snags ≥10-cm d.b.h.	0-185	49.0	1	Meadows, unpublished data[b] Society of American Foresters 1980
Downed logs (m^3/ha)[d]	–	–	–	
Decadent trees (no./ha)[e] —trees ≥10-cm d.b.h.	0-152	107.0	3	Meadows, unpublished data[b] Putnam and Bull 1932 Society of American Foresters 1980
Number of canopy layers	Multilayered	--[d]	5	Arkansas Dept. of Planning 1974 Meadows, unpublished data[b] Putnam and Bull 1932 Putnam et al. 1960 Society of American Foresters 1980
Percent canopy in gaps[d]	–	–	–	
Other features[d]	–	–	–	

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Soils and Microtopography

These woodlands occur principally along streams where there is seasonal flooding for short periods. Coarse sediment deposited near the bank of the river during floods forms narrow ridges or natural levees (Putnam et al. 1960). Farther from the river, where flood waters eddy and slow, finer sediments are deposited, forming low, broad areas of poorly drained, slack water clay soils. Seasonally wet oak-hardwood woodlands may occur on any of these sites (i.e., low ridges, flats, and sloughs). Because of their lowland situation and unique soil properties (e.g., clay hardpans), soil moisture in these woodlands tends to fluctuate dramatically throughout the year, from excessively moist during high water to moisture deficits during the growing season. Soil pH varies from approximately 5.0 to 8.0, depending on age, topography, and parent material. The organic mat (0 horizon) is usually several inches thick, and organic-matter content in the A horizon can be as high as 5 percent.

Even though this definition is for seasonally wet oak-hardwood woodlands, we must keep in mind this oak type is transitory. The soils that support this group would normally be occupied first by the pioneer species (cottonwood and willow), followed by the riverfront type and the oaks. Over most of its range, the seasonally wet oak-hardwood woodland would ultimately be replaced by more tolerant types and finally beech (*Fagus* spp.) -magnolia (*Magnolia* spp.) as the climax if succession were allowed to proceed naturally. Only good forest management can maintain the seasonally wet oak-hardwood woodland type.

Other Important Features

The abundance of undergrowth usually makes these woodlands good habitat for deer. However, the number of deer may be limited by flooding, especially in the absence of high, wooded ground (Arkansas Department of Planning 1974). Many bird and rodent species usually inhabit these woodlands, especially during the old-growth stage. Aquatic animals (e.g., fishes, amphibians) can also be numerous during wet periods.

Forest Dynamics and Succession

Only small, scattered remnants of old-growth, seasonally wet, oak-hardwood woodlands remain. Because of the long history of logging and other human disturbances, most present-day woodlands differ from their presettlement counterparts. However, based on regeneration trends, the natural forces that formed past woodlands are still working today, so recovery from human disturbance seems likely for many stands (Arkansas Department of Planning 1974).

A typical succession for these woodlands is as follows: within 15 years of a stand-initiating disturbance, a full canopy is produced by trees and large shrubs. Over the next 30 to 50 years, the woodland will mature and old-growth processes will begin (e.g., canopy-tree deaths, gap-phase regeneration). Within 100 to 150 years, mature trees will begin to die, and, as younger trees replace them, a "multiple-aged" forest will develop (Arkansas Department of Planning 1974). This process could continue for another 100 years or until the next stand-altering disturbance.

Winters et al. (1938) reported that settlement in the North Louisiana Delta began early in the 19th century. By 1850, cotton was being produced on much of the high, riverfront land where water transportation was easily available. The pattern of land disturbance they described in that area is probably typical of most of the area where seasonally flooded oak-hardwood woodlands were found.

During the Civil War and the subsequent reconstruction period, agriculture was interrupted and thousands of acres of abandoned farmland reverted to forests. Shortly after 1900, large timber companies began to acquire land, and lumber production became an important industry. World War I brought another agricultural boom, and cutover timberlands were converted to farming again. Land clearing for farming continued until the depression of the 1930's. Much of the remaining virgin forest was also cutover by the late 1930's to the early 1940's. By the late 1930's, only about half the original forests remained. Clearing continued at a rapid pace through the late 1970's, by which time only about 20 percent of the original forest in the Lower Mississippi River valley was left.

Presently, much of the cleared land is in crop production and will probably remain so. Some acreage that is marginal to submarginal for agriculture may be converted to forest under government programs, such as the Conservation Reserve Program and the Wetlands Restoration Project. However, these tracts will make up only a small portion of the total land area and will take a long time to develop into old-growth forests.

Representative Old-Growth Stands

Some representative stands exist on the 2,700-acre (1093.5-ha) Delta Experimental Forest, Washington County, Stoneville, MS, and the 58,000-acre (23,490.0-ha) Delta National Forest, Sharkey County, Rolling Fork, MS. Another unique site is located on the Edgefield Ranger District of the Sumter National Forest. A non-alluvial swamp forest, dominated by large willow oak, is located at this site. Soils are a montmorillonite clay (Nelson 1986). There are probably other representative stands unknown to [illegible] Are[illegible] other representative old growth stands may appear [illegible]clude Coochie Brake, Winn Parish, LA; Big Oak Tree Natural Area, Big Oak Tree State Park, MO; Deep Slough, St. Charles County, MO; and Quercus Flatwoods Natural Area, George White State Forest Nursery, MO.

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United States
Department of
Agriculture

Forest Service

Southern Research Station

General Technical Report SRS-9

An Old-Growth Definition for Southern Mixed Hardwood Forests

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A Section of the Old-Growth Definition Series

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Preface

Old growth is widely acknowledged today as an essential part of managed forests, particularly on public lands. However, this concept is relatively new, evolving since the 1970's when a grassroots movement in the Pacific Northwest began in earnest to define old growth. In response to changes in public attitude, the U.S. Department of Agriculture, Forest Service, began reevaluating its policy regarding old-growth forests in the 1980's. Indeed, the ecological significance of old growth and its contribution to biodiversity were apparent. It was also evident that definitions were needed to adequately assess and manage the old-growth resource. However, definitions of old growth varied widely among scientists. To address this discrepancy and other old-growth issues, the National Old-Growth Task Group was formed in 1988. At the recommendation of this committee, old growth was officially recognized as a distinct resource by the Forest Service, greatly enhancing its status in forest management planning. The committee devised "The Generic Definition and Description of Old-Growth Forests" to serve as a basis for further work and to ensure uniformity among Forest Service Stations and Regions. Emphasis was placed on the quantification of old-growth attributes.

At the urging of the Chief of the Forest Service, all Forest Service Stations and Regions began developing old-growth definitions for specific forest types. Because the Southern and Eastern Regions share many forest communities (together they encompass the entire Eastern United States), their efforts were combined, and a cooperative agreement was established with The Nature Conservancy for technical support. The resulting project represents the first large-scale effort to define old growth for all forests in the Eastern United States. This project helped bring the old-growth issue to public attention in the East.

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April 1997

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An Old-Growth Definition for Southern Mixed Hardwood Forests

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Introduction

The southern mixed hardwood forest, one of the southernmost mesic temperate forest types in North America, occurs along the southeastern Coastal Plain of the United States from the Carolinas to eastern Texas. These forests contain a diverse mixture of evergreen and deciduous broad-leaved trees combined with evergreen coniferous trees. Typically, they are dominated by American beech *(Fagus grandifolia* Ehrh.), southern magnolia (*Magnolia grandiflora* L.), and *Pinus* spp. (Quarterman and Keever 1962; Monk 1965, 1967, 1968; Marks and Harcombe 1975; Clewell 1985; Godfrey 1988; Platt and Schwartz 1990; Vankat 1990). As the climate of the southeastern Coastal Plain, at least along the coast of the Gulf of Mexico, remained relatively constant during the Pleistocene, present mesic hardwood forests may represent relicts derived from the early Tertiary flora (Axelrod 1958, 1966; Platt and Schwartz 1990). In addition, they would have served as refuges for many northern temperate species during the Pleistocene glaciations (Davis 1981, Delcourt and Delcourt 1987, Webb 1990).

Before European settlement, stands of southern mixed hardwood forests formed narrow bands of vegetation between floodplain forests and upland xeric forests or savannas dominated by longleaf pine (*Pinus palustris* Mill.). These sites were naturally protected from frequent flooding and from growing-season fires initiated in the pine savannas (Williams 1827; Delcourt and Delcourt 1974, 1977; Marks and Harcombe 1981; Schafale and Harcombe 1983; Platt and Schwartz 1990; Ware et al. 1993; Schwartz 1994; Harcombe et al. 1993). After European settlement, virtually all pine savannas were clearcut, and their characteristic growing-season fires were suppressed. Following such disruption, hardwood species and pines, especially loblolly pine (*P. taeda* L.), replaced longleaf pine forming woodlands and forests that replaced most of the savannas. Stands of southern mixed hardwood forests are frequently affected by hurricanes along the Coastal Plain (Jarvinen et al. 1984, Neumann et al. 1992). These disturbances, which recur within the lifespan of most canopy trees, greatly influence the dynamics of these forests (Glitzenstein et al. 1986, Platt and Schwartz 1990).

Preservation or restoration of the southern mixed hardwood forests requires criteria for recognizing the so-called old-growth stands (Thomas et al. 1988). The concept of old growth was originally developed for Pacific Northwest forests, based on the notion that those forests undergo a directional autogenic succession toward a steady-state climax that is disrupted by natural devastations (Franklin et al. 1981, 1986; Franklin and Spies 1984). In this context, old-growth condition becomes essentially synonymous with climax state. Application of the old-growth concept in other regions has tended to result in transferral of this connotation to different forests (e.g., Barnes 1989, Hayward 1991). This created difficulties for characterizing the old-growth condition of forests that, being affected by frequent disturbances (Tyrrell 1992), may not approach a climax or a steady state (Jones 1945, Raup 1964, White 1979, Denslow 1980, Pickett and White 1985, Platt and Schwartz 1990). In these cases, an old-growth forest would be one that has not been recently cleared and whose dynamics are essentially the same as those that historically shaped forest structure and composition ("age" and "disturbance" criteria) (Hunter 1989). The old-growth definition would then contain attributes expected in a forest likely to change under a natural disturbance regime, rather than attributes expected in a steady-state community.

In this report, we characterize the old-growth condition for the southern mixed hardwood forests based on published accounts and on data from five exemplary stands that show no evidence of having been cleared by humans or by natural agents during the last 200 years. The two easternmost stands are located near each other, one (Woodyard Hammock) in northern Florida and the other (Titi Hammock) in southern Georgia; two central stands (Zemurray Forest and Tunica Hills) are in eastern Louisiana, and the westernmost stand (Weir Forest) is in eastern Texas (see appendix for a detailed presentation of the exemplary forests). Structure and composition data were compiled from mapped-plot data bases and published reports related to all five forests. Description of immediate hurricane effects was based on censuses conducted after 1985 Hurricane Kate in Woodyard Hammock and Titi Hammock. Dynamics over a 14-year period were described based on an ongoing long-term study in Woodyard

Hammock. This forest type was defined by Quarterman and Keever (1962) and corresponds to the lower slope hardwood pine forest of Marks and Harcombe (1981), to forest type 66 in Vankat (1990), and partially to Southern Research Station types 31, 37, 46, and 59, as well as Society of American Foresters (SAF) types 82 and 89 (Eyre 1980).

Old-Growth Characteristics

Distribution in the Landscape

Old-growth southern mixed hardwood forests are small stands whose origin predates extensive European settlement in the United States. All of the exemplary forests occupied mesic sites associated with streams or lakes. These sites are moister than the uplands and therefore are relatively protected from the lightning-initiated fires that frequently burned the upland pine savannas (Platt and Schwartz 1990, Harcombe et al. 1993).

Strata and Growth Forms

Southern mixed hardwood forests have an overstory of evergreen and deciduous broad-leaved species and evergreen needle-leaved species, mostly composed of trees 66 to 98 feet [20 to 30 meters (m)] tall, and an understory of trees less than 49 feet (15 m) tall, usually of evergreen and deciduous broad-leaved species (Harcombe and Marks 1977, Platt 1985, Platt and Hermann 1986). Trees support lianas and sometimes fairly abundant epiphytes. Except in gaps, the ground cover of herbs is sparse, probably as a result of the abundance of evergreen trees (Marks and Harcombe 1975, Platt and Schwartz 1990).

Overall Diversity

The exemplary forests averaged 37 tree species ≥1 inch [2 centimeters (cm)] in diameter at breast height (d.b.h.). About 28 of these species reached at least 4 inches (10 cm) in d.b.h. (table 1). The rest were large shrubs and a few species dispersed from nearby environments and present only as juveniles. Diversity index $N1$ ($= e^{H'}$) indicates that about 15 of the species in each stand contributed significantly to total density, and $N2$ ($= 1/D$) that about 11 shared dominance (table 1).

Overstory Species

Dominant species of large overstory trees in the exemplary forests always included American beech, southern magnolia, and sweetgum (*Liquidambar styraciflua* L.); some of the oak species, water oak (*Quercus nigra* L.), white oak (*Q. alba* L.), swamp chestnut oak (*Q. michauxii* Nutt.); and, except in Tunica Hills, either spruce pine (*P. glabra* Walt.), or loblolly pine (tables 2 and 3). In each exemplary forest, there were about 13 species of large overstory trees [d.b.h. ≥20 inches (50 cm)], about one-half of which shared dominance (respectively, *N0* and *N1*, table 1). Thus, the composition of the overstory was fairly constant among the exemplary forests despite some variation in species abundance. American beech was always either the first or the second most abundant species in the overstory. An additional 30 native overstory species were represented in the exemplary forests (table 2).

Understory and Vine Species

The understory of the exemplary forests contained small individuals of overstory species and several species that never reach the overstory (table 2). Among the latter, American holly (*Ilex opaca* Ait.), American hornbeam (*Carpinus caroliniana* Walt.), and eastern hophornbeam [*Ostrya virginiana* (Mill.) K. Koch] frequently shared dominance (table 2). However, species abundance in the understory was variable among sites. The dominant

Table 1—Tree species diversity in five southern mixed hardwood forests

Sizes	Range	Median	Number of sites
D.b.h. ≥2 cm			
N0[a]	28-60	37	4
N1[b]	5-20	15	4
N2[c]	3-12	11	4
D.b.h. ≥10 cm			
N0[a]	25-43	28	4
N1[b]	12-16	14	4
N2[c]	9-11	10	5
D.b.h. ≥50 cm			
N0[a]	8-15	13	5
N1[b]	8-15	7	5
N2[c]	4-12	6	5

[a] N0 is the total number of species.
[b] $N1 = e^{H'}$, where H' is the Shannon-Wiener index, measures the number of nonrare species.
[c] N2 = 1/D, where D is the Simpson index, measures the number of dominant species (Hill 1973). All indices were calculated with overall stand tree-density data.

Table 2—Large and small tree presence (number of sites out of five), density ranges, and density averages (median number of trees per hectare) for common species in five old-growth southern mixed hardwood forests

	Large trees d.b.h. >50 cm			Small trees 10 cm < d.b.h. ≤50 cm		
Species	Presence	Density range	Density median	Presence	Density range	Density median
Overstory[a] species:						
Fagus grandifolia	5	6.0-18.0	9.0	5	3.0-102.0	38.5
Magnolia grandiflora	5	2.0-24.7	5.4	5	10.0- 59.0	19.6
Liquidambar styraciflua	5	0.3- 5.0	3.0	5	10.6- 66.9	36.0
Quercus nigra	4	0.2- 5.0	3.0	5	0.8- 22.0	12.7
Q. alba	4	0 - 5.0	2.0	5	1.5- 40.5	5.0
Q. michauxii	4	0.4- 2.0	0.9	4	1.8- 28.0	6.5
Liriodendron tulipifera	4	0.9- 5.4	2.0	4	1.0- 6.5	1.8
Nyssa sylvatica	4	0.5- 3.5	0.8	4	13.0- 22.4	18.9
Pinus glabra	3	4.4-16.5	4.4	3	10.9- 25.4	10.9
P. taeda	3	1.6-22.0	1.6	4	0.2- 48.0	0.4
Carya glabra	3	0.7- 2.4	0.7	3	1.0- 9.4	1.0
Q. hemisphaerica	3	0.2- 1.8	0.2	4	0.4- 15.8	1.0
Q. shumardii	2	0.4- 9.0	0	2	0.9- 6.0	0
M. virginiana	1	1.4- 1.4	0	4	0.7- 10.6	4.0
C. tomentosa	1	0.4- 0.4	0	3	0.8- 2.2	0.8
C. cordiformis	1	1.0- 1.0	0	2	1.0- 8.4	0
Tilia americana	1	0.8- 0.8	0	2	4.0- 5.2	0
All overstory species:		40.0-70.0	46.0		140.0-275.0	227.0
Understory[b] species:						
Ilex opaca				5	1.0- 59.0	30.4
Carpinus caroliniana				5	1.3- 41.0	21.1
Ostrya virginiana				4	8.0- 69.8	27.0
Cornus florida				4	2.4- 30.0	7.8
Acer rubrum				4	0.8- 32.0	1.0
Symplocos tinctoria				4	0.4- 5.5	1.0
Prunus serotina				4	0.2- 3.0	0.4
Aralia spinosa				2	0.2- 1.0	0
Cercis canadensis				2	0.2- 2.4	0
Halesia diptera				2	5.0- 8.5	0
Oxydendron arboreum				2	5.8- 16.0	0
All understory species:					114.0-163.2	125.0
All species:[c]		40.0-70.0	46.0		304.0-389.0	351.6

[a] Overstory: *Carya illinoiensis, Castanea pumila, Celtis laevigata, Gleditsia triacanthos, Juglans nigra, Magnolia pyramidata, Paulownia tomentosa, Pinus echinata, Platanus occidentalis, Quercus falcata, Q. marilandica, Q. muehlenbergii, Q. nuttallii, Q. pagodaefolia, Q. phellos, Q. stellata, Q. virginiana, Tilia americana, Ulmus alata, U. americana.*
[b] Understory: *Acer negundo, A. saccharum, Bumelia lanuginosa, Fraxinus americana, F. caroliniana, F. pennsylvanica, Lindera benzoin, Morus rubra, Osmanthus americana, Persea borbonia, Planera aquatica, Prunus caroliniana, Sassafras albidum, Ulmus rubra, Viburnum rifidulum.*
[c] Includes additional species found in only one exemplary forest. All nomenclature follows Godfrey (1988).

Table 3—Range and median basal area (m^2/ha) for common overstory species, for all trees, and for small and large trees in five old-growth southern mixed hardwood forests

Group	Basal area Range	Basal area Median
Fagus grandifolia	2.6- 9.3	5.4
Magnolia grandiflora	1.5-11.6	4.0
Liquidambar styraciflua	1.1- 4.3	3.7
Quercus nigra	0.7- 3.2	1.9
Q. alba	0.2- 3.0	1.0
Q. michauxii	0.1- 1.1	0.9
Liriodendron tulipifera	0.4- 2.7	0.8
Nyssa sylvatica	0.7- 2.3	1.1
Pinus glabra	3.9- 6.9	3.9
P. taeda	0.1-10.5	0.5
Carya glabra	0.5- 1.8	0.5
Q. hemisphaerica	0.3- 1.0	0.3
Q. shumardii	0.1- 3.1	0
M. virginiana	0.1- 1.2	0.1
C. tomentosa	0 - 0.5	0
C. cordiformis	0.3- 0.3	0
Tilia americana	0.2- 0.6	0
All trees	29.0-40.0	33.0
Small trees (d.b.h. ≥10 cm)	27.0-38.0	33.0
Large trees (d.b.h. ≥50 cm)	12.0-24.0	13.0

Minimum d.b.h. of trees included in the calculation of basal area for common species and for all trees was 2 cm for Woodyard Hammock, Titi Hammock, and Tunica Hills; 1 cm for Zemurray Forest; and 4.5 cm for Weir Woods. All nomenclature follows Godfrey (1988).

understory species were eastern hophornbeam in Woodyard Hammock, flowering dogwood (*Cornus florida* L.) in Titi Hammock, two-wing silverbell (*Halesia diptera* Ellis) and Florida anise (*Illicium floridanum* Ellis) in Zemurray Forest, American hornbeam in Tunica Hills, and American holly in Weir Forest. In stands not recently affected by a hurricane, understory trees may be clumped in localized gaps (Platt and Hermann 1986). Characteristic species of lianas in the exemplary forests were cross-vine (*Bignonia capreolata* L.), wood-vamp (*Decumaria barbara* L.), poison-ivy [*Toxicodendron radicans* (L.) Kuntze], bullbriar (*Smilax rotundifolia* L.), and summer grape (*Vitis aestivalis* Michx.); the main epiphyte was Spanish-moss [*Tillandsia usneoides* (L.)].

Density and Basal Area

Total basal area in the exemplary forests was similar to the 269 to 377 square feet per acre [25 to 35 square meters per hectare (ha) (m^2/ha)] range reported by Parker (1989) for hardwood forests of the central hardwood region (table 3). However, density of trees 4 inches (10 cm) in d.b.h. or larger ranged from 139 to 176 trees per acre (344 to 435 trees per ha) [median 160 trees per acre (396 trees per ha)], while the density range reported for the central hardwood region was 65 to 173 trees per acre (161 to 427 trees per ha) (Parker 1989). In addition, the median tree density in the exemplary forests exceeds the 101 trees per acre (250 trees per ha) reported by Martin (1992) for a mixed mesophytic forest in Kentucky. High density in the exemplary forests resulted largely from the large number of small trees (table 2). Reported density and basal area of large overstory trees [d.b.h. ≥20 inches (50 cm)] were extremely high in Zemurray Forest [28 trees per acre (70 trees per ha)], [258 square feet per acre (24 m^2/ha)] (White 1987). In the rest of the exemplary forests, density of large overstory trees ranged from 16.2 and 19.0 trees per acre (40 and 47 trees per ha) and basal area from 129 to 151 square feet per acre (12 to 14 m^2/ha) (table 2).

Size/Age Distributions

Few overstory trees in the exemplary stands reached 39 inches (100 cm) in d.b.h., but many exceeded 20 inches (50 cm) (table 4). In the overstory of these forests, long-lived species, such as American beech, southern magnolia, and sweetgum, were mixed with short-lived trees, such as spruce pine or loblolly pine (table 4). When all tree species were combined, density of trees in these forests decreased with tree size (Harcombe and Marks 1978, White 1987, Platt and Schwartz 1990). Populations of *Pinus* spp., however, usually had a scarcity of small sized classes, suggesting a single-aged condition. For long-lived dominant overstory species, small trees were scarce in some forests but not in others. For example, southern magnolia had very few juveniles in Woodyard Hammock, but many in Weir Forest (see also Harcombe and Marks 1978, Hirsh 1981, Glitzenstein et al. 1986, White 1987).

Gaps

Expanded gaps (Runkle 1982) in Woodyard Hammock occupied about 30 percent of the area before Hurricane Kate. Before Hurricane Kate, small individuals of hickories (*Carya* spp.), water oak, and swamp chestnut oak in Woodyard Hammock were associated with old gaps (Platt and Hermann 1986). In addition, rapidly growing, short-lived, deciduous understory species (such as eastern hophornbeam, American hornbeam, and flowering dogwood) were associated with new gaps, while the slow-growing, long-lived, evergreen American holly and sweetleaf [*Symplocos tinctoria* (L.) L'Hér.] were associated

Table 4—Ranges and averages (medians) of forest structural characteristics observed in southern mixed hardwood forests

Structural characteristic	Range	Median	Number of sites
	Cm	*Cm*	
D.b.h. of largest tree			
Magnolia grandiflora	72-126	95	5
Fagus grandifolia	77- 98	86	5
Nyssa sylvatica	58- 86	81	4
Pinus glabra	72- 81	80	3
Liriodendron tulipifera	54-116	78	4
P. taeda	47- 80	72	4
Quercus alba	48- 82	71	4
Carya glabra	60- 78	70	3
Q. nigra	31- 79	68	5
Liquidambar styraciflua	54- 91	63	5
Q. michauxii	39- 74	61	5
Q. hemisphaerica	38- 55	54	3
Age of old trees in years[a]			
M. grandiflora		214	1
F. grandifolia		210	1
L. styraciflua		210	1
Q. alba		170	1
P. taeda		94	1
P. glabra			
Variation in tree diameter			
No. of 10-cm d.b.h. classes	8- 11	9	4
Evergreen species			
Basal area (percent of total)	7- 52	43	5
Dead trees			
Standing dead (snags per ha)		11	1
Downed logs (m^3 per ha)		72	1

[a] Percentile 95 of the age frequency distribution. All nomenclature follows Godfrey (1988).

with old gaps (Platt and Schwartz 1990). After Hurricane Kate, many juvenile spruce pine and eastern hophornbeam reached 1 inch (2 cm) in d.b.h. in gaps enlarged by the disturbance.

Dead Component

Density of standing dead trees observed in Woodyard Hammock 7 years after Hurricane Kate [5 snags per acre (11 snags per ha)] was lower than the 8 to 18 snags per acre (19 to 44 snags per ha) range reported for the central region mixed mesophytic forest (Parker 1989). Total volume of dead wood on the forest floor in Woodyard Hammock in 1992 was probably influenced by Hurricane Kate (table 4). Twice as much dead wood per unit area occurred in gaps as beneath closed canopy. It took about 9 years for one-half of the dead trees [d.b.h. ≥4 inches (10 cm)] to disappear (estimated in 1992 from the presence or absence of remains of mapped trees that died in Woodyard Hammock between 1978 and 1990). Logs of spruce pine and eastern hophornbeam disappeared more slowly than logs of southern magnolia, American beech, American hornbeam, and American holly.

Regional and Local Variation

Southern mixed hardwood forest species composition, diversity, and proportion of evergreen and deciduous trees vary throughout the Coastal Plain. The geographical distributions of some tree species terminate or are interrupted within the Coastal Plain, presumably in relation with climatic gradients or geological history. For example, the distributions of spruce pine and sourwood (*Oxydendron arboreum)* do not extend west of the Mississippi River, and the distribution of yellow-poplar (*Liriodendron tulipifera* L.) terminates in central Louisiana (Beck 1990, Kossuth and Michael 1990, Overton 1990). Before European settlement, no pines grew near the Mississippi River (Delcourt and Delcourt 1974), explaining the absence of pines in the Tunica Hills old-growth forest.

The number of evergreen species in the southern mixed hardwood forests decreases to the north, while the number of deciduous species decreases to the south (Blaisdell et al. 1974, Greller 1980, Ware et al. 1993). The northernmost limit of southern magnolia occurs at the southeastern corner of North Carolina (Ware 1970, Ware et al. 1993). This limit has been proposed to be associated with seed and seedling sensitivity to freezing (Evans 1933). American beech and white oak do not grow in southeastern Georgia and the peninsula of Florida (Ward 1967). Ranges of the other temperate tree species terminate progressively from north to south along the central ridge of the peninsula of Florida, and very little mixing occurs with tropical tree species. As a result, tree-species diversity in temperate hardwood forests decreases southward along the peninsula (Greller 1980, Schwartz 1988, Platt and Schwartz 1990). Diversity of epiphytes and ferns, however, increases in this direction by the addition of tropical species (Schwartz 1988, Platt and Schwartz 1990). In mesic hardwood forests of northern Florida, less than one-third of the overstory species are evergreen; but farther south in the peninsula, evergreens are more than one-half of the overstory species (Greller 1980). Located west of the Florida peninsula, the exemplary forests contained less than one-third evergreen species in the overstory, but the basal area of these evergreen species was 43 to 52 percent (table 4) of total basal area of overstory species (except in the Tunica Hills, where it was 7 percent).

Old-growth composition of southern mixed hardwood forests varies with local soil conditions and subtle topographic gradients. In northern Florida, Monk (1965) found that the proportion of evergreen trees in hardwood forests was highest on dry, sterile soils and that maximum community diversity occurred on mesic calcareous soils. In ordination analyses of the original 30 quantitative censuses from Quarterman and Keever (1962), Ware (1978, 1988) found that higher abundance of laurel oak (*Q. hemisphaerica* Michx.) and lower abundance of American beech were apparently associated with relatively low moisture and coarse soil texture. In eastern Texas, Marks and Harcombe (1981) found that species composition varied with changes of soil texture over the landscape. Their lower slope hardwood pine forest, which had the maximum proportion of evergreen species, occurred in the middle of the soil texture gradient. In northwest Florida, Gibson (1992) found that topography accounted for the main compositional differences within a forest dominated by laurel oak.

Both Platt and Schwartz (1990) and Harcombe et al. (1993) suggested that fire occurrence interacts with edaphic factors and topography to determine the distribution of hardwood forest tree species. According to Platt and Schwartz (1990), low intensity, growing-season fires on the uplands may prevent some species from mesic and hydric forests, such as sweetgum, water oak, loblolly pine, and American hornbeam, from invading upslope. A similar situation was proposed for the Kisatchie National Forest in western Louisiana, where fire was hypothesized to play a key role in determining the differences between mesic stands, dominated by American beech, southern magnolia, swamp chestnut oak, white oak, and water oak, and drier stands dominated by post oak (*Q. stellata)*, blackjack oak (*Q. marilandica)*, southern red oak (*Q. falcata)*, black oak (*Q. velutina)*, white oak, *Carya* spp., shortleaf pine (*P. echinata* Mill.), and loblolly pine (Martin and Smith 1991).

Old-Growth Dynamics

Tree recruitment, growth, and mortality in old-growth southern mixed hardwood forests do not seem to have occurred at steady annual rates. Instead, these processes would have had pulses as a result of natural disturbances (Harcombe and Marks 1978, Glitzenstein et al. 1986, Platt and Schwartz 1990). In the past, creeping fires that started in the uplands might have frequently killed seedling and understory trees and damaged adult trees (especially American beech) (Blaisdell et al. 1974). In contrast, crown or devastating fires have not been recorded in these forests. In Woodyard Hammock, a summer drought in 1981 killed many small trees and slowed the growth rate of trees. Intermittent streams, changing their course across the forest, have also caused localized tree mortality in Woodyard Hammock.

The most conspicuous disturbances affecting southern mixed hardwood forests are hurricanes. All of the exemplary forests were exposed to four to six storms with winds over 62 miles per hour [100 kilometers per hour (km/hour)] between 1886 and 1992 (see appendix). In 1985, Hurricane Kate passed near Woodyard Hammock and Titi Hammock with winds of about 100 miles per hour (160 km/hour). In Woodyard Hammock, this storm extensively disrupted the canopy; expanded gaps (Runkle 1982) were increased from 31 to 62 percent of the area, and 58 percent of large hardwood trees and 80 percent of large pines were damaged. However, tree mortality was low; 98 percent of all hardwoods, 95 percent of large [d.b.h. ≥18 inches (45 cm)] hardwoods, 65 percent of all pines, and 61 percent of large pines survived. The effect of Hurricane Kate on species diversity was minor; the number of common species (measured as $N1 = e^{H'}$) was 12.0 in 1984 and 11.7 in 1986. In Titi Hammock, the patterns of tree damage and mortality were similar. None of the hurricanes recorded near the exemplary forests between 1886 and 1992 greatly exceeded the intensity of Hurricane Kate (Jarvinen et al. 1984). Hence, none of these forests has undergone a hurricane of the magnitude of Camille (1969) or Hugo (1991). Such major hurricanes are, however, very unlikely to impact on these forests because they have a low frequency of landfall along the Gulf of Mexico coastline.

In Woodyard Hammock, disruption of the canopy by Hurricane Kate prompted marked changes in tree recruitment, growth, and mortality in subsequent years. Before the disturbance, recruitment rates were low, and thinning of juveniles and small trees was intense. Tree mortality decreased with increasing size, and large tree mortality was very low. Average growth rates of large trees were high, and juveniles were almost completely suppressed (table 5). As a result, total density was decreasing, and basal area was becoming increasingly concentrated in large trees. After the Hurricane, there was a massive recruitment into the juvenile size class [d.b.h. ≥1 inch (2 cm)], which mostly resulted from release of small individuals present at the time of the storm. Juvenile mortality decreased and juvenile annual growth rate more than doubled (table 5). Mortality of large trees increased greatly, and large-tree annual growth rate was halved (table 5). As the result, total tree density (d.b.h. ≥1 inch (2 cm)] increased 36 percent in 6 years, even though total tree basal

Table 5—Average rates of recruitment, tree growth, and mortality observed in Woodyard Hammock during periods before (1978-84), including (1984-86), and after (1986-92) Hurricane Kate

Vital rates	1978-84	1984-86	1986-92
Recruitment (trees/ha/yr)	13.8	43.3	81.0
Annual growth (mm/yr)			
Juveniles	.66 (.02)	1.27 (.04)	1.61 (.03)
Small trees	1.90 (.05)	1.30 (.04)	1.94 (.06)
Large trees	4.07 (.19)	1.64 (.15)	1.96 (.16)
Annual mortality (percent)			
Juveniles	5.58 (.21)	5.31 (.38)	3.41 (.15)
Small trees	2.58 (.15)	4.04 (.33)	1.98 (.14)
Large trees	.71 (.23)	4.73 (.99)	2.03 (.39)

Standard errors shown in parentheses. Juveniles (2 cm ≤ d.b.h. <10 cm); small trees (10 cm ≤ d.b.h. <50 cm); large trees (50 cm ≤ d.b.h.).

area remained stable. As most of the new recruits were spruce pine or eastern hophornbeam, forest species composition [d.b.h. ≥1 inch (2 cm)] changed rapidly in the years that followed Hurricane Kate. In contrast, the rate of change in species composition of trees ›4 inches (10 cm) in d.b.h. declined from the prehurricane period, mainly because ongoing thinning of suppressed spruce pine and American hornbeam ceased.

The Nature of Old Growth

The southern mixed hardwood forests were presented by Quarterman and Keever (1962) as the “climatic climax” in the southeastern Coastal Plain, as part of a long tradition of assigning climax status to the mesic hardwood forests of the region (Gano 1917; MacGowan 1937; Kurz 1944; Braun 1950; Monk 1965, 1967, 1968; Blaisdell et al. 1974; Delcourt and Delcourt 1974, 1977; Ware et al. 1993). The main basis for this argument has been that fire suppression in the upland pine-savannas is followed by hardwood encroachment. This concept was based on the assumption that southern mixed hardwood forests were essentially equilibrium forests that resulted from a directional autogenic succession (Quarterman 1981). However, this concept gave little consideration to hurricanes that frequently impact the Coastal Plain (Jarvinen et al. 1984, Neumann et al. 1992). These disturbances constitute a strong allogenic influence that may prevent these forests from approaching an equilibrium (Glitzenstein et al. 1986, Platt and Schwartz 1990).

The hurricane regime affecting the southern mixed hardwood forests is characterized by high frequency (several per century) of storms that, while extensively damaging the canopy, result in low tree mortality. In contrast, complete forest devastation by natural agents, such as very intense hurricanes or crown fires, appears to be extremely rare. In each site, recurrence time of hurricanes may be highly variable, and patterns of hurricane damage may vary among storms. Frequent, nondevastating hurricanes would account for the larger proportion of the area occupied by gaps, lower density of standing dead trees, and relatively smaller sizes of canopy trees than in northern temperate old-growth forests (Quigley and Platt 1996). High tree density would occur because mortality of suppressed trees is likely to be interrupted by a disturbance. Repeated canopy disruption, with the consequent increases in light in the understory, would account for high rates of recruitment and growth.

Hurricanes can be followed by waves of tree recruitment, growth, and death resulting in changes in the density and structure of tree populations and in consequent fluctuations in forest species composition. Under a regime of frequent low intensity hurricanes, stands of southern mixed hardwood forests are not likely to reach an equilibrium structure and composition. Regeneration in periodic canopy openings would prevent the long-lived, shade-tolerant canopy trees from displacing the short-lived, shade-intolerant pines and the small statured understory species (Connell 1978). However, the nondevastating nature of such disturbances also results in shade-tolerant species surviving frequent disruptions. In addition, since hurricanes may disrupt large proportions of the canopy, changes in disturbed patches are likely to be reflected throughout the stand (O'Neill et al. 1986, Smith and Urban 1988). The classical interpretation of these effects of frequent, nondevastating disturbances, consistent with the directional succession model, is that disturbances produce a retrogression to preclimax seral stages followed by a new autogenic succession toward the climax (MacGowan 1937). However, because hurricanes often occur at intervals shorter than the lifespan of trees, and because their immediate effects can be variable, successional tendencies due to tolerance and competitive displacement would be minor compared to the processes of regeneration and change that result from the timing and immediate effects of the disturbances (Platt and Schwartz 1990). One strong suggestion against the retrogression notion is that spruce pine, a light-demanding species that is recruited into the canopy in gaps enlarged by the hurricanes, does not behave as a pioneer, but instead is endemic to these old-growth forests. As the climate of the southeastern Coastal Plain along the Gulf of Mexico coastline remained relatively unchanged during the Pleistocene age, chronic disturbance of these forests may have selected traits in the life history of the tree species that make them adapted for, or even dependent on, the disturbance (Denslow 1980, Platt and Schwartz 1990).

Disturbances affecting the southern mixed hardwood forests appear to be critical for both regeneration and change in old-growth stands. Allogenic disturbances would have been necessary for recruitment or growth of many of the tree species into the canopy of these forests and, therefore, for their continued coexistence. Wide variation in the frequency of disturbances and probably in their immediate effects would have determined changes in stand structure and composition. As complete stand devastation by natural agents was probably very rare in this forest type, old-growth stands may have existed for many generations of trees under the effects of frequent, nondevastating disturbances. Regeneration and change associated with these disturbances, rather than the hypothesized directional succession (Quarterman and Keever 1962, Bormann and Likens 1979, Quarterman 1981), are likely to have dominated the natural dynamics of these forests over most of their history.

Acknowledgments

Funding for this research was provided by Cooperative Research Agreement 29-834 with the Southern Research Station and the U.S. Department of Agriculture, Forest Service. We thank Jeff Glitzenstein and Paul Harcombe for permission to use data from the Weir Woods; Martin Quigley for data from the Tunica Hills; and Julie Denslow, Margaret Devall, Paul Harcombe, David White, and Bob Wray for reviews of earlier versions of this report. Tall Timbers Research Station and The Nature Conservancy provided support for mapping and monitoring the plots in Woodyard Hammock and in Titi Hammock, respectively. Over the years, many people, including Steve Rathbun, Don Hirsh, Greg Evans, Mary Davis, Bruce Means, Margaret Platt, Sharon Hermann, Martin Quigley, Paul Drewa, Jason Bill, Charles Kwit, and especially Maynard Hiss, have helped with the field work in Woodyard Hammock and Titi Hammock.

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Appendix

Exemplary Forests

Woodyard Hammock is a 74-acre [30-hectare (ha)] hardwood forest located 20 miles [32 kilometers (km)] north of Tallahassee, Leon County, in northern Florida (30°35' N, 84°20' W). It occupies flat terrain along the northern shore of Lake Iamonia. Part of an antebellum plantation established in the early 1800's, it has been managed as a part of Tall Timbers Research Station since 1959 (Blaisdell et al. 1974, Hirsh 1981, Platt and Hermann 1986, Platt and Schwartz 1990). According to records of the National Oceanic and Atmospheric Administration (NOAA) (Neumann et al. 1992), between 1886 and 1992 four hurricanes with winds over 62 miles per hour [100 kilometers per hour (km/h)] in 1886, 1894, 1941, and 1985 (Hurricane Kate), passed within 62 miles (100 km) of Woodyard Hammock. Even though creeping fires originating in surrounding pine land entered the forest in the past, this has not happened recently, at least since 1959 (Hirsh 1981). During the early 1900's, dead trees were salvaged for firewood and some large loblolly pine (*Pinus taeda*) were cut. In 1978, an 11-acre (5-ha) permanent study plot was established in the middle of Woodyard Hammock (Hirsh 1981, Platt and Hermann 1986). All trees in the plot 1 inch [2 centimeters (cm)] in d.b.h. or larger were measured, mapped, and tagged. Censuses were repeated biennially to record tree recruitment, growth, and death. Gaps were periodically mapped as polygons formed by connecting the bases of their bordering canopy trees (expanded gaps) (Runkle 1982). After Hurricane Kate in 1985, damage to each mapped tree was assessed. Trees that died between 1978 and 1992 and extant dead material were sampled in 1992 to estimate density of snags, volume of downed logs, and rates of disappearance.

Titi Hammock is a 289-acre (117-ha) hardwood forest located in Thomas County, in southern Georgia, 22 miles (14 km) south of Thomasville (30°41' N, 84°00' W). It is part of Springhill Plantation, was established in the early 1800's, and is currently managed by The Nature Conservancy. This forest occupies steep terrain with a 66-feet [20-meters (m)] change in elevation along the bluffs of Titi Creek. Along the slope, three different plant associations can be distinguished (Platt 1985). In the past, dead trees were salvaged for firewood and some large pines may have been selectively cut on the upper slope. A creeping fire entered the forest in 1968 (Blaisdell et al. 1974). The site is near Woodyard Hammock and was exposed to the same hurricanes as that forest. A 12-acre (5-ha) permanent study plot was established in Titi Hammock in 1985 before Hurricane Kate struck the area. All trees in the plot 1 inch (2 cm) in d.b.h. or larger were tagged, measured, and mapped. Damage to mapped trees by Hurricane Kate was assessed in 1986, and in 1990 the whole plot was surveyed for tree growth and survival.

Zemurray Forest is an 87-acre (35-ha) hardwood forest located in Tangipahoa Parish in eastern Louisiana, 50 miles (80 km) north of New Orleans (30°37' N, 90°21' W). It occupies a level site with acid soil, in the floodplain of Chappepeela Creek (White 1987). According to NOAA records (Jarvinen et al. 1984), between 1886 and 1992 four hurricanes passed within 62 miles (100 km) of this location with wind of more than 62 miles per hour (100 km/h). Quarterman and Keever (1962) included this forest in their extensive survey of the southern mixed hardwood forest. In this report, detailed information on structure and composition of this forest was obtained by White (1987), and was based on the analysis of ten 1-acre (0.2-ha) plots.

Tunica Hills is a forest tract located in West Feliciana Parish in eastern Louisiana, 38 miles (60 km) northwest of Baton Rouge and 1 mile (2 km) east of the Mississippi River (30°47' N, 91°29' W). It has second-growth pine forests on the uplands and old-growth hardwood forests on steep ravine slopes (Delcourt and Delcourt 1974). The forest is being managed as a preserve by The Nature Conservancy. According to NOAA records (Jarvinen et al. 1984), between 1886 and 1992 six hurricanes with winds more than 62 miles per hour (100 km/h) passed within 62 miles (100 km) of this site. Data used in this report were obtained by Quigley (1994), who measured, tagged, and mapped all trees that were 0.4 inches (1 cm) in d.b.h. or greater in 16 randomly located hardwood plots of 0.2 acres (1/16 ha) each.

Weir Forest is located 10 miles (16 km) north of Beaumont, in Hardin County in eastern Texas, (30°16' N, 94°12' W). It occupies gently sloping terrain, slightly dissected by intermittent streams near the Neches River (Harcombe and Marks 1977). According to Glitzenstein et al. (1986), this forest was not directly affected by humans before the late 1800's. Around 1917, pines were selectively logged. According to NOAA records (Jarvinen et al. 1984), four hurricanes with winds more than 62 miles per hour (100 km/h) passed within 62 miles (100 km) of this forest. An 8-acre (3-ha) plot in Weir Woods has been mapped and monitored since 1980. Data on species composition and tree sizes were provided by J. Glitzenstein and P. Harcombe. Additional information was taken from detailed analyses of structure and dynamics of this forest (Harcombe and Marks 1978, Glitzenstein et al. 1986).

Batista, William B.; Platt, William J. 1997. An old-growth definition for southern mixed hardwood forests. Gen. Tech. Rep. SRS-9. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 11 p.

This report provides an old-growth definition for the southern mixed hardwood forests based on five exemplary stands that show no evidence of having undergone any natural catastrophe or clearcutting for at least 200 years. This forest type occurs in the U.S. southeastern Coastal Plain from the Carolinas to eastern Texas. The exemplary old-growth stands were restricted to slopes or slightly elevated terraces between uplands and river- or lake-margin floodplains. They had a diverse overstory, typically dominated by *Fagus grandifolia, Magnolia grandiflora, and Pinus* spp., and a particularly diverse woody understory. Observed rates of tree recruitment, growth, and death were rather high. These processes would occur in pulses, associated with the frequent but nondevastating effect of hurricanes, that may result in fluctuations of species composition. We suggest that under this disturbance regime, old-growth southern mixed hardwood forests would not undergo a directional succession.

Keywords: Coastal Plain, conservation, disturbance, *Fagus grandifolia*, hurricane, *Magnolia grandiflora*, old growth, restoration, southern mixed hardwood forests, temperate forest.

The Forest Service, U.S. Department of Agriculture, is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.

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United States
Department of
Agriculture

Forest Service

Southern
Research Station

General Technical
Report SRS-10

An Old-Growth Definition for Red River Bottom Forests in the Eastern United States

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A Section of the Old-Growth Definition Series

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Preface

Old growth is widely acknowledged today as an essential part of managed forests, particularly on public lands. However, this concept is relatively new, evolving since the 1970's when a grassroots movement in the Pacific Northwest began in earnest to define old growth. In response to changes in public attitude, the U.S. Department of Agriculture, Forest Service, began reevaluating its policy regarding old-growth forests in the 1980's. Indeed, the ecological significance of old growth and its contribution to biodiversity were apparent. It was also evident that definitions were needed to adequately assess and manage the old-growth resource. However, definitions of old growth varied widely among scientists. To address this discrepancy and other old-growth issues, the National Old-Growth Task Group was formed in 1988. At the recommendation of this committee, old growth was officially recognized as a distinct resource by the Forest Service, greatly enhancing its status in forest management planning. The committee devised "The Generic Definition and Description of Old-Growth Forests" to serve as a basis for further work and to ensure uniformity among Forest Service Stations and Regions. Emphasis was placed on the quantification of old-growth attributes.

At the urging of the Chief of the Forest Service, all Forest Service Stations and Regions began developing old-growth definitions for specific forest types. Because the Southern and Eastern Regions share many forest communities (together they encompass the entire Eastern United States), their efforts were combined, and a cooperative agreement was established with The Nature Conservancy for technical support. The resulting project represents the first large-scale effort to define old growth for all forests in the Eastern United States. This project helped bring the old-growth issue to public attention in the East.

Definitions will first be developed for broad forest types and based mainly on published information and so must be viewed accordingly. Refinements will be made by the Forest Service as new information becomes available. This document represents 1 of 35 forest types for which old-growth definitions will be drafted.

In preparing individual old-growth definitions, authors followed National Old-Growth Task Group guidelines, which differ from the standard General Technical Report format in two ways—the abstract (missing in this report) and the literature citations (listed in Southern Journal of Applied Forestry style). Allowing for these deviations will ensure consistency across organizational and geographic boundaries.

May 1997

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Introduction

Red rivers originate in the Piedmont or mountains of the Southern and Southeastern United States (Kellison et al. 1982), where their floodplains are usually narrow and their waters are generally retained in their channels. After flowing over the fall line onto the Coastal Plain, the waters can flood the low ridges along the rivers (the first bottoms). Sediments are deposited across the bottoms as the waters lose turbulence, making these sites some of the most productive in the South. The red river bottom soils are well-drained loams and silt loams. Tree species found there include red maple (*Acer rubrum* L.), river birch (*Betula nigra* L.), water hickory [*Carya aquatica* (Michx. f.) Nutt.], green ash (*Fraxinus pennsylvanica* Marsh.), sweetgum (*Liquidambar styraciflua* L.), sycamore (*Platanus occidentalis* L.), willow oak (*Quercus phellos* L.), laurel oak (*Q. laurifolia* Michx.), overcup oak (*Q. lyrata* Walt.), water oak (*Q. nigra* L.), and elms (*Ulmus* L. spp.). Adjacent to the first bottoms are higher elevation second bottoms, where flooding is less frequent. Cherrybark oak (*Q. falcata* var. *pagodifolia* Ell.), swamp chestnut oak (*Q. michauxii* Nutt.), hickories (*Carya* spp.), American beech (*Fagus grandifolia* Ehrh.), and yellow-poplar (*Liriodendron tulipifera* L.) occur there.

History of Red River Bottomland Development

Red river describes the river water, colored by the large volume of red clay sediment it carries, particularly after storms. There is no evidence that red rivers occurred on the southern landscape before the 18th century—they are a modern invention. Trimble (1974)[1] described the development of the southern Piedmont from 1700 to 1970. He found that all the early explorers of the Southern United States noted that the streams and rivers ran clear. Colonel Byrd described the Dan River in 1728 as ". . . perfectly clear, running about two miles an hour." Spangenburg in 1752 called the water of the Catawba River "crystal clear, so that one can see the stones on the bottom even when the water is deep" and the water of the Yadkin River "clear and delicious." William Bartram described the streams he encountered on the Piedmont as clear, even one swollen with runoff from a previous day's rain. The few small turbid streams were considered anomalies. Erosion was very limited. The river bottom soils were dark, of uniform texture, and showed no signs of the sediment deposition that would later color them red and brown.

Extensive upland clearing for farming occurred over the next two centuries. The soils were highly productive but very erosive, and were exhausted after several years of primitive farming. Land was cheap and considered disposable, so the farms were abandoned with little or no vegetative cover and continued to erode. By the middle of the 19th century, much of the South had been deforested and left to wash into the streams. This erosion led to dramatic changes in the hydrology and soils of the bottomlands. Many streambeds filled with sediment to levels near or above the valley floors. Some sections of bottomland aggraded dramatically >16.4 feet [>5 meters (m)]. Bottomlands often became swampy as groundwater levels rose. Many forests were drowned, and the sediment deposits often left the land unfit for agriculture.

This process was not interrupted until well into the 20th century. Conversion of the landscape from agricultural use back to forest reduced surface water runoff and increased evapotranspiration, thereby reducing the flow volume within the streams. Streams then downcut rapidly [more than 6.6 feet (2 m) in 20 years] as they dissected the sediment deposits. We believe that these landscape changes have resulted in streams with deeper channels that do not flow over their banks as often as they historically did. As a result, historic floodwater volumes are often contained within the channel, and the occurrence of floods is decreased. We expect that the net effect of these factors on site vegetation is a shift toward less flood-tolerant species (Shear et al. 1996). Dramatic changes to the red rivers and adjacent bottoms are still occurring, and the forests there have not yet stabilized. In some areas, the sediments are still migrating downstream; where channels continue to fill and flood, deposition causes the valleys to become wetter. The

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[1] Much of this section is based on this excellent description of the modern development of the southern Piedmont landscape.

spatial distribution of this sediment migration has not been quantitatively described but is known to be widespread.

In addition to the effects of massive erosion, extensive areas of red river bottomland were cleared for agriculture and later abandoned. Because these bottoms are good wood producers, wood for fuel and fiber has been extracted from them continuously since European settlement. In recent years, many dams have been and continue to be built on the red rivers for flood control and water supply. These also have dramatically altered the hydrology of the bottomlands downstream, mainly by reducing the frequency and magnitude of floods.

Because red rivers are a relatively new landscape feature (most <250 years old), and because of the dramatic changes to their floodplains that continue to occur, we do not believe that any old-growth red river forests exist. All the stands along these rivers present at European settlement have been cut and/or otherwise severely altered. In the dynamic landscape after settlement, there have been no opportunities for new old-growth forests to develop. Stands older than 50 to 60 years are rare. Therefore, we propose a stand condition called older growth.

Examples of Older Red River Bottom Forests

Only two older red river bottom stands have been described in the scientific literature. In addition, we located and described five stands ≥100 years old. These stands are unusual because of the age and size of the trees and species composition and structure. All have been selectively cut, periodically burned, and probably grazed. However, none were ever cleared for agriculture and probably were never clearcut. We used these stands as the basis for our descriptions of older-growth red river bottom forests, and refer to them hereafter as the study forests. Species compositions are given in table 1.

Boiling Springs Natural Area (as described by Jones et al. 1981)

This is a 2.5-acre [1.0-hectare (ha)] stand in the poorly drained, alluvial floodplain of the Lower Three Runs Creek within the upper Coastal Plain in Barnwell County, South Carolina. The soil is wet, mucky, loam atop sand. The tract was designated as a natural area by the Appalachian Section of the Society of American Foresters in 1957. The dominant overstory trees are yellow-poplar, sweetgum, and loblolly pine (*Pinus taeda* L.). Five yellow-poplars were 113 to 186 years old, and five loblolly pines were 85 to 105 years old. Jones et al. (1981) speculated that the stand originated after a major catastrophic event 180 to 200 years ago and has not been disturbed since. However, we suspect that the pines became established after a later disturbance.

The loblolly pines were senescent and dying, with more than 50 percent of the large ones [>4.9 feet (>1.5 m) at breast height (d.b.h.), apparently older than the five trees cored] having died in the preceding 25 years. Red maple, green ash, and sweetgum are regenerating in the resulting gaps. The pines die standing, and therefore, do not expose bare mineral soil necessary for seed germination by species such as yellow-poplar. However, yellow-poplar is long-lived and is expected to maintain its density for another 100 to 150 years. Sweetgum and swamp tupelo [*Nyssa sylvatica* var. *biflora* (Walt.) sarg.] should respond favorably to the increased light and grow into the upper canopy on the wettest portion of the site. Shade-tolerant species (hickories and some oaks) in the understory will gradually gain importance.

Falling Creek Tract (as described by Edwards and McNab 1986)

This 2.2-acre (0.9-ha) stand in Jones County, Georgia, is a bottomland oak association at the confluence of an intermittent stream and Falling Creek, a major stream that flows into the Ocmulgee River 1 mile [1.6 kilometers (km)] downstream. Loblolly pine was the dominant overstory tree species, although there were no small trees, seedlings, or sapling individuals. Florida maple (*A. barbatum* Michx.), red maple, water oak, white oak (*Q. alba* L.), yellow-poplar, green ash, and sycamore also were prominent in the overstory. Most of the seedlings and saplings were flowering dogwood (*Cornus florida* L.), with significant amounts of American hornbeam (*Carpinus caroliniana* Walt.), eastern redbud (*Cercis canadensis* L.), and eastern hophornbeam [*Ostrya virginiana* (Mill.) K. Koch]. The understory was dominated by dense cane [*Arundinaria giganta* (Walter) Muhl].

Loblolly pine was declining at a rate of 3 to 7 percent annually. The oaks were expected to decline, with hickory and maples gaining in prominence.

Tennessee Valley Authority Tracts (as described by Shear et al. 1996)

These three stands are on the first bottoms of two Tennessee River tributaries: Blood River and Jonathan Creek. They are in Marshall and Calloway Counties, Kentucky, part of the northern extension of the east Gulf

Table 1—Species composition and structure of the overstories of seven older-growth red river bottom forests

Species	Relative basal area						
	Boiling Springs	Falling Creek	Union Camp	Devil's Gut	Blood River S	Blood River N	Jonathan Creek
Liriodendron tulipifera	49.5	5.2		5.0	12.0		
Liquidambar styraciflua	23.0		13.7	10.6	30.7	15.3	1.0
Pinus taeda	13.0	21.4		22.4			
Quercus laurifolia	3.0						
Nyssa sylvatica	2.5		6.3	.2		2.8	
Fagus grandifolia	2.0			33.0			
Acer rubrum	2.0	2.0	4.6	.3	9.7	13.3	25.2
Magnolia grandiflora	2.0						
Carya ovata	1.5				2.7		4.1
C. cordiformis	1.0				.9		.6
Quercus nigra	.5	4.7					
Other species (not specified)		18.8					
Acer barbatum		14.3					
Platanus occidentalis		10.6	3.5	.1			9.1
Carya tomentosa		9.9		1.6			
Quercus alba		5.5		1.2			
Fraxinus pennsylvanica		5.0	17.2	.0	2.9	13.8	9.9
Betula nigra		2.8			11.9		
Ulmus americana			21.9	3.4	1.0	20.8	6.5
U. rubra			10.7				
Q. phellos			9.6				
Celtis occidentalis			7.4				
Diospyros virginiana			2.1			1.4	
Q. falcata var. *pagodaefolia*			1.9	18.6	9.1		
Acer negundo			.4				3.5
U. alata			.3				
Q. bicolor			.3				
Carpinus caroliniana				2.2		1.8	1.3
Q. michauxii				.7		20.7	
Ostrya virginiana				.4			
Q. lyrata					17.6		
Celtis laevigata					1.1		10.1
Prunus serotina					.4		
Q. palustris						10.1	28.6
Total number of species	11	11	14	15	12	9	11
Total basal area, m^2/ha	34	20	30	30	32	27	34
Density, number of trees/ha	276	339	255	220	400	350	450
Diameter of largest trees, cm	110	69	89	118	68	84	69

Coastal Plain bounded on the east by the Tennessee River. We determined from aerial photographs and Tennessee Valley Authority (TVA) records that these are the only remaining bottomland forests in these watersheds not cleared for agriculture at some time. All are ditched to some degree for mosquito control. The Blood River South stand is a 4.5-acre (1.8-ha) tract on Waverly silt loam. The Blood River North stand occupies 7.4 acres (3.0 ha) on Falaya silt loam. The Jonathan Creek stand is a 5.4-acre (2.2-ha) tract on Waverly silt loam.

In 1993, the oldest trees were >100 years old. The Blood River South stand was dominated by sweetgum, with lesser amounts of overcup oak, river birch, red maple, and cherrybark oak. The Blood River North stand was dominated by American elm (*U. americana* L.), swamp chestnut oak, sweetgum, green ash, red maple, and pin oak (*Q. palustris* Muenchh.). In contrast, sweetgum was only a minor component of the Jonathan Creek stand, which was dominated by pin oak, red maple, hackberry (*Celtis occidentalis* L.), green ash, and sycamore. American elm, red maple, sweetgum, and hackberry were the predominant midstory species in all stands.

In the future, the overstories will probably consist of American elm, hackberry, and red maple. They are moderately shade tolerant and respond well to release at advanced ages (Fowells 1965). Since they are vigorous stump sprouters, future disturbances will not likely alter the current successional trends toward these species. The shade-intolerant sweetgum, an overstory dominant, loses sprouting ability after 50 years of age (Fowells 1965). It will probably become a minor overstory component as succession continues.

Devil's Gut Tract

This 49.4-acre (20-ha) stand is in Martin County, North Carolina, on a Coastal Plain ridge adjacent to Devil's Gut, a small tributary of the Roanoke River. The soils are of the Conetoe and Roanoke series, formed in sandy and loamy fluvial sediments.

The major dominant tree species is American beech, with lesser amounts of loblolly pine, cherrybark oak, and sweetgum. Two pines measured were 154 and 162 years old, and two beeches were 100 and 92 years old. There is some evidence of selective removal of the loblolly pine during the past 100 years. The high relative basal area of beech is typical of second-bottom forests. The stand should continue to be dominated by beech as it ages, while the pines gradually lose prominence and the oaks gain prominence.

Union Camp Tract

This 4.9-acre (2.0-ha) stand is located in Greensville County, Virginia, on the floodplain of the Meherrin River. The river has no dams and still floods one to four times a year. The soils are Congaree, a moderately well to well-drained fluvial loam soil, and the Riverview series, a well-drained fine, sandy loam.

The stand is an undisturbed remnant of an approximately 100-year-old tract that was logged. The overstory is dominated by elms, green ash, sweetgum, willow oak, and hackberry. The elms and hackberry should continue to dominate as the green ash, sweetgum, and oak gradually diminish.

Distinguishing Characteristics of Older Red River Bottom Forests

It is generally recognized that there can be no universally accepted definition of old-growth forests (Thomas et al. 1988, Hunter 1989). Hunter (1989) outlined a core definition as "old-growth forests are relatively old and relatively undisturbed by humans." He proposed several age and disturbance criteria that characterize an old-growth forest, each of which is discussed below in relation to the seven sites we have described.

1. The forest has reached an age at which the species composition has stabilized (the climax stage has been reached).

None of the species compositions of the study forests have stabilized (predictions about changes in species composition are given in the descriptions). The species composition of each study stand is expected to change over time, probably to a climax stage in which the forests are dominated by elm, hackberry, ironwood (*Bumelia* spp.), and boxelder (*A. negundo* L.).

2. The forest has reached an age at which the average net annual growth has stabilized.

Held and Winstead (1975) suggested that basal area might be an indicator of climax status for mesophytic forests, with basal areas of 130.8 square feet per acre (30 m^2/ha) for all trees greater than 3.9-inches [10-centimeters (cm)] d.b.h. representing climax stands. However, basal areas of natural

Piedmont bottomland hardwood forests peak at 130.8 to 174.4 square feet per acre (30 to 40 m^2/ha) between the ages of 50 and 60 years (depending on site index) and then may gradually decrease over time (Kenney 1983). Therefore, we do not believe that the stabilization of average net annual growth is a distinguishing characteristic of older-growth red river bottom stands.

3. The forest is significantly older than the average interval between natural disturbances severe enough to lead to succession.

The frequency of catastrophic events in these stand types has not been adequately described. We believe that a disturbance, either natural or man-made, allowed for the establishment of the loblolly pine of advanced age in a number of the stands we examined. No major disturbance could have occurred since because the pines would have been the first species eliminated by minor disturbances or to reintroduce themselves if the disturbance was great enough.

4. The dominant trees have reached the average life expectancy for that species on that site type.

All the study stands contain early- and mid-succession species (loblolly pine, sweetgum, oaks, etc.) that have reached maturity. However, these tree species are successional to the elms and hackberry and are not dominant in a climax stage.

5. The annual growth rate is below the average annual growth rate.

This criterion is met by a forest that has not been cut at the typical rotation age. All the study stands are older than the typical rotation age (40 to 60 years) of red river bottom forests. Shear et al. (1996) analyzed the patterns of growth over the past 30 years in the TVA stands. Biomass accumulation was constant during the 30 years and was about one-third that of 50-year-old stands.

6. The forest has never been extensively or intensively cut.

This criterion includes not only clearcuts but also selective cuts that could change species composition. There is evidence (stumps, land records, etc.) that there has been partial cutting in the five stands we measured ourselves. The reports of the Boiling Springs and Falling Creek stands indicate that they have been undisturbed but do not elaborate on selective cutting. It is unlikely that any of the study forests are virgin.

7. The forest has never been converted to another type of ecosystem.

None of the study forests has ever been converted to agriculture or another type of ecosystem, so far as we can determine.

The study sites meet only criteria 2, 5, and 7. Hunter (1989) suggested that stands that meet criteria 2 and 6 be called old growth, while those that meet criteria 3 and 7 be called simply "old." Other criteria have been suggested as characteristic of old-growth forests, such as high species richness and diversity, snags and coarse woody debris, and tree-fall gaps (Thomas et al. 1988, Muller and Liu 1991, Martin 1992).

Many red river bottomlands were cleared for agriculture and later abandoned. Shear et al. (1996) compared the plant community structures and compositions of the TVA stands to 50-year-old stands that had been restored on agricultural fields. They found that the restored stands were composed almost entirely of light-seeded species. Importation of heavy-seeded species (oaks, hickories, etc.) was occurring slowly (fig. 1), and they were likely to be absent from the restored stands for a long time. A criterion for classification as an older-growth red river bottom forest should be that the nut species are prominent in the stand.

Many gaps were noticed in the two stands we measured directly and the three TVA stands. The gaps were created by fallen trees and standing dead trees and contained large numbers of various tree seedlings and saplings. These gaps are not apparent in the typical, younger red river bottom forests.

A large accumulation of coarse woody debris is often considered an important old-growth condition (Parker 1989, Muller and Liu 1991). To our knowledge, coarse woody debris has never before been characterized in an older red river bottom forest. On a floodplain, woody debris constantly comes and goes with flood waters. How this affects the accumulation of such debris is not known. Scouring of the soil surface was apparent in the Union Camp stand and the TVA stands. In many places, this removed the leaf litter and exposed bare soil and fine roots. Woody debris was piled up in mounds next to standing and fallen trees, where it was pushed by flood waters. Because of the constant redistribution by flood waters, with export apparently exceeding import in the stands we observed, we do not believe that coarse woody debris is an important characteristic of older red river bottom stands. The Devil's Gut stand did not show signs of scouring and redistribution

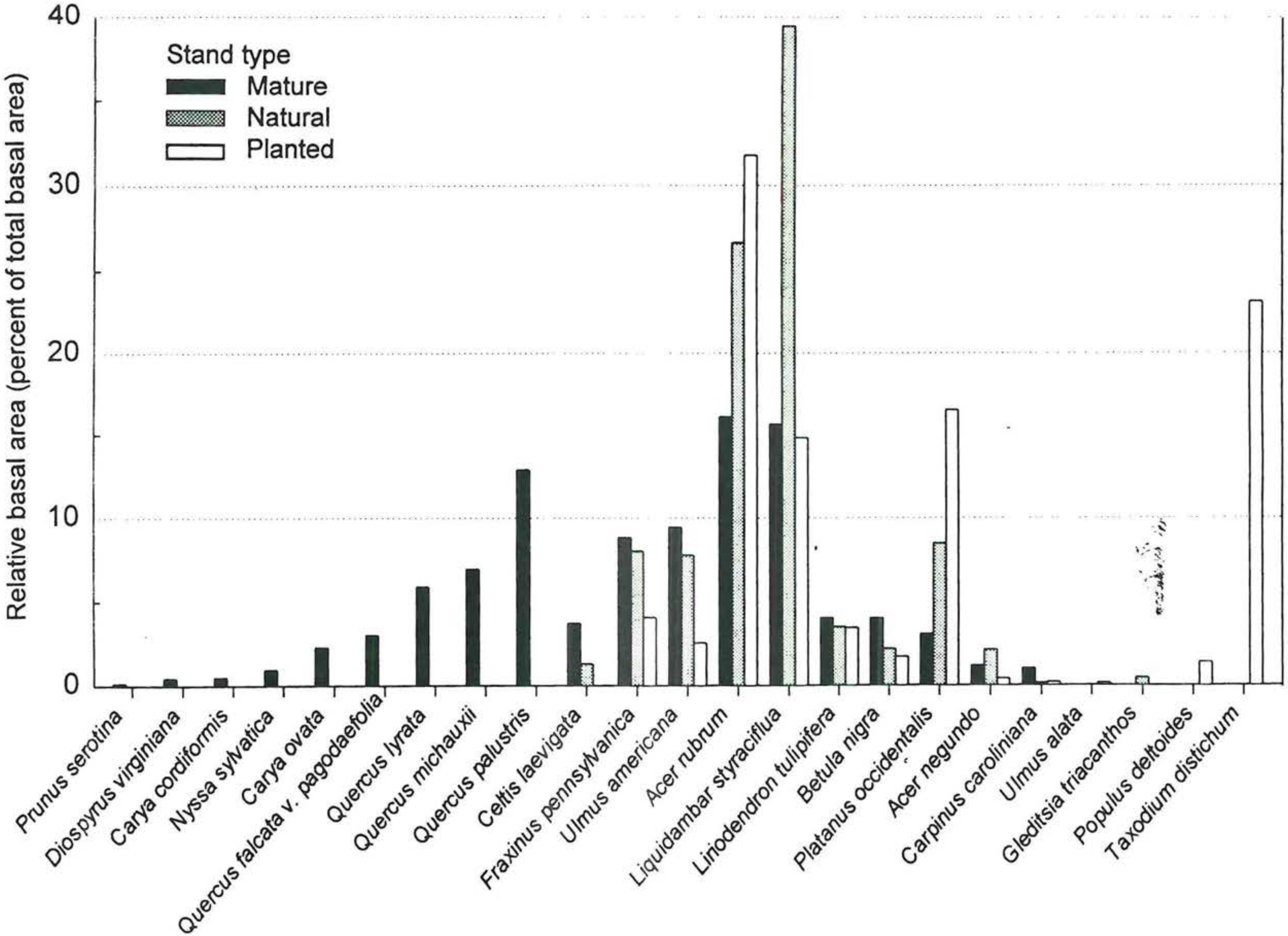

Figure 1—Relative species basal areas of older-growth (mature) and 50-year-old red river bottom forests restored on agricultural land by planting and natural regeneration. Note that the restored stands are depauperate of heavy-seeded species (adapted from Shear et al. 1996).

of coarse woody debris. Therefore, we measured the amount of debris (using the method of Brown 1974). The stand contained 7.2 metric tons per acre [16.1 megagrams (Mg)/ha] of coarse woody debris, which is about 10 percent of the total biomass of the overstory [81.2 metric tons per acre (182 Mg/ha, calculated from basal area from Gardner et al. 1982)]. This is within the range found for warm, temperate zone, deciduous forests [7.6 to 10.7 metric tons per acre (17 to 24 Mg/ha)] (Muller and Liu 1991). Muller and Liu (1991) found 9.7 metric tons per acre (21.8 Mg/ha) of coarse woody debris in an old-growth upland deciduous forest in southeastern Kentucky, also equivalent to 10 percent of the overstory biomass [95.3 metric tons per acre (213.6 Mg/ha)].

We inventoried the understory of the Devil's Gut stand and also examined the descriptions of the understories of the three TVA stands (table 2). There was nothing about the species composition that would be characteristic of older-growth forests. Poison ivy (*Toxicodendron radicans* Ktze.) was the dominant understory species in all the stands, equalled in abundance only by spicebush (*Lindera benzoin* L.) in the Devil's Cut stand. The presence of poison ivy usually indicates disturbance. However, poison ivy occurred in much greater abundance in the older TVA stands than in the restored stands mentioned above (Shear et al. 1996). In addition, sweetgum seedlings were prevalent in the restored stands but were completely absent from the older stands.

Based on our observations, we define older-growth red river bottom forests as having the following characteristics:

- Relatively undisturbed for at least 50 years
- Never converted to field or pasture and abandoned
- The oldest trees are >100 years old
- Low tree densities [<988.4 trees per acre(<400 trees/ha)]
- Trees of all diameters, including >15.8 inches (>40 cm) in diameter
- A variety of plant species of many seed types, with a large proportion of heavy-seeded species, including oaks (cherrybark, swamp chestnut, overcup, and pin), hickories, and blackgum (*Nyssa sylvatica* Marshall)
- Well-developed midstories and understories similar to younger stands, with poison ivy often predominating in the understory
- Gaps distributed throughout the stand

With time and stable site conditions, we believe that old-growth red river forests can develop from older-growth forests. We expect these old-growth forests to have basal areas equivalent or slightly lower than older-growth forests, lower tree densities, and to be dominated by elms, hackberry, ironwood, and boxelder. On higher second bottoms, beech will also be an important component.

Landscape changes have altered species composition. Many wetland forests in which the hydrology has been disturbed appear to develop overstories dominated by red maple. This shift to red maple is also apparent throughout the eastern deciduous forest, where it replaces oaks in relatively mature forests (Abrams 1992). This is probably a result of fire suppression. We have also observed that American beech is gaining prominence in red river bottom forests, particularly on the second bottoms. This is apparently a response to reduced flooding. These conditions of reduced flooding and burning are likely to continue. As a result, red maple and American beech are likely to become more common in bottomland forests than they were before European settlement.

Table 2—Understory species composition of four older-growth red river bottom stands

Species	Percent cover: Union Camp	Blood River S	Blood River N	Jonathan Creek
Lindera Benzoin	17.3	9.5		
Toxicodendron radicans	16.1	10.5	33.6	20.3
Smilax rotundifolia	8.9	1.8	<.1	7.8
Ilex decidua	6.9			
Viburnum prunifolium	5.6			
Boehmeria cylindrica	3.4	.9	1.0	2.3
Campsis radicans	3.4		.8	7.3
Arisaema triphylum	1.6			
Saururus cernuus	1.4	3.2	2.5	
Anisostichus capreolata	.8		1.5	.7
Viola spp.	.7	<.1	<.1	.2
Urtica dioica	.6			9.3
Cryptotaenia canadensis	.5	.5		2.3
Grasses	.4		1.6	4.6
Tovara virginica	.4	.5		.8
Lonicera japonica	.4	3.1	.2	
Onoclea sensibilis	.4			
Impatiens capensis	.2	2.9	4.3	.3
Arisaema dracontium	.2			
Crataegus viridus	.2			
Parthenocissus quinquefolia	.1	1.6		
Fraxinus pennsylvanica	.1	1.7	.3	
Passiflora lutea	.1			
Mitchella repens	.1			
Oxydendrum arboreum		6.5		
Clethra alnifolia		4.0		
Asteracea (composites)		2.6		
Sambucus canadensis		2.3		2.1
Corylus americana		2.0		
Microstegium vimineum		1.6		7.2
Polistricum spp. (moss)		1.5		
Agrostis spp.		1.4		
Aster dumosus		1.0	5.1	.2
Athyrium asplenioides		.8		
Carex spp.		.8	.7	.1
Geum canadense		.7	.1	.4
Clematis virginiana		.5		
Lactuca spp.		.5		
Sanicula gregaria		.5		.2
Vitis baileyana		.5		
Smilacina racemosa		.3		
Acer rubrum		.2		
Cornus stricta		.2	.3	
Euonymous americanus		.2		
Galium triflorum		.2		.1
Rubus allegheniensis		.2		
Hypericum spp.			.3	
Celtis occidentalis			.3	5.5
Asimina triloba				.4
Dioscorea villosa		.2		.8
Botrychium virginianum		.3		.1
Carya spp.		.3		
Ulmus americana		.3	.6	.3
Lycopus virginicus		.1		
Quercus spp.		.1	.4	.2
Pilea pumila				.2
Solidago spp.			1.2	.7
Crataegus marshallii			.5	
Peltandra virginica			.5	
Carpinus caroliniana			.2	
Juncus spp.			.1	
Acer negundo				.7
Vitis riparia				.7
Stachys tenuifolia				.6
Woodwardia aerolata				.2
Total percent cover	70	66	56	77
Total number of species	24	40	24	30

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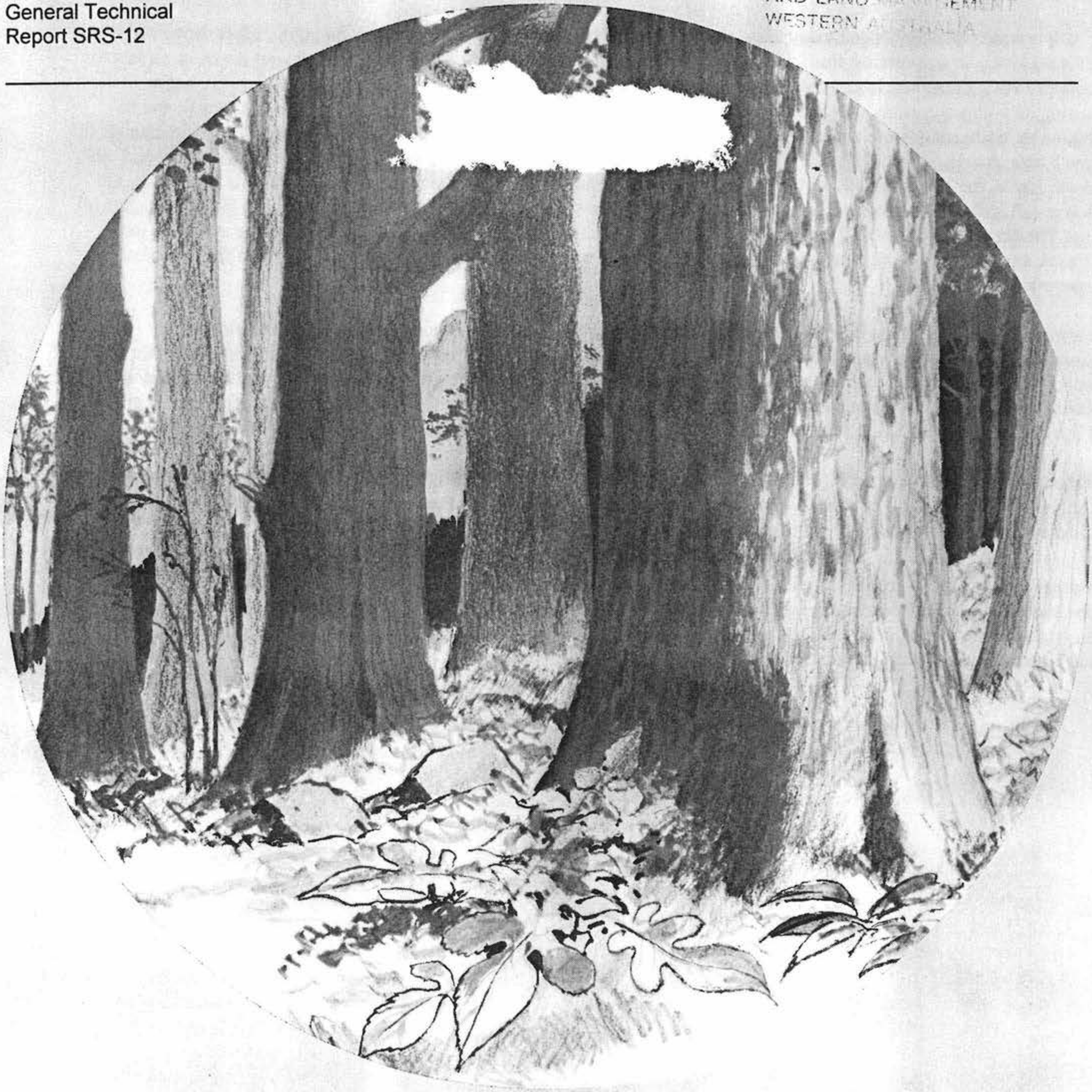
General Technical
Report SRS-12

An Old-Growth Definition for Sand Pine Forests

Kenneth W. Outcalt



A Section of the Old-Growth Definition Series

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Preface

Old growth is widely acknowledged today as an essential part of managed forests, particularly on public lands. However, this concept is relatively new, evolving since the 1970's when a grassroots movement in the Pacific Northwest began in earnest to define old growth. In response to changes in public attitude, the U.S. Department of Agriculture, Forest Service, began reevaluating its policy regarding old-growth forests in the 1980's. Indeed, the ecological significance of old growth and its contribution to biodiversity were apparent. It was also evident that definitions were needed to adequately assess and manage the old-growth resource. However, definitions of old growth varied widely among scientists. To address this discrepancy and other old-growth issues, the National Old-Growth Task Group was formed in 1988. At the recommendation of this committee, old growth was officially recognized as a distinct resource by the Forest Service, greatly enhancing its status in forest management planning. The committee devised "The Generic Definition and Description of Old-Growth Forests" to serve as a basis for further work and to ensure uniformity among Forest Service Stations and Regions. Emphasis was placed on the quantification of old-growth attributes.

At the urging of the Chief of the Forest Service, all Forest Service Stations and Regions began developing old-growth definitions for specific forest types. Because the Southern and Eastern Regions share many forest communities (together they encompass the entire Eastern United States), their efforts were combined, and a cooperative agreement was established with The Nature Conservancy for technical support. The resulting project represents the first large-scale effort to define old growth for all forests in the Eastern United States. This project helped bring the old-growth issue to public attention in the East.

Definitions will first be developed for broad forest types and based mainly on published information and so must be viewed accordingly. Refinements will be made by the Forest Service as new information becomes available. This document represents 1 of 35 forest types for which old-growth definitions will be drafted.

In preparing individual old-growth definitions, authors followed National Old-Growth Task Group guidelines, which differ from the standard General Technical Report format in two ways—the abstract (missing in this report) and the literature citations (listed in Southern Journal of Applied Forestry style). Allowing for these deviations will ensure consistency across organizational and geographic boundaries.

July 1997

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An Old-Growth Definition for Sand Pine Forests

Kenneth W. Outcalt

Introduction

Sand pine scrub, Society of American Foresters cover type 69 (Eyre 1980), grows on deep, droughty, infertile sands of marine and aeolian origin. Water and wind formed these features as sea levels fluctuated during past glacial and interglacial periods (Kurz 1942, Laessle 1958, Brooks 1972). Because of washing and sorting during transport and deposition, soil parent material was nearly pure quartz sand (Laessle 1958). This produced soils that are almost exclusively entisols and mostly Quartzipsamments (Myers 1990), typified by the Astatula, Lakeland, Paola, and St. Lucie soil series.

The Ocala variety (*Pinus clausa* var. *clausa* D.B. Ward) of sand pine is native to the central ridge of Florida and a strip of old dunes stretching from St. John's County south to the northern portion of Dade County on the east coast and from near Cedar Key south to Naples on the west coast (Small 1921, Harper 1927, Myers 1990). Choctawhatchee sand pine (*P. clausa* var. *immuginata* D.B. Ward) is the dominant tree in scrubs along the Gulf Coast (including off-shore islands) of northwest Florida from the Apalachicola River westward into Alabama. The largest concentration of sand pine is the interior scrub, which occupies about 250,000 acres (ac) [101,250 hectares (ha)] on the Ocala National Forest (Brendemuehl 1990).

Sand pine is native to areas that have hot, humid summers, somewhat dry winters, and a long growing season (269 to 312 days). Precipitation is abundant, 53.0 to 60.0 inches per year [1345 to 1525 millimeters (mm) per year]; July is the wettest and May the driest month. Because of the low moisture-holding capacity of the soils, drought conditions can exist within 2 weeks of a heavy rainfall. Surface temperatures of exposed soils can also be extreme, reaching 140 °F (60 °C) on summer days (Burns and Hebb 1972).

Ocala sand pine forests have an overstory of even-aged sand pine with twisted and leaning trunks growing over an understory of evergreen shrubs (Myers 1990). Typical understory species include myrtle oak (*Quercus myrtifolia* Willd.), sand live oak [*Q. virginiana* var. *geminata* (Small) Sarg.], Chapman oak (*Q. chapmanii* Sarg.), turkey oak (*Q. laevis* Walt.), rusty lyonia [*Lyonia ferruginea* (Walt.) Nutt.], rosemary (*Ceratiola ericoides* Michx.), scrub palmetto (*Sabal etonia* Swingle ex Nash), and saw-palmetto [*Serenoa repens* (Bartr.) Small]. Because of dry soils and competition from the sand pine overstory and understory shrubs, herbs and grasses are very sparse in mature scrub habitats. Typical species include beak-rush (*Rhynchospora megalocarpa* Vahl), milk-peas (*Galactia* spp.), and bluestem (*Andropogon* spp.). Lichens (*Cladonia* spp.) form extensive patches on the forest floor.

Because of its sparse ground cover and compacted litter layer, Ocala sand pine scrub seldom burns. Periodically (every 10 to 100 years), usually during the spring drought, high winds and extreme conditions result in high-intensity fires. These fires burn off the understory and kill the sand pine overstory (Myers 1990). These fires also open the many serotinous cones contained in the crowns of the sand pine, releasing the seed for establishment of the next stand. Choctawhatchee sand pine trees produce cones that open at maturity, so catastrophic fires are not required for regeneration. Overstory trees are more likely replaced as a result of blow-down from periodic tropical storms.

These sand pine scrub communities are unique habitats with a mix of species that occur nowhere else (Christman and Judd 1990). Although most of the endemic species thrive in the open scrub when sand pine trees are just seedlings, the old-growth stage is still an important part of the ecosystem.

Old-growth sand pine [*P. clausa* (Chapm. ex Engelm.) Vasey ex Sarg.] stands were inventoried and a set of attributes developed to characterize what constitutes old growth for this forest ecosystem. Preliminary sampling indicated that there was a change in stand structure around age 50 years for Ocala sand pine. Based on this information, three stands of Ocala sand pine were randomly chosen from all the stands on the Ocala National Forest with an average age of 50 years or more. Within each stand, three circular plots 0.25 ac (0.1 ha) were established. The species, diameter, and crown class were recorded for all trees 4 inches [10 centimeters (cm)] or larger within these plots.

Snags and stumps were also recorded. Age and height were determined for the two largest sand pines in each plot as were the number of canopy layers and their height range. The species and diameter of all trees 0.8 inches (2.0 cm) to 4.0 inches (10.0 cm) in diameter (tall shrub layer) were recorded from a 0.025-ac (0.01-ha) circular plot at the center of each larger plot. Subplots of 10.8 square feet [1.0 square meter (m)] were established 9.9 feet (3.0 m) from the plot center in each of the four cardinal directions. The number of stems less and greater than 3.3 feet (1.0 m) tall was recorded by species for all woody vegetation less than 0.8 inches (2.0 cm) in diameter within these plots. The number of herbaceous stems on these subplots was also recorded by species. The percentage cover of lichens was estimated by ocular comparison to templates of known coverage. Depth of the forest floor was measured at the center of each subplot. Cover of downed woody material greater than 4.0 inches (10.0 cm) in diameter and gaps in the overstory canopy were determined along two 49.0-feet (15.0-m) line transects between the large plot boundaries.

Three Choctawhatchee sand pine stands were also sampled. Two of the sample stands were located on Eglin Air Force Base, and the third was on Fred Gannon State Park located near Niceville, FL. Sample stands were chosen from within the historical range of the variety. Also, only stands in the interior of the cover type were used to avoid sampling a former sandhills site that had been invaded by sand pine due to a reduction in natural fires. (Because herbaceous species were more prevalent in Choctawhatchee sand pine stands, cover estimates were used rather than stem counts.)

Old-Growth Attributes

Ocala Sand Pine

Some of the paleodunes Ocala sand pine occupy are only an acre (0.4 ha) in size, but they can still develop old growth. Conversely, old growth can develop over extensive areas in the even-aged stands that follow the large fires once prevalent in the big scrub area of the Ocala National Forest.

The overstory of old-growth Ocala sand pine stands, as in younger stands, is composed entirely of sand pine (table 1). Dominant trees made up 50 percent and codominants 25 percent of the total overstory of the sample stands. Ocala sand pine is a small tree, and stands had an average tree diameter of only 7.5 inches (19.1 cm). The largest sand pines in the stands, however, had a mean diameter of 14.0 inches (35.0 cm), were more than 70.0 feet (22.0 m) tall, and averaged 55 years old. Because of the sparse stocking and small tree size, stand basal area was low, about 40.0 square feet per ac (9.0 m^2 per ha). Ocala sand pine is susceptible to root rot fungi, with mortality increasing sharply beyond age 40 years (Ross 1970). Because of this mortality, snags and canopy gaps were common in most old-growth stands. The low tree density of sample plots is not typical of all old-growth stands. A sample of 12 stands older than 60 years in the big scrub area of the Seminole District, Ocala National Forest, had an average density of 200 trees per ac (480 trees per ha).[1]

Mid-story oaks were a significant part of the old-growth vegetation, occupying the canopy gaps between the overstory sand pine. About half (56 percent) of the mid-story oaks were sand live oak, and 26 percent were myrtle oak. The mid-story oaks were nearly as large as the overstory sand pine, with an average diameter of 6.9 inches (17.5 cm). This canopy layer was typically 15.0 to 25.0 feet (4.6 to 7.6 m) tall. Sapling-size oaks formed a tall shrub layer of moderate density 10.0 to 15.0 feet (3.0 to 4.6 m) in height. This layer was a mixture of myrtle, Chapman, and sand live oaks, mostly of small diameter (table 2). Beneath the tall shrubs was a sparse understory of mostly woody species, a few scattered herbs, and some lichens (table 3). Sand pine seedlings and saplings were rare in these old-growth stands. The forest floor was thin with an average depth of 1.7 inches (4.4 cm).

No indicator species are specific to old-growth Ocala sand pine stands. These stands contain the same mix of species found in nearly all stands older than 20 years. The main indicators of old growth are the size and age of the sand pine overstory, and the presence of large, mid-story oaks, canopy gaps, and numerous snags. Composition of the mid-story, tall shrub, and understory layers may vary in other locations, especially in isolated scrubs such as those of the Lake Wales Ridge and near coastal areas. Structure and physiognomy, however, will remain similar for old-growth Ocala sand pine stands across most of its range. On some extremely dry sites, however, even the sand pine is stunted and sparse. Old-growth Ocala sand pine on these areas will not look like the typical stands described here.

[1] Personal communication. 1996. Janet Hinchee, Silviculturist, Ocala National Forest, Seminole Ranger District, 40929 State Road 19, Umat FL 32784.

Table 1 (English units)—Standardized table of old-growth attributes for Ocala sand pine forests [a] [b]

Quantifiable attribute	Value: Range	Value: Mean
Stand density (no./acre)		
—trees ≥4 in. d.b.h.		
Ocala sand pine	65 - 121	79.0
Dominants	38 - 53	41.0
Codominants	8 - 51	21.0
Intermediates	6 - 24	11.0
Suppressed	4 - 9	6.0
Mid-story oaks	4 - 40	25.0
Stand diameter (in)		
Ocala sand pine	6.2 - 8.6	7.5
Dominants	8.6 - 12.5	10.8
Codominants	6.7 - 8.3	7.5
Intermediates	5.8 - 6.3	6.0
Suppressed	4.9 - 5.0	4.9
Mid-story oaks	5.9 - 7.9	6.9
Stand basal area (ft^2/acre)		
—trees ≥4 in. d.b.h.		
Ocala sand pine	36.6 - 39.2	37.5
Mid-story oaks	.4 - 7.0	3.5
Age of largest trees (yrs)		
Ocala sand pine	45 - 70	55.0
Diameter of largest trees (in)		
Ocala sand pine	10 - 17	14.0
Height of largest trees (ft)		
Ocala sand pine	50 - 82	72.0
Standing snags (no./acre)		
—snags ≥4 in. d.b.h.	5 - 30	19.0
Downed logs (% cover)	.5 - 5.0	2.4
Number of canopy layers	--	3.0
Canopy gaps (% cover)	5 - 75	27.0
Other features		
Stumps (no./acre)	--	3.0

[a] Number of stands is three in all attributes.
[b] The reference for all attributes is Kenneth W. Outcalt.

Table 1 (metric units)—Standardized table of old-growth attributes for Ocala sand pine forests [a] [b]

Quantifiable attribute	Value: Range	Value: Mean
Stand density (no./ha)		
—trees ≥10 cm d.b.h.		
Ocala sand pine	160 - 300	194.0
Dominants	93 - 130	101.0
Codominants	20 - 125	51.0
Intermediates	15 - 60	27.0
Suppressed	10 - 23	15.0
Mid-story oaks	10 - 100	62.0
Stand diameter (cm)		
Ocala sand pine	15.7 - 21.8	19.1
Dominants	21.9 - 31.8	27.4
Codominants	17.1 - 21.0	19.0
Intermediates	14.6 - 15.9	15.3
Suppressed	12.5 - 12.6	12.5
Mid-story oaks	15.0 - 20.0	17.5
Stand basal area (m^2/ha)		
—trees ≥10 cm d.b.h.		
Ocala sand pine	8.4 - 9.0	8.6
Mid-story oaks	.1 - 1.6	.8
Age of largest trees (yrs)		
Ocala sand pine	45 - 70	55.0
Diameter of largest trees (cm)		
Ocala sand pine	26 - 43	35.0
Height of largest trees (m)		
Ocala sand pine	15 - 25	22.0
Standing snags (no./ha)		
—snags≥10 cm d.b.h.	13 - 73	47.0
Downed logs (% cover)	.5 - 5.0	2.4
Number of canopy layers	--	3.0
Canopy gaps (% cover)	5 - 75	27.0
Other features		
Stumps (no./ha)	--	8.0

[a] Number of stands is three in all attributes.
[b] The reference for all attributes is Kenneth W. Outcalt.

Table 2—Density of species in tall shrub layer of old-growth Ocala sand pine stands

Species	Diameter class					
	0.8-2.39 in	2.4-3.14 in	3.5-3.9 in	2.0-5.9 cm	6.0-7.9 cm	8.0-9.9 cm
	- - - - - - -Number per acre- - - - - - -			*- - - - - - -Number per hectare- - - - - -*		
Quercus myrtifolia	162	91	9	400	225	23
Q. chapmanii	162	91	3	400	225	8
Q. virginiana var. *geminata*	93	69	12	230	170	30
Pinus clausa var. *clausa*	12	6	3	30	16	8
Lyonia ferruginea	--	--	2	--	--	5

Table 3—Abundance of major understory species found in old-growth Ocala sand pine stands

Species	English		Metric	
	>3.3 ft	≤3.3 ft	>1 m	≤1 m
	- - -No./yd²- - -		*- - -No./m²- - -*	
Shrubs				
Quercus myrtifolia	0.25	13.46	0.28	14.72
Q. virginiana var. *geminata*	.08	2.72	.08	2.97
Q. chapmanii	.18	1.63	.19	1.78
Vaccinium myrsinites	--	1.17	--	1.28
Lyonia ferruginea	.25	.51	.28	.56
Sabal etonia	.03	.43	.03	.47
Gaylussacia dumosa	--	.15	--	.17
Asimina obovata	.03	.08	.03	.08
Serenoa repens	--	.08	--	.08
Ceratiola ericoides	.03	.03	.03	.03
Persea humilis	--	.03	--	.03
Ilex opaca var. *arenicola*	--	.03	--	.03
Pinus clausa var. *clausa*	--	.03	--	.03
Herbs				
Galactia volubilis	--	.20	--	.22
Rhychospora spp.	--	.20	--	.22
Lichens (% cover)				
Cladonia spp.		7.70		7.70

Old-growth conditions will develop as stands progress beyond age 50 years; numerous examples exist on the Ocala National Forest. A good example of old-growth coastal scrub is found in the Southwest Florida Water Management District and occupies a portion of the Starkey Tract in southwestern Pasco County.

Land managers can produce old-growth by carrying some stands past the normal rotation age of 35 to 40 years. Old growth is a short-lived state, however, as stands rapidly lose their sand pine beyond 70 years (Richardson 1977). Without some disturbance from fire or harvesting, stands will eventually form xeric hammocks dominated by oaks (Laessle 1958, Veno 1976, Myers 1985). For this reason, fire needs to be allowed to occur naturally or should be introduced artificially in designated Ocala sand pine wilderness areas. This will open the area to the many endemic plants and animals that prefer the young scrub and will foster natural regeneration and establishment of even-aged sand pine stands that will later again develop into old-growth stands.

Choctawhatchee Sand Pine

The overstory of old-growth Choctawhatchee sand pine stands is almost exclusively sand pine with an occasional longleaf pine (*P. palustris* Mill.) or large sand live oak. The old-growth stands sampled were relatively well stocked, with groups of overstory sand pine and fair-sized oaks in the intervening canopy gaps (table 4). Because Choctawhatchee sand pine sheds most of its seed when cones mature, regeneration is a continuous process. This results in a large number of trees in the intermediate and suppressed crown classes (46 percent) and fewer dominants (35 percent).

Average tree diameter was 7.9 inches (20.1 cm), while dominant trees averaged more than 12.0 inches (30.0 cm) in diameter. The largest trees in the old-growth stands had a mean diameter of more than 15.0 inches (39.0 cm), were 70.0 feet (22.0 m) tall and 80 years old. Good stocking and tree size gave a basal area of 70.0 square feet per ac (16.0 square meters per ha). Snags were evident but not prevalent. Canopy gaps were numerous, occupying 25 percent of the area. Most of these gaps were the result of blow-down from a major hurricane that occurred about 20 years ago. Downed logs occurred but were not common.

Mid-story oaks were a prominent feature of the old-growth stands. More than one-third of all trees larger than 4.0 inches (10.0 cm) diameter at breast height were oaks. The average diameter of the oaks was 1.6 inches (4.0 cm) smaller than that of the sand pine, but they made up 20 percent of the total stand basal area. Sand live oak was predominant, making up 84 percent of the mid-story layer. Most of the trees in this layer were 20.0 to 35.0 feet (6.1 to 10.7 m) tall with an occasional individual 40.0 to 50.0 feet (12.2 to 15.2 m) high reaching into the lower portion of the overstory canopy. Beneath the mid-story was a shrub layer from 10.0 to 20.0 feet (3.0 to 6.1 m) tall, dominated by sand pine regeneration and oaks with lesser numbers of tree blueberry (*Vaccinium* spp.) (table 5). Ongoing work at Eglin Air Force Base indicates that the composition of these shrub layers can be quite variable.[2] The sparse understory layer was mostly woody species and a few herbs growing between patches of lichens (table 6). The thin forest floor had a mean thickness of 1.7 inches (4.3 cm).

There were no indicator species specific to old-growth Choctawhatchee sand pine stands. The best identifiers of old-growth status are the size and age of the sand pine overstory; the presence of numerous large, mid-story oaks; and the abundant canopy gaps. The amount of downed woody material is a poor indicator because it varies greatly depending on the length of time since the last major hurricane.

The ecology and dynamics of the Choctawhatchee sand pine community have been studied less than those of the Ocala scrubs. The importance and natural abundance of old-growth stands is not specifically known. However, since some old growth was part of the natural landscape, it is wise to allow for its continued existence until we better understand its function and importance to the ecosystem. To do this, land managers can produce old growth by allowing some stands to reach 70 to 100 years of age. A good example of these old-growth conditions occurs in stands at Fred Gannon State Park near Niceville, FL. Other old-growth Choctawhatchee sand pine stands occupy areas on nearby Eglin Air Force Base.

[2] Personal communication. 1996. Stephen Seiber, Acting Chief, Natural Resources Division, Eglin Air Force Base, AFDTC/EMNF, 107 Highway 85N, Niceville, FL 32542.

Table 4 (English units)—Standardized table of old-growth attributes for Choctawhatchee sand pine forests [a] [b]

Quantifiable attribute	Value: Range	Value: Mean
Stand density (no./acre)		
—trees ≥4 in. d.b.h.		
Choctawhatchee sand pine	100 - 182	143.0
Dominants	31 - 68	50.0
Codominants	19 - 31	24.0
Intermediates	16 - 47	26.0
Suppressed	25 - 51	40.0
Mid-story oaks	42 - 109	74.0
Stand diameter (in)		
Choctawhatchee sand pine	7.7- 8.2	7.9
Dominants	12.5- 13.0	12.8
Codominants	8.8- 9.5	9.1
Intermediates	6.3- 7.3	6.7
Suppressed	5.1- 5.4	5.2
Mid-story oaks	5.6- 6.7	6.3
Stand basal area (ft^2/acre)		
—trees ≥4 in. d.b.h.		
Choctawhatchee sand pine	48.8- 83.6	70.1
Mid-story oaks	8.3- 32.2	17.4
Age of largest trees (yrs)		
Choctawhatchee sand pine	60 - 113	83.0
Diameter of largest trees (in)		
Choctawhatchee sand pine	12.8- 18.9	15.4
Height of largest trees (ft)		
Choctawhatchee sand pine	62 - 85	72.0
Standing snags (no./acre)		
—snags ≥4 in. d.b.h.	3 - 19	9.0
Downed logs (% cover)	1.0- 3.0	1.2
Number of canopy layers	--	3.0
Canopy gaps (% cover)	13.0- 37.0	26.0
Other features		
Stumps (no./acre)	8 - 21	12.0

[a] Number of stands is three in all attributes.
[b] The reference for all attributes is Kenneth W. Outcalt.

Table 4 (metric units)—Standardized table of old-growth attributes for Choctawhatchee sand pine forests [a] [b]

Quantifiable attribute	Value: Range	Value: Mean
Stand density (no./ha)		
—trees ≥10 cm d.b.h.		
Choctawhatchee sand pine	247 - 450	354.0
Dominants	77 - 167	124.0
Codominants	47 - 77	59.0
Intermediates	40 - 117	65.0
Suppressed	63 - 127	99.0
Mid-story oaks	103 - 270	183.0
Stand diameter (cm)		
Choctawhatchee sand pine	19.5- 20.7	20.1
Dominants	21.7- 33.1	32.6
Codominants	22.4- 24.0	23.2
Intermediates	16.0- 18.5	16.9
Suppressed	12.9- 13.6	13.1
Mid-story oaks	14.1- 17.0	15.9
Stand basal area (m^2/ha)		
—trees ≥10 cm d.b.h.		
Choctawhatchee sand pine	11.2- 19.2	16.1
Mid-story oaks	1.9- 7.4	4.0
Age of largest trees (yrs)		
Choctawhatchee sand pine	60 - 113	83.0
Diameter of largest trees (cm)		
Choctawhatchee sand pine	32.5- 47.9	39.2
Height of largest trees (m)		
Choctawhatchee sand pine	19 - 26	22.0
Standing snags (no./ha)		
—snags≥10 cm d.b.h.	7 - 47	22.0
Downed logs (% cover)	1.0- 3.0	1.2
Number of canopy layers	--	3.0
Canopy gaps (% cover)	13 - 37	26.0
Other features		
Stumps (no./ha)	20 - 53	30.0

[a] Number of stands is three in all attributes.
[b] The reference for all attributes is Kenneth W. Outcalt.

Table 5—Density of species in tall shrub layer of old-growth Choctawhatchee sand pine stands

Species	Diameter class					
	0.8-2.39 in	2.4-3.14 in	3.5-3.9 in	2.0-5.9 cm	6.0-7.9 cm	8.0-9.9 cm
	------ *Number per acre* ------			------ *Number per hectare* -----		
Pinus clausa var. *immuginata*	214	26	9	530	65	22
Quercus virginiana var. *geminata*	36	18	9	90	44	22
Vaccinium arboreum	40	13	9	100	33	22
Q. laevis	44	9	--	110	22	--
Q. laurifolia	26	4	--	65	11	--
Q. myrtifolia	36	--	--	90	--	--

Table 6—Abundance of major understory species found in old-growth Choctawhatchee sand pine stands

Species	English		Metric	
	>3.3 ft	≤3.3 ft	>1 m	≤1 m
	--- *No./yd²* ---		---- *No./m²* ---	
Shrubs				
Ilex vomitoria	0.10	3.6	0.10	3.3
Quercus laurifolia	.03	2.2	.03	2.0
Smilax spp.	--	2.2	--	2.0
Pinus clausa var. *immuginata*	.30	2.0	.30	1.8
Q. myrtifolia	--	1.4	--	1.3
Q. virginiana var. *geminata*	.03	1.3	.03	1.2
Licania michauxii	--	.7	--	.6
Q. laevis	--	.1	--	.1
Herbs (% cover)				
Rhychospora spp.		3.0		3.0
Galactia volubilis		2.0		2.0
Panic spp.		2.0		2.0
Lichens (% cover)				
Cladonia spp.		30.0		30.0

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United States
Department of
Agriculture

Forest Service

Southern
Research Station

General Technical
Report SRS-13

An Old-Growth Definition for Tropical and Subtropical Forests in Florida

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A Section of the Old-Growth Definition Series

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Preface

Old growth is widely acknowledged today as an essential part of managed forests, particularly on public lands. However, this concept is relatively new, evolving since the 1970's when a grassroots movement in the Pacific Northwest began in earnest to define old growth. In response to changes in public attitude, the U.S. Department of Agriculture, Forest Service, began reevaluating its policy regarding old-growth forests in the 1980's. Indeed, the ecological significance of old growth and its contribution to biodiversity were apparent. It was also evident that definitions were needed to adequately assess and manage the old-growth resource. However, definitions of old growth varied widely among scientists. To address this discrepancy and other old-growth issues, the National Old-Growth Task Group was formed in 1988. At the recommendation of this committee, old growth was officially recognized as a distinct resource by the Forest Service, greatly enhancing its status in forest management planning. The committee devised "The Generic Definition and Description of Old-Growth Forests" to serve as a basis for further work and to ensure uniformity among Forest Service Stations and Regions. Emphasis was placed on the quantification of old-growth attributes.

At the urging of the Chief of the Forest Service, all Forest Service Stations and Regions began developing old-growth definitions for specific forest types. Because the Southern and Eastern Regions share many forest communities (together they encompass the entire Eastern United States), their efforts were combined, and a cooperative agreement was established with The Nature Conservancy for technical support. The resulting project represents the first large-scale effort to define old growth for all forests in the Eastern United States. This project helped bring the old-growth issue to public attention in the East.

Definitions will first be developed for broad forest types and based mainly on published information and so must be viewed accordingly. Refinements will be made by the Forest Service as new information becomes available. This document represents 1 of 35 forest types for which old-growth definitions will be drafted.

In preparing individual old-growth definitions, authors followed National Old-Growth Task Group guidelines, which differ from the standard General Technical Report format in two ways—the abstract (missing in this report) and the literature citations (listed in Southern Journal of Applied Forestry style). Allowing for these deviations will ensure consistency across organizational and geographic boundaries.

July 1997

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An Old-Growth Definition for Tropical and Subtropical Forests in Florida

Kenneth W. Outcalt

Introduction

In the United States, tropical and subtropical forests are found only in south Florida, covering the southern part of the Floridian Coastal Plain and the Florida Keys. The climate is typically hot and humid with abundant rainfall, although droughts do occur. Soils range widely depending on landform and parent material, and can be organic, fine-textured silts, or coarse-textured sands. These forests develop best on moist hammocks with organic soils. They are the stable climax vegetation on the slightly higher portions of the landscape where fire is infrequent. South Florida slash pine (*Pinus elliottii* var. *densa* Little & Dorman) dominates areas with more frequent fires with the fire-sensitive subtropical and tropical hardwoods restricted to subordinate positions. Lower wet areas are occupied by cypress, saw grass, or wet prairie communities.

Physical Environment

Geographic Distribution

Tropical and subtropical forests correspond to Society of American Foresters cover type 105 (Eyre 1980). In the United States, these forests grow only on the Florida section of the coastal plain physiographic province (Fenneman 1938) and on the Florida Keys. They are most common in Dade, Monroe, and Collier Counties (Woodall 1980) with extensions farther north near the coast where ocean waters mediate freezing temperatures (Simpson 1920). Within this region, these forests occupy areas of the Miami rock ridge, the Keys, the Everglades, the Florida Bay coast, and the gulf coast. This community occupied about 25,000 acres (ac) [10,000 hectares (ha)] in pre-Columbian times (Woodall 1980).

Geologic Substratum

The Miami rock ridge, an outcropping of Miami oolite limestone (Craighead 1971), extends down the Atlantic coast through Miami south and west through Homestead to the Long Pine Key area of the Everglades. Elevations range from more than 23.0 feet [7 meters (m)] above sea level near Miami to 13.0 feet (4.0 m) near Homestead and 6.5 feet (2.0 m) or less around Long Pine Key (Snyder et al. 1990). The upper Keys are islands of coral rock (Key Largo limestone) formed during the Pleistocene age, while the lower Keys are oolitic limestone (Craighead 1971). The Everglades, often referred to as the river of grass, is a large expanse of wetlands dominated by saw grass that stretches south from Lake Okeechobee behind the Atlantic coast ridge. The Florida Bay and gulf coasts are mostly low, wet areas dominated by mangrove forest and coastal marsh.

The Miami rock ridge has an extremely rough, irregular surface pitted by solution holes. Pine lands, dominated by south Florida slash pine, cover most of this area. Tropical and subtropical hammocks generally occupy the higher areas, but the difference in elevation is difficult to detect because it is actually only a few inches (Alexander 1967). A more prominent feature of tropical hammocks is the presence of numerous solution holes, ranging in diameter and depth from 1.5 to 8.0 feet (0.5 to 2.5 m) (Small 1909), created by organic acids dissolving the limestone (Craighead 1974). All the higher areas on the Keys north of Bahia Honda were once covered by tropical hardwood forests (Gifford 1911). In the Everglades, tropical and subtropical forests form teardrop-shaped tree islands (Carr 1973). These tropical hardwood hammocks occur where organic matter has accumulated on platforms of the underlying limestone, which are slightly higher, 1 to 4 feet (0.3 to 1.0 m), than the general area. Along the coast of Florida Bay, tropical and subtropical hardwoods grow on storm-deposited embankments and shell mounds (Olmsted et al. 1981). In the gulf coast region, these forests occupy the high ridges, outcrops of Tamiami limestone, which are scattered throughout the area (Craighead 1971). Although these communities are often surrounded by water, they are rarely inundated (Schomer and Drew 1982).

Soils

Because of fluctuations in sea level (most recently 5,000 to 8,000 years ago) soils for the entire area are of recent origin. These soils are mostly calcareous muds or organic deposits mixed with shell remains (Craighead 1971), although some areas of the coast have soils derived from storm-deposited sands. Soils are thin layers over the irregular, porous, limestone rock, with hardwood hammock soils being generally deeper and having a higher organic matter content than those of adjoining pine lands (Wade et al. 1980). Much of the actual soil material accumulates in channels, fissures, and depressions in the bedrock.

Climate

The region has a subtropical climate with about a 15 °F (8 °C) range between mean summer highs and winter lows (Craighead 1971). Killing frosts occur as far south as Miami about once every 5 years, while summer maximums seldom exceed 94 °F (34 °C) (Davis 1943). There is a distinct summer, wet season from May to October, when 60 to 80 percent of the rainfall occurs, followed by a 6-month winter, dry season. Annual rainfall is highest along the Atlantic coast, averaging 60 inches [1524 millimeters (mm)] from Miami to West Palm Beach. Inland precipitation drops to 55 inches (1397 mm) over Lake Okeechobee and the Everglades around Homestead. Mean annual rainfall declines farther both south and west of Homestead, averaging 50 inches (1270 mm) in the upper Keys and along the southwest coast and about 40 inches (1016 mm) at Key West. Wet-season rainfall comes from frequent, convective thunderstorms accompanied by locally high winds and lightning, while winter precipitation comes from the passage of cold fronts (Schomer and Drew 1982).

General Vegetation

Hammock Origin

Live oak (*Quercus virginiana* Mill.) is often a pioneer species in hardwood hammock development on the Miami rock ridge, commonly occurring near solution holes, which provide water storage and fire protection (Sand 1971). As other species invade, a closed canopy forms, dominated by trees with crooked trunks, dense hardwood, and stiff evergreen leaves (Harper 1927). These trees produce a dense canopy that modifies the microclimate to a moister and shadier environment (Carr 1973, Olmsted et al. 1983). Other early successional species are wild-tamarind [*Lysiloma latisiliquum* (L.) Benth.] and mahogany (*Swietenia mahagoni* Jacq.), which do not reproduce in shade but are prevalent in hammocks because of disturbance from fire and storms (Robertson 1962).

Species Composition

Hammocks are dominated by mostly broad-leaved, evergreen trees of West Indian origin and a few temperate species (Craighead 1974). This is a diverse community containing 150 to 170 native species of trees and shrubs (Snyder et al. 1990). Species richness is greatest in the large hammocks, such as those in the Long Pine Key area of Everglades National Park. Because of landscape diversity and differences in species distribution, composition varies greatly, but nearly all hammocks contain gumbo-limbo [*Bursera simaruba* (L.) Sarg.] and pigeon-plum (*Coccoloba diversifolia* Jacq.) in the canopy and stopper (*Eugenia* spp.) in the midstory and understory layers.

Other common canopy species found in many hammocks include poisonwood [*Metopium toxiferum* (L.) Krug & Urban], willow bustic [*Dipholis salicifolia* (L.) A. DC.], strangler fig (*Ficus aurea* Nutt.), wild-tamarind, mastic [*Mastichodendron foetidissimum* (Jacq.) H.J. Lam], live oak, and cabbage-palm [*Sabal palmetto* (Walt.) Lodd ex J.A. & J.H. Schult]. Temperate species are less common in hammocks on the Florida Keys (Schomer and Drew 1982), while some tropical species such as black-ironwood [*Krugiodendron ferreum* (Vahl) Urban], Jamaica-dogwood [*Piscidia piscipula* (L.) Sarg.], and thatchpalm (*Thrinax morrisii* H. Wendl.) are more common. Other trees, such as lignum vitae (*Guaiacum sanctum* L.) and milkbark (*Drypetes diversifolia* Krug & Urban), grow only in the Keys. Hammocks in western Florida generally have fewer species; and the canopy is more likely to be dominated by one or a few species (Craighead 1971).

Although there are several species in the canopy, most of the woody species in a hammock community occur in the midstory and understory layers (table 1). Hammocks contain few herbaceous species (Snyder et al. 1990), having a clean forest floor composed of leaflitter (Small 1916). Olmsted et al. (1980) reported herbaceous cover, including tree seedlings to be 1 to 5 percent, except in canopy gaps. Epiphytes (e.g., ferns, bromeliads, and orchids) are common around solution holes and canopy gaps where light is prevalent (Carr 1973). Air plants are less prevalent on the Keys because of a drier climate.

Natural Disturbance

Frosts, droughts, fires, and tropical storms significantly stress the vegetation of south Florida hammocks (Richardson 1977). Most species, however, are well adapted to these natural forces as shown by the stable species composition during a 25-year period reported by Alexander (1967) for a hammock near Miami. The dense canopy of hammocks acts like a natural greenhouse, keeping the interior warmer in winter, which limits most frost damage to the edge (Craighead 1974). The closed

Table 1—Major tree species of tropical and subtropical hammocks of Florida[a]

Position[b]/scientific name	Common name	Range[c]	Type
Overstory:			
Annona glabra L.	Pond-apple	All[d]	Tropical
Bursera simaruba (L.) Sarg.	Gumbo-limbo	All	Tropical
Coccoloba diversifolia Jacq.	Pigeon-plum	All	Tropical
Dipholis salicifolia (L.) A. DC.	Bustic	All	Tropical
Ficus aurea Nutt.	Strangler fig	All	Tropical
Ficus citrifolia Mill.	Shortleaf fig	All	Tropical
Lysiloma latisiliquum (L.) Benth.	Wild-tamarind	All	Tropical
Manilkara bahamensis (Baker) Lam & Meeuse	Wild-dilly	LG,K	Tropical
Mastichodendron foetidissimum (Jacq.) H.J. Lam	Mastic	All	Tropical
Metopium toxiferum (L.) Krug & Urban	Poisonwood	MR,EG,K	Tropical
Morus rubra L.	Mulberry	MR,EG	Temperate
Persea borbonia (L.) Spreng.	Redbay	All	Temperate
Quercus virginiana Mill.	Live oak	All	Temperate
Roystonea elata (Bartr.) F. Harper	Royalpalm	EG,GC	Tropical
Sabal palmetto (Walt.) Lodd ex J.A. & J.H. Schult	Cabbage-palm	All	Temperate
Sapindus saponaria L.	Soapberry	EG,K,GC	Tropical
Simarouba glauca DC.	Paradise-tree	All	Tropical
Swietenia mahagoni Jacq.	Mahogany	EG,K	Tropical
Midstory:			
Amyris elemifera L.	Torchwood	MR,K	Tropical
Ardisia escallonioides Schiede & Deppe ex Schlecht.& Cham.	Marlberry	All	Tropical
Byrsonima lucida DC.	Locust-berry	EG,K	Tropical
Canella winterana (L.) Gaertn.	Wild-cinnamon	K,GC	Tropical
Cephalanthus occidentalis L.	Buttonbush	All	Temperate
Chrysobalanus icaco L.	Cocoplum	All	Tropical
Chrysophyllum oliviforme L.	Satinleaf	All	Tropical
Citharexylum fruticosum L.	Fiddlewood	MR,EG,K	Tropical
Cordia sebestena L.	Geiger-tree	LG,K	Tropical
Drypetes diversifolia Krug & Urban	Milkbark	K	Tropical
Eugenia confusa DC.	Red stopper	MR,K	Tropical
Exothea paniculata (Juss.) Radlk.	Inkwood	All	Tropical
Guaiacum sanctum L.	Lignumvitae	K	Tropical
Hippomane mancinella L.	Manchineel	LG,K	Tropical
Krugiodendron ferreum (Vahl) Urban	Black-ironwood	MR,EG,K	Tropical
Nectandra coriacea (Sw.) Griseb.	Lancewood	All	Tropical
Persea borbonia var. *pubescens* (Pursh) Little	Swampbay	All	Temperate
Piscidia piscipula (L.) Sarg.	Jamaica-dogwood	LG,K,GC	Tropical
Spondias purpurea L.	Hog plum	Introduced	
Rapanea punctata (Lam.) Lundell	Myrsine	All	Tropical
Schoepfia schreberi J.G. Gmel.	Whitewood	All	Tropical
Tetrazygia bicolor (Mill.) Cogn.	Tetrazygia	EG	Tropical
Understory:			
Bumelia celastrina H.B.K.	Saffron-plum	MR,K,GC	Tropical
Drypetes lateriflora (Sw.) Krug & Urban	Guiana-plum	All	Tropical
Eugenia spp.	Stoppers	All	Tropical
Guapira discolor (Spreng.) Little	Blolly	All	Tropical
Guettarda elliptica Sw.	Velvetseed	MR,EG,K	Tropical
Gymnanthes lucida Sw.	Crabwood	MR,EG,K	Tropical
Hypelate trifoliata Sw.	White-ironwood	EG,K	Tropical
Prunus myrtifolia (L.) Urban	West Indian cherry	EG,UK	Tropical
Psychotria spp.	Wild coffee	All	Tropical
Reynosia septentrionalis Urban	Darling-plum	K	Tropical
Schaefferia frutescens Jacq.	Florida-boxwood	K	Tropical
Trema micranthum (L.) Blume	Florida trema	All	Tropical
Zanthoxylum fagara (L.) Sarg.	Wild-lime	All	Tropical

[a] Based on a compilation of species lists in Alexander (1958, 1967); Austin et al. (1977); Bureau of Land & Water Management (1976); Craighead (1971); Davis (1943); Duever et al. (1982); Gifford (1911); Harper (1927); Harshberger (1914); Olmsted et al. (1980, 1981, 1983); Schomer and Drew (1982); Simpson (1920); and Weiner (1979).
[b] Based on information from Long and Lakela (1976), Scurlock (1987), and Stevenson (1992).
[c] Based on Little (1979).
[d] All = all of south Florida and Keys, EG = Everglades, LG = lower glades, MR = Miami rock ridge, K = Keys, UK = upper Keys, and GC = gulf coast.

canopy, greenhouse effect also mediates moisture losses, reducing the impact of dry periods. In addition, many species (e.g., gumbo-limbo) drop their leaves during dry periods and refoliate when the rainy season begins (Bureau of Land & Water Management 1976). Natural fires start from lightning strikes associated with thunderstorms. Because most thunderstorms occur during the summer (wet season) many of the hammocks are protected by surrounding water, or the organic matter is too moist to carry fires (Craighead 1971). If the peat is dry enough to burn, the soil can be consumed down to bare rock, eliminating the hammock (Schomer and Drew 1982).

High winds from tropical storms frequently strike hammocks, but only very intense storms cause much damage. The closed canopy deflects winds (Duever et al. 1986), and the high density of stems provides a sort of mutual buffering (Bureau of Land & Water Management 1976) that, along with the extensive root system (Small 1922), allows most individuals to resist storm damage. A hurricane with winds exceeding 125 miles per hour (200 kilometers per hour) occurs about every 25 years (Gentry 1974). Winds of this magnitude blow many large trees over and prune all but the largest branches from many others (Craighead and Gilbert 1962). This occurrence opens the canopy, admitting sunlight, which stimulates growth of trees and shrubs. Damage near the coast is much worse from farther inland because of the storm surge. The severest damage, however, is often confined to small areas (Richardson 1977).

Old-Growth Attributes

Size and Composition

Old-growth hammocks, like hammocks in general, are mostly small patches of broad-leaved forest dominated by tropical species and surrounded by other vegetation (Snyder et al. 1990). Hammock size ranges from 0.25 to 100 ac (0.1 to 40 ha) (Craighead 1974), with most being less than 25 ac (10 ha) (Olmsted et al. 1983). A minimum size of 0.6 ac (0.25 ha) is probably required for old-growth development. Species composition of old-growth stands is similar to that for hammocks in general.

Tree Size and Basal Area

Although species such as mastic and mahogany can grow much larger, to be classified as old-growth hammock, the community must have some trees at least 16 inches (40 cm) in diameter (table 2). The largest trees in old-growth hammocks are at least 100 years old with a few individuals 150 years old. Old-growth hammocks on the Miami rock ridge have a well-developed, closed canopy of hardwoods 20 to 33 feet (6 to 10 m) in height, with some large trees 50 to 56 feet (15 to 17 m) in height rising above the general canopy and an understory of tropical trees and shrubs 3 to 16 feet (1 to 5 m) in height (Olmsted et al. 1980, 1983). Maximum heights are less for old growth west and south of Homestead because of lower annual rainfall (Alexander 1958). Basal area in old-growth stands averages about 260 feet^2 per ac (60 m^2 per ha), with a minimum of at least 130 feet^2 per ac (30 m^2 per ha) required.

Microenvironment

The edge of many old-growth hammocks is a dense, jungle-like growth of mostly small stems forming a barrier to the interior (Phillips 1940, Gantz 1971). The interior of old-growth hammocks, however, is composed mostly of old trees with a dense, leafy canopy (Simpson 1920, Carr 1973) that filters out as much as 85 percent of ambient sunlight (Schomer and Drew 1982), creating twilight-like conditions even at midday (Harshberger 1914, Simpson 1920). Because of extreme shade, the herbaceous understory is extremely sparse and composed of few species (Olmsted et al. 1980). The forest floor is clean with an open, almost park-like appearance (Sand 1971, Bureau of Land & Water Management 1976). Most herbaceous growth and epiphytes grow in the occasional canopy gaps. Much of the bird and insect life exists high in the canopy where sunlight is available (Simpson 1920). The solution holes provide a specialized habitat occupied by a lush growth of ferns.

Soil and Forest Floor

A major distinguishing attribute of old-growth hammocks is the accumulation of an organic soil layer that is at least 4.7 inches (12 cm) thick (Olmsted et al. 1980) and can reach depths greater than 12 inches (30 cm) (Small 1909, Simpson 1920, Craighead 1971). This rich, dark, organic layer develops from leaves and detritus of the hardwoods (Gifford 1911), which have an average annual litterfall of 5,370 pounds per acre (6100 kilograms per hectare) (Ross et al. 1992). This accumulation of organic matter conceals much of the underlying rock. The pitted, irregular nature of the substratum, however, is revealed at tip-up mounds, where trees blown over by tropical storms have torn the organic layer from the rock. Because many of the tropical species have dense, decay-resistant woods, fallen timber generously litters the forest floor of old-growth stands (Simpson 1920). Many of the trees can sprout from the base or can send up a branch from their fallen trunk to form a new main stem. Examples of both of these adaptations to tropical storm damage can usually be found in old-growth stands.

Table 2 (English units)—Standardized table of old-growth attributes for tropical and subtropical hammocks of Florida

Quantifiable attribute	Value Range	Mean	Number of stands	Site[a]	References
Stand density (no./acre)					
Trees ≥1 in d.b.h.	2,090–2,390	2,240	2	EG	Olmsted et al. 1980
Trees ≤1 in d.b.h. and ≥2 ft height	3,370–6,000	4,685	2	EG	Olmsted et al. 1980
Trees ≤2 ft height	65,540–85,250	75,400	2	EG	Olmsted et al. 1980
Trees ›4 in d.b.h.		6,075	1	MR	Alexander 1967
Stand basal area (ft²/acre)					
Trees ›1 in d.b.h.	190–400	300	2	EG	Olmsted et al. 1980
Trees ›4 in d.b.h.		250	1	MR	Alexander 1967
Age of large trees (yrs)					
All species	100–200	150	UN[b]	EG	Tyrell 1992
All species		200	4	EG	Craighead 1971
Swietenia mahagoni Jacq.		225	UN	EG	Wade et al. 1980
S. mahagoni		200	UN	EG	Craighead and Gilbert 1962
Maximum d.b.h. (in)					
All trees	48–72	60	UN	EG	Craighead 1971
All trees	28–36	32	5	EG	Gantz 1971 Olmsted et al. 1980
Bursera simaruba (L.) Sarg.		40	UN		Long and Lakela 1976
B. simaruba		36	UN	UK	Bureau of Land & Water Mgmt. 1976
Ficus aurea Nutt.		60	UN		Small 1929
Mastichodendron foetidissimum (Jacq). H.J. Lam		60	UN		Small 1929
Metopium toxiferum (L.) Krug & Urban		19	1	UK	Author's data
S. mahagoni		60	1	EG	Robertson 1962
S. mahagoni	15–17	16	UN	LG	Olmsted et al. 1981

[a] EG = Everglades, MR = Miami rock ridge, UK = upper Keys, LG = lower glades.
[b] UN = Unknown.

Table 2 (metric units)—Standardized table of old-growth attributes for tropical and subtropical hammocks of Florida

Quantifiable attribute	Value Range	Mean	Number of stands	Site[a]	References
Stand density (no./ha)					
Trees ≥3 cm d.b.h.	5160–5895	5530	2	EG	Olmsted et al. 1980
Trees ≤3 cm d.b.h. and ≥.6 m height	8325–14820	11570	2	EG	Olmsted et al. 1980
Trees ≤.6 m height	161,835–210,500	186,165	2	EG	Olmsted et al. 1980
Trees ›6 cm d.b.h.		15000	1	MR	Alexander 1967
Stand basal area (m^2/ha)					
Trees ›3 cm d.b.h.	44–91	68	2	EG	Olmsted et al. 1980
Trees ›6 cm d.b.h.		57	1	MR	Alexander 1967
Age of large trees (yrs)					
All species	100–200	150	UN[b]	EG	Tyrell 1992
All species		200	4	EG	Craighead 1971
Swietenia mahagoni Jacq.		225	UN	EG	Wade et al. 1980
S. mahagoni		200	UN	EG	Craighead and Gilbert 1962
Maximum d.b.h. (cm)					
All trees	122–183	152	UN	EG	Craighead 1971
All trees	72–91	82	5	EG	Gantz 1971 Olmsted et al. 1980
Bursera simaruba (L.) Sarg.		100	UN		Long and Lakela 1976
B. simaruba		91	UN	UK	Bureau of Land & Water Mgmt. 1976
Ficus aurea Nutt.		152	UN		Small 1929
Mastichodendron foetidissimum (Jacq). H.J. Lam		152	UN		Small 1929
Metopium toxiferum (L.) Krug & Urban		48	1	UK	Author's data
S. mahagoni		150	1	EG	Robertson 1962
S. mahagoni	37–42	40	UN	LG	Olmsted et al. 1981

[a] EG = Everglades, MR = Miami rock ridge, UK = upper Keys, LG = lower Glades.
[b] UN = Unknown.

Indicator Species

Live oak, wild-tamarind, and mahogany do not reproduce in the shade of old-growth hammocks but rather persist as large individuals only. Large individuals in the upper canopy and a lack of small individuals of these species in the shady interior of the hammock indicate old-growth conditions. Another striking feature of old-growth stands is naked stems of vines hanging from the upper crowns 39 to 49 feet (12 to 15 m) above the forest floor (Simpson 1920). Old growth also has fewer epiphytes than other hammocks because of the very dense shade. Tree snails (*Liguus* spp.) were once native to all hammocks where a closed canopy maintained the moist, shady microclimate required to promote the growth of the fungi and algae upon which they fed. Although not restricted to old growth, tree snails should be present in such stands.

Past History

There are few stands of tropical hardwoods left in Florida undisturbed by humans. The large mastic, mahogany, and other species were selectively harvested for shipbuilding in the 1800's. Because of its toxic effect on humans, poisonwood has been selectively removed from many forests. Wood carvers and collectors have scavenged the downed logs from most areas. Many areas were also cleared for agriculture sometime during the last 300 years. Hammock vegetation will quickly reinvade abandoned areas if fire has not destroyed the organic soil substratum. Many of the trees grow rapidly and can reach heights of 39 feet (12 m) in 25 years. It takes much longer, however, for old-growth characteristics to develop (150 to 200 years).

An example of a stand that meets the minimum qualifications for old growth is Chastain hammock on North Key Largo. Jeanne Parks[1] has observed other stands in the area that also qualify as old-growth hammock vegetation. The best remaining example of old-growth hardwood hammock is on Lignumvitae Key State Botanical Site. Other old-growth stands such as Royal Palm and Mahogany hammocks in Everglades National Park and Castellow and Matheson hammocks in Miami, were severely damaged by Hurricane Andrew and it will take several years for them to recover (Jewell 1993).

[1] Personal communication. 1993. Jeanne Parks, Biologist, Key Largo Hammocks State Botanical Site, P.O. Box 487, Key Largo, FL 33037.

Management Recommendations

Tropical hammocks of south Florida are a unique and important community that humans have severely depleted, primarily by urban development, making management of the remaining areas especially critical. After first protecting the area from future development, the key to maintaining this community is fire control. Fires need to be excluded during the winter months when natural fires rarely occur and hammock soils are dry enough to be totally combusted. Fragmentation of hammocks by power lines, roads, etc., should be avoided also because these artificial openings increase the severity of hurricane damage (Craighead and Gilbert 1962, Craighead 1974). Old-growth hammocks also need to be established across the entire former range of tropical hammocks. This will provide habitat for species that inhabit only certain areas and will increase the probability that some old-growth stands will survive major hurricanes.

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United States
Department of
Agriculture

Forest Service

Southern
Research Station

General Technical
Report SRS-15

An Old-Growth Definition for Western Juniper Woodlands: Texas Ashe Juniper Dominated or Codominated Communities

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A Section of the Old-Growth Definition Series

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Preface

Old growth is widely acknowledged today as an essential part of managed forests, particularly on public lands. However, this concept is relatively new, evolving since the 1970's when a grassroots movement in the Pacific Northwest began in earnest to define old growth. In response to changes in public attitude, the U.S. Department of Agriculture, Forest Service, began reevaluating its policy regarding old-growth forests in the 1980's. Indeed, the ecological significance of old growth and its contribution to biodiversity were apparent. It was also evident that definitions were needed to adequately assess and manage the old-growth resource. However, definitions of old growth varied widely among scientists. To address this discrepancy and other old-growth issues, the National Old-Growth Task Group was formed in 1988. At the recommendation of this committee, old growth was officially recognized as a distinct resource by the Forest Service, greatly enhancing its status in forest management planning. The committee devised "The Generic Definition and Description of Old-Growth Forests" to serve as a basis for further work and to ensure uniformity among Forest Service Stations and Regions. Emphasis was placed on the quantification of old-growth attributes.

At the urging of the Chief of the Forest Service, all Forest Service Stations and Regions began developing old-growth definitions for specific forest types. Because the Southern and Eastern Regions share many forest communities (together they encompass the entire Eastern United States), their efforts were combined, and a cooperative agreement was established with The Nature Conservancy for technical support. The resulting project represents the first large-scale effort to define old growth for all forests in the Eastern United States. This project helped bring the old-growth issue to public attention in the East.

Definitions will first be developed for broad forest types and based mainly on published information and so must be viewed accordingly. Refinements will be made by the Forest Service as new information becomes available. This document represents 1 of 35 forest types for which old-growth definitions will be drafted.

In preparing individual old-growth definitions, authors followed National Old-Growth Task Group guidelines, which differ from the standard General Technical Report format in two ways—the abstract (missing in this report) and the literature citations (listed in Southern Journal of Applied Forestry style). Allowing for these deviations will ensure consistency across organizational and geographic boundaries.

September 1997

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An Old-Growth Definition for Western Juniper Woodlands: Texas Ashe Juniper Dominated or Codominated Communities[1]

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Description

Prominent juniper species that dominate or codominate woodlands or shrub lands of the American Southwest include Rocky Mountain juniper (*Juniperus scopulorum* Sarg.), Pinchot juniper (*J. pinchottii* Sudw.), oneseed juniper [*J. monosperma* (Engelm.) Sarg.], alligator juniper (*J. deppeana* Steud.), Utah juniper [*J. osteosperma* (Torr.) Little], and Ashe (mountain-cedar, Mexican) juniper (*J. ashei* Buchholz) (nomenclature follows Correll and Johnston 1970). Among these, Ashe juniper is nearly restricted in the United States to the Edwards Plateau and Lampasas Cut-Plain of Texas, with outlier populations over limestone in Oklahoma and Arkansas (see illustrations of natural regions in Diamond et al. 1987, Riskind and Diamond 1988). As classified by the Society of American Foresters (SAF), this is an eastern forest cover type 66, southern region, Ashe juniper-redberry juniper (*J. Erythrocarpa* Cory) (Eyre 1980). I will not consider the SAF western cover types, Rocky Mountain juniper or pinyon (*Pinus edulis* Engelm.)-juniper, here. Also, although Pinchot juniper does grow in mixed stands with Ashe juniper and oaks (*Quercus* sp.) on the western Edwards Plateau, it is not a significant component in woodlands discussed here; this species may grow with oaks and Ashe juniper to form open woodlands in the far western Edwards Plateau, but such communities have not been described in the literature.

Ashe juniper communities are most common in the southern and eastern Edwards Plateau (Balcones Canyonlands, Texas hill country) and the Lampasas Cut-Plain to the north. Both regions are underlain by Cretaceous limestones, but these are of various types that weather to form different soils and a wide variety of different abiotic site potentials for any given geomorphic position. Thus, site potentials are not only controlled by slope and exposure, but also may vary across flat uplands, across gentle slopes, etc., due to subtle differences in substrate. Climate also varies across the range of Ashe juniper community types, with annual precipitation ranging from 20 inches [50 centimeters (cm)] in the west to 34 inches (86 cm) in the east and average January low temperatures from 37 °F (2.8 °C) in the south to 30 °F (-1.1 °C) in the north. Superimposed on these climatic, topographic, and edaphic variables are variations in land use; together these account for the communities on the contemporary landscape.

Extent of the Original Woodlands

Often-repeated dogma indicates that Ashe juniper has increased in importance in former grasslands (Amos and Gehlbach 1988), but the real extent of this increase and its impact on contemporary woodland and forest distribution and composition are unclear. Following are some accounts of the perception of the expansion or contraction of Ashe juniper communities and a discussion of the composition of woodlands and forests on uplands and on slopes and creek bottoms.

Ashe juniper is seen as economically undesirable on rangeland, and many of the early accounts of its increase may be traced to human impressions, range science literature, or other sources primarily interested in addressing the use of natural resources to generate economic income (Bray 1904, Beuchner 1944, Huss 1954, Harris 1958, Smeins 1980, Fuhlendorf 1992). Many of these sources, however, indicate the presence of a variety of natural juniper codominated communities, a decrease in "virgin cedar (old-growth Ashe juniper)" communities, and the use of juniper and other species for wood products. For example, Huss (1954) wrote of the use of juniper for posts and of accounts of the shipment of three trains per week out of Real County on which " . . . it was not uncommon for a single train to have a load of 40,000 posts." Contrary to showing a dramatic increase in juniper woodlands, he wrote,

[1] Literature search and preliminary description.

"It is difficult to believe that such timber once existed in the valley of the Nueces." As evidence that it did, he noted that one unusual 23,000-acre ranch in Edwards County still had virgin cedar and calculated its worth at over $1 million. Beuchner (1944) mapped all of Kerr County as some type of woodland and 24 percent as cedar brakes (dense forests dominated by Ashe juniper) and states that, " . . . a large part of the area now designated as cedar brakes was originally covered with cedar when white man made his first appearance . . . ."

As further evidence of the existence of extensive forests on the Edwards Plateau, Bray (1904) wrote that, "A large part of the support of the Hill Country population comes from the sale of wood for fuel," and that, "Cedar is handled at all points within hauling distance of brakes; but cedar timber large enough to furnish ties and poles is becoming scarce, except in remote districts." The following excerpt from Bray also provides additional insight into the historical extent of juniper codominated woodlands in the Edwards Plateau: "With the exception of cedar, the hill country timber finds a market chiefly as fuel, of which enormous quantities are consumed, both in stoves and grates and in the furnaces of lime and brick kilns, gin engines, etc. Cedar likewise is extensively consumed as fuel and in charcoal burning, but its great value lies in its yield of railway ties, poles, posts, sills, and innumerable other articles which utilize its great durability."

Pulich (1976), Clark (1985), Weniger (1988), Wahl et al. (1990), and Keddy-Hector (1992) all document or suggest a decline in woodlands on the Edwards Plateau. Weniger wrote that the Edwards Plateau was about half wooded and half open at the time of European settlement, based on analysis of survey notes from more than 6,500 witness trees. Rates of loss range from 20 percent of the "virgin cedar" from 1962 to 1974, based on Soil Conservation Service records (Pulich 1976), to 30 percent of all woodland lost in urbanizing counties from 1974 to 1990, based on remote sensing data (Keddy-Hector 1992). Most of this loss was due to land clearing for agriculture and urbanization.

Old-growth Ashe juniper stands are difficult to find in the contemporary landscape and may not even be easily recognizable; certainly, examples of all variants of different community types with Ashe juniper as a dominant or codominant do not exist. No accounts were found that specifically document old-growth stands. I have visited more than 100 sites that support Ashe juniper woodlands or forests, and have tentatively identified only 1 as old growth, and even it had small patches of disturbance (i.e., stumps from the removal of individual trees, apparently for posts). The reasons for disturbance presumably include the high value of Ashe juniper for timber products and, later, cedar oil, the extensive clearing of timbered land for use by domestic livestock, and the less extensive destruction of woodlands by urban growth.

Upland Woodlands

On disturbed sites, young Ashe juniper sometimes forms nearly pure stands or grows on repeatedly cleared rangeland. However, from Bray (1904), Beuchner (1944), Huss (1954), Wahl et al. (1990), and personal observation, at least two upland site types support natural juniper-oak woodlands. These include Bray's "hardscrabble" areas, with exposed, massive, cracking limestone at the surface. Hardscrabble areas sometimes occur within extensive uplands and are also prominent near the lip of canyon rims, usually extending no more than 100 feet [30 meters (m)] away from the rim and often restricted to within 33 feet (10 m) of the rim. This substrate supports mainly evergreen or mixed woodlands, including juniper-shin oak [*Q. durandii* var. *breviloba* (Torr.) Palmer] in the east and central Plateau, Vasey oak [*Q. pungens* var. *vaseyana* (Buckl.) C.H. Muller] in the west, or juniper-plateau live oak [*Q. virginiana* var. *fusiformis* (Small) Sarg.] communities throughout. Canopy cover reaches about 90 percent and height about 26 feet (8 m) in these communities. Lacey oak (*Q. glaucoides* Mart. & Gal.) may also be an overstory species in the south central and southwestern Edwards Plateau, especially on flats just above canyon rims. Cedar elm (*Ulmus crassifolia* Nutt.) and sugarberry (*Celtis laevigata* Willd.) are also sometimes important. Common understory shrubs include Texas persimmon (*Diospyros texana* Scheele), mountain-laurel (*Kalmia latifolia* L.), and eastern redbud (*Cercis canadensis* L.). Elbowbush (*Forestiera pubescens*), sumacs (*Rhus* sp.), and agorita (*Berberis trifoliolata*) may grow in openings, although apparently none of these is especially shade tolerant.

A second type of upland woodland with Ashe juniper as a component is described by Buechner (1944) and Huss (1954), and from a single stand by Wahl et al. (1990). Soils are described as red or reddish and may develop over siliceous limestone or "flintrock" (Hill and Vaughn 1897) or may represent ancient Pleistocene paleosols or "terra rosa" as described by Young (1986). These two different types of substrate may support slightly different types of woodland but, in either case, apparently post oak (*Q. stellata* Wangenh.) or blackjack oak (*Q. marilandica* Muenchh.) or both, are among the overstory dominants. I have also observed this type of community in which the canopy was about 40 feet (12 m) and the community was relatively open. Huss reported on an Ashe juniper-blackjack oak community type on the "flintrock" divide of Real County and noted that Lacey oak, bigleaf shin oak (probably *Q. sinuata*), and Texas madrone (*Arbutus texana* Buckl.) were important components. Beuchner reported post oak, blackjack oak, and live oak as dominant in this community type in Kerr County; post oak and Ashe juniper dominated the stand sampled by Wahl et al.

Slope, Canyon, and Creekside Forests and Woodlands

Ashe juniper and deciduous species are seldom evenly distributed within uniform woodlands on slopes or in canyon systems. Rather, deciduous trees and shrubs often form rather narrow, distinct, linear, horizontal bands from perhaps 30 to 100 feet (9 to 30 m) wide, associated with seepage zones near the tops of slopes, and sometimes at intervals downslope, with wider, mostly evergreen Ashe juniper bands interspersed up slope and downslope. This type of banding is especially clear where massive, resistant limestone forms a thin cap over less resistant materials as in the vicinity of Post Oak Ridge north of Austin, TX, where Edwards limestone caps give way to Glen Rose limestone slopes. Indeed, landscape patterns (i.e., the degree of incision of canyons, degree of canyon slope, difference in elevation of plateau tops versus canyon bottoms, etc.) depend on geologic substrate as well as drainage patterns. The Balcones Canyonlands region along the southern and western boundary of the Plateau harbor some of the most spectacular ravines and the most extensive slope forests. Slope exposure also influences community structure, with south exposures more evergreen and approaching the look of upland woodlands, but with banding of deciduous trees sometimes still prominent. Deciduous trees also grow more abundantly in ravine bottoms, ravine heads, or near streams, and composition depends both on moisture regime and landscape/disturbance variables.

Recognition of distinct community types is problematic in many canyon systems. For example, a series of quadrants could be placed within deciduous-tree-dominated bands to define a deciduous forest or within mainly juniper-dominated bands to define an evergreen woodland on the same slope. Different authors have treated this variation differently; also, some have reliably recognized disturbed communities versus undisturbed stands while others apparently have not. I have tried to account for this type of variation in the following description of slope, canyon, and streamside community types. The descriptions are based primarily on data from Beuchner (1944), Huss (1954), Blair (1965), Kroll (1980), Van Auken et al. (1981), Gehlbach (1988), Riskind and Diamond (1988), Van Auken (1988), and Wahl et al. (1990). See especially chapters in Van Auken et al. (1979, 1980, 1981) and Amos and Gehlbach (1988) and for quantitative data.

A generalized description of slope woodlands in the Balcones Canyonlands would show Texas oak and Ashe juniper among the canopy dominant in most stands. Cedar elm is usually present in the canopy and is reported as a dominant in some stands. Plateau live oak, black cherry (*Prunus serotina* Ehrh.), Texas ash [*Fraxinus texensis* (Gray) Sarg.], scalybark oak [*Q. sinuata* (Torr.) C.M. Mull.] = shin oak = bigleaf shin oak = Durand oak (*Q. durandii* Buckl.), sugarberry, and Arizona walnut [*Juglands major* (Torr.) Heller] are often present in the canopy, and may be among the dominants. Lacey oak is important in the central and western sections. Chinkapin oak (*Q. muhlenbergii* Engelm.), Carolina basswood (*Tilia caroliniana* Mill.), and American elm (*U. americana* L.) are sometimes components in wet canyons or in streamside communities. These mesic forests may have a rather diverse understory composed variously of Texas persimmon, yaupon (*Ilex vomitoria* Ait.), American beautyberry (*Callicarpa americana* L.), hoptree (*Ptelea trifoliata* L.), Mexican-buckeye (*Ungnadia speciosa* Endl.), deciduous holly (*Ilex decidua* Walt.), redbud, and roughleaf dogwood (*Cornus drummondii* C.A. Meyer). Other understory species may include rusty blackhaw (*Viburnum rufidulum* Raf.), Carolina buckthorn (*Rhamnus caroliniana* Walt.), red buckeye (*A. pavia* L.), Texas madrone, Lindheimer's silktassel (*Garrya lindheimeri* Dougl. ex Lindl.), and kidneywood (*Eysenhardtia texana* Scheele). In a few deep, moist canyons, bigtooth maple (*Acer grandidentatum* Nutt.) is among the dominants and may form stands in which it comprises more than 70 percent of the relative cover as in Lost Maples State Natural Area. In the south central and southwest portions of the Edwards Plateau, isolated oak-juniper-pinyon and mainly evergreen woodlands grow on uplands, but are best developed in shallow canyons and canyon heads.

Table 1 summarizes communities and dynamics. Only Van Auken et al. (1981), Gehlbach (1988), and Van Auken (1988) have provided data on relatively mature stands, although perhaps none of the stands sampled could be characterized as old growth.

Old-Growth Definitions

Ashe juniper is a component of at least three different but related community types, including (1) upland mainly evergreen to mainly deciduous woodlands on fractured, massive limestone in flat uplands and on canyon rims; (2)

Table 1—Major pre-European woodland and forest community types of the Edwards Plateau with Ashe juniper as a component

Community type	Landscape position, soils, and geology	Characteristics of the community	Fire frequency and type	Relative diversity of woody species
Plateau live oak-Ashe juniper	Flat or rolling uplands; soils fairly deep and of relatively uniform depth	Open grassland or savannah with individuals or mottes of oak; Ashe juniper and other tree species in mottes	High; ground fires with few crown fires	Low
Post oak/blackjack oak-Ashe juniper	Flat or rolling uplands; soils over silica-containing limestone or composed of Pleistocene terra rosa	Savannah to well-developed woodland; Ashe juniper and other tree species in dense mottes or better developed woodlands	High to medium; few crown fires	Medium
Scalybark oak/Vasey oak (west)-Ashe juniper	Flat or rolling uplands or canyon rims; soils over massive, fractured limestone and of variable depth	Shrub land or woodland depending on fire frequency; Ashe juniper increasing with time since previous burn	Medium to low; some crown fires	Medium to high
Ashe juniper-Texas oak/deciduous tree species	Slopes, canyons, creek sides	Evergreen woodland (dry exposures/dry slopes) to deciduous forest (wet exposures, seeps, creek sides; vegetation forming horizontal bands)	Low to very low; crown fires at low return intervals	High

mainly deciduous woodlands over either terra rosa or silica-containing limestone on uplands; and (3) forests and woodlands on slopes, in canyons, and along streams. Generalized characteristics of these community types in terms of tree size and density for old-growth conditions follow. These, however, are based on the data available, and at best are hypothetical extrapolations, because few authors have described mature, let alone old-growth stands.

Upland Hardscrabble

Live oak and Ashe juniper were and are growing under less disturbed conditions, often the leading dominant of woodlands or mottes (clumps) on relatively deep, continuous soil of flat uplands on much of the Plateau, whereas scalybark oak and Ashe juniper dominated hardscrabble areas (Bray 1904, Beuchner 1944, Van Auken et al. 1981, Gehlbach 1988, Van Auken 1988). Scalybark oak, and perhaps Texas oak, apparently sometimes formed dense "shinneries" (Bray 1904) in which multiple-stemmed individuals formed low canopies in response to fire; Bray reports that these shinneries contained a mixture of species, including live oak, sugarberry, and sumac. Post oak and blackjack oak may also grow in these hardscrabble areas. The live oak-juniper woodlands may indeed represent former climax savannahs or grasslands and the shin oak-juniper climax woodlands. The mature canopy height of these communities is about 26 to 30 feet (8 to 9 m) (Kroll 1980, Wahl et al. 1990). Canopy closure in mature stands reaches about 90 percent and basal area about 40 to 50 feet^2 per acre [40 to 50 m^2 per hectare (ha)] (Van Auken 1988). Number of trees over 1.2 inches (3 cm) diameter at breast height (d.b.h.) ranged from 1,155 to 1,465 per acre (2,841 to 3,605 per ha) (Van Auken 1988). The average d.b.h. of mature canopy trees reported by Gehlbach for scarp edges was 13 inches (34 cm) for scalybark oak, 14 inches (36 cm) for cedar elm, and 16 inches (41 cm) for plateau live oak. Harris (1958) reported that "little leaf shin oak" (probably *Q. vaseyana*) on the west central Edwards Plateau reached 6.5 inches (16 cm) d.b.h. and 76 years old on upland sites. Ashe juniper in Real County was 70 to 100 years old at 5 to 6 inches (13 to 15 cm) d.b.h. and reached 10.5 inches (27 cm) d.b.h. and 172 years old (Huss 1954). However, few or no "virgin cedar brakes" were found in Real County. Kroll (1980) found Ashe junipers as large as 16 inches (40 cm) d.b.h. and more than 100 years old.

Only one stand of this community type was apparently old growth among dozens I visited. Ashe juniper was the leading dominant occupying more than 80 percent of the relative canopy cover, which reached 26 to 30 feet (8 to 9 m). The d.b.h. of large canopy trees was estimated at more than 18 inches (45 cm), but many smaller individuals reached the canopy. Canopy trees were flat-topped (less mature junipers have pointed tops with easily identifiable apical growing points) and total canopy cover was estimated about 80 percent. Scalybark oak, Texas oak, and live oak were also in the canopy and the understory contained a few tall, spindly Texas persimmons. The aspect was open under the canopy, with few low branches; this contrasts with younger stands of juniper, which are often nearly impenetrable due to low branching of junipers or dense growth of many individual stems. Recruitment was mainly seedling Ashe juniper, but there were almost no sapling trees. Numerous large, downed junipers occurred (probably as many as 10 percent of the number of live trees standing) and I saw one standing dead tree. Despite this, I could detect no old light gaps, which suggests that the death of individual junipers, whose canopies are small, does not dramatically affect forest dynamics. The ground layer was lush; apparently enough diffuse light penetrated the canopy to support grass.

Upland Flintrock or Terra Rosa Soils

Over upland flintrock (siliceous limestone) or terra rosa soils, Ashe juniper occurs mixed with post oak and blackjack oak. Fire may have historically diminished the dominance of Ashe juniper. Buechner (1944) reported blackjack oak, live oak, and post oak in over 90 percent of the 5-acre stands of this community type sampled in Kerr County (number sampled not reported); canopy coverage was highest for blackjack oak and intermediate for post oak and live oak. Ashe juniper was present in 70 to 90 percent of the stands but provided less than 1 percent of the canopy coverage in 75 percent of those in which it occurred. Wahl et al. (1990) found post oak dominating one stand with a density of 180 trees per acre (73 trees per ha) and a mean height of 26 feet (7.9 m). Ashe juniper was the next most important species with a mean of 393 trees per acre (159 trees per ha) and a mean height of 17 feet (5.3 m). Total canopy cover of the stand at 16 feet (5 m) was 21 percent. The tallest post oaks were over 45 feet (12 m), whereas the tallest junipers were over 26 feet (8 m); this corresponds to observations of similar stands. My vision of this type of community in an old-growth stand is that of an open woodland with 40 to 60 percent canopy at about 45 feet (12 m) with scattered post oak and blackjack oak along with dense mottes of these species in which Ashe juniper is a component.

Slope, Canyon, and Creekside Communities

Van Auken (1988) reported north slope communities with a total basal area of 168 ft^2 per acre (38.6 m^2 per ha) and total tree density of 729 per acre (1,851 per ha). Gehlbach (1988) reported mean d.b.h. of canopy trees on slopes and floodplains in the range of 15 to 17 inches (38 to 44 cm) for Texas oak, Texas ash, sugarberry, cedar elm, and scalybark oak. Various sources report average canopy height to be 39 to 49 feet (12 to 15 m). An unusual stand dominated by bigtooth maple, Texas oak, and Lacey oak, sampled by Wahl et al. (1990), contained canopy trees 33 to 46 feet (10 to 14 m) tall and a total canopy cover of 145 percent, due to overlapping layers of tree canopy. My vision of an old-growth slope community includes a diverse, essentially interlocking canopy of mainly deciduous trees and Ashe juniper at about 49 feet (15 m) tall and a diverse understory of mainly deciduous shrubs. However, junipers and deciduous species are usually not evenly intermixed but form distinct patches or bands.

Forest Dynamics and Ecosystem Function

Fire greatly helped control the distribution of vegetation on the Edwards Plateau prior to European settlement. Smeins (1980) and Fonteyn et al. (1988) concluded that frequent fires, set by lightning or Native Americans, were so common on the Plateau that flats and rolling hills, especially outside of the hill country, were maintained as open grassland. Effects of fire on the Plateau are summarized by Amos and Gehlbach (1988):

> Indeed, fire may have been the single most important, non-edaphic factor controlling patterns of vegetation. The historic Plateau was likely a mosaic of woodland along the rocky scarps and in canyons (fires infrequent), forest along the creeks and rivers (also

infrequent fire), and grassland in the uplands where comparatively deep soil and fire were more frequent. Occasional trees, especially plateau live oaks, grew on the uplands, root- and stump-sprouted into clumps (mottes) due to fire and perhaps browsing disturbance and fostered the establishment of commensals like Ashe juniper and Texas persimmon because of the cool, moist, fire-resistant carpet of thick oak leaves.

Wells (1965) concluded that extensive scarp woodlands in the Great Plains are a result of the protection from fire. Similarly, the natural woodlands of the Edwards Plateau may likewise have been the result of protection of canyons and scarps from fire. Thus, mesic woodlands and forests codominated by juniper could have been protected from fire and maintained in canyons. Hardscrabble areas in the uplands, with massive limestone exposed at the surface, may also have prevented accumulation of fine fuel and prevented frequent fires. In fact, some hardscrabble areas are raised slightly above the surrounding flat uplands [perhaps 3 feet (1 m) on Post Oak Ridge north of Austin, TX] and, hence, not only act as scarps but actually are low scarps. But were fires frequent enough in these flat or rolling areas to exclude Ashe juniper, which is not resistant to fire? In some areas probably so, in others probably not. The dynamics no doubt were controlled by geologic/edaphic variables, such as (1) the size of the hardscrabble area; (2) the degree of exposure of rock or thin soil; (3) the water and nutrient relations of the soil and, hence, its ability to support trees; and (4) the lay of the land (i.e., distance to the nearest fire break in the form of a scarp or stream and its relation to prevailing winds, etc.).

Certainly, juniper is favored on the modern landscape not only by the absence of fire but also by its rapid seed dispersal and low palatability to browsers. However, even today in areas of continuous soils on the flat central and western Edwards Plateau, junipers are not as abundant as in areas of shallow or discontinuous soils. In fact, many areas approach the motte-like appearance described by Amos and Gehlbach (1988) where, except for the existence of junipers in mottes, the landscape has few junipers. Therefore, it is not hard to imagine how frequent fire could have excluded junipers from openings between live oak-Ashe juniper mottes on deeper or more continuous uplands (Smeins 1980).

Bray (1904) provides some clues to the timing and nature of large-scale community dynamics when he describes shinneries, which covered upland hardscrabble, as being composed of a mixture of species, some of which are not fire tolerant. Also, he notes that fire was so frequent in cedar (Ashe juniper) that "It is probable that during the past twenty-five years far more cedar timber has been burned than has been marketed, and vastly greater areas denuded by fire than by the axe." He goes on to state that cedar generally replaces itself on these burned areas. However, he quotes one "reliable" source as saying "When the (cedar) brakes are burnt out they never recover, but very soon grow up with different kinds of brush . . . . Some of my own cedar was burned about five years ago, and the ground is now covered with shin oak and Spanish oak sprouts."

Obviously, the oaks were a part of the "cedar brake" before it burned. Could this have been the formation of a new shinnery and might that area, if not burned for decades, have been reinvaded by juniper to form a cedar brake and perhaps then burned again to reform a shinnery? This type of decades-long dynamic is likely for upland woodlands of the Edwards Plateau. For example, Huss (1954) described the interaction of grazing by domestic livestock and fire and concluded that a juniper-oak community will succeed after burning to a new juniper-oak community within 60 years under various grazing regimes, although the abundance of secondary species can be controlled by grazing pressure. Presumably a canopy fire could restart the process at any stage, but would become more likely as the canopy of Ashe juniper closed.

The existence of blackjack oak and post oak communities containing Ashe juniper on uplands is probably explained by edaphic factors interacting with fire. Both of these oak species are known in Texas on deep, slightly acid soils of the Post Oak Savannah and Cross-Timbers. The terra rosa and siliceous flintrock soils on which post oak and blackjack oak communities grow best have slightly lower pH values (often below 7.0), a different nutrient content, and perhaps better moisture relations than do most "typical" limestone-derived soils. Both blackjack oak and post oak are fire tolerant and, thus, in pre-European settlement times may have grown as scattered individuals or may have formed mottes or rather extensive, diverse, deciduous woodlands or forests, depending on subtle differences in substrate, fire history, and landscape position.

Drought also greatly influences woodlands on the Edwards Plateau. The drought of the fifties killed many oaks and junipers. Harris (1958) wrote "During the periods of detailed study in 1952 and 1953 the extended drought had not hindered littleleaf shin oak (probably *Quercus vaseyana),* although many plants of live oak, Spanish (= Texas) oak, and large areas of cedar were dead from the drought . . . . In August 1957, after extended drought from

1951 through 1956, it was noted that many littleleaf shin oak mottes were dead."

Standing dead junipers can still be seen on the western Edwards Plateau. Young (1956) likewise noted changes in vegetation due to the drought of the early 1950's and chronicled the death of many woody plants on the Sonora Research Station in the west central Plateau.

Other than the obvious impracticality of allowing hot wildfires to burn in an urbanizing region, or at least of controlling large enough areas to make such a strategy practical and the inability to control drought cycles, the primary controllable influence on the current woodlands is browsing. Van Auken (1993) and a host of others (Amos and Gehlbach 1988) have noted that browsing by domestic livestock and white-tailed deer may reduce recruitment of palatable woody species such as Texas oak. Establishment of these species may have in the past responded to fire or drought cycles, and may have in the past 100 years responded to rapid human clearing of patches of from a few to hundreds of acres for range improvement or the harvesting of wood products. Certainly, browsing by confined domestic livestock and introduced feral species and the control of hot wildfires may change community composition over time. However, the type and extent of these possible changes is not certain. For example, the establishment of only a few trees may ensure their representation in old-growth communities, especially if these species have large, spreading canopies. Palatable species, such as Texas oak, cedar elm, and sugarberry, are still major components of mature woodlands and forests despite a 100-plus-year history of human settlement, land clearing, and grazing of domestic livestock. Thus, the effects of overbrowsing and control of wildfire could be less dire for these species than it might appear.

Conservation of Ashe juniper and related woodlands and forests of the Edwards Plateau is of high concern, according to Diamond et al. (1987) and the Texas Natural Heritage Program (TNHP)[2]. While not imminently imperiled, these communities are threatened by expanding urbanization and agriculture, especially land clearing for range improvement. Of 80 sites supporting variations of Ashe juniper codominated communities in the TNHP database, only 6 are listed as excellent or good to excellent quality (i.e., old growth).

Conserving the biodiversity within the major variants of Ashe juniper dominated or codominated woodlands would require managing representative examples of each major topographic and edaphic type (upland hardscrabble, upland terra rosa or flintrock, and slope/canyon/creekside) within different regions of the Edwards Plateau. Carefully located preserves might capture all three habitats within a single 30,000-acre (1,181-ha) area, although the immediate practicality of acquiring land from willing sellers or easements from private landowners so that such an area could be managed as a unit is questionable. The management strategies for such an area might include removing domestic livestock and reducing deer and feral ungulates, prescribed burning, and restoring heavily impacted woodlands to reduce fragmentation where forests have been cleared in the past. Recalling the importance of hot as well as cool fires in pre-European settlement times, an area large enough to allow such a burn policy would be practical only for a very large preserve, especially considering the likelihood of special management requirements for rare species.

The Edwards Plateau, in general, and especially the Balcones Canyonlands or hill country, have long been recognized as important centers of endemism and biological diversity for both plants and animals (Blair 1950, Amos and Rowell 1988). Ashe juniper codominated woodlands are the defining component of this region. Several rare or endemic endangered species are indigenous to these woodlands, including the golden-cheeked warbler (*Dendroica chrysoparia)* and the black-capped vireo *(Vireo atricapillus)*. These species are currently in the center of a controversy over the effects of the Endangered Species Act on private property rights in central Texas. Attempts to conserve juniper woodlands and forests in this region would need to address the habitat requirements of these species.

Representative Old-Growth Stands

Representative old-growth forests on the Edwards Plateau, southern Great Plains occur at the following locations:

- Balcones Canyonlands National Wildlife Refuge, Travis and Williamson Counties
- Bull Creek Drainage, Travis County
- Emmous Retreat, Travis County
- Guadalupe River State Park/Honey Creek State Natural Area, Comal County
- Fort Hood, Bell and Coryell Counties
- Garner State Park, Uvalde County
- Lost Maples State Natural Area, Bandera County
- Mother Neff State Park, Coryell County
- Pedernales Falls State Park, Blanco County

[2] Texas Natural Heritage Program. 1992. Description of the natural communities of Texas, series level. 45 p. Unpublished manuscript. On file with: Texas Parks and Wildlife Department, 4200 Smith School Road., Austin. TX 78744.

Consult TNHP database for locations of these and other examples of Ashe juniper-oak series woodlands and forests.

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United States
Department of
Agriculture

Forest Service

Southern
Research Station

General Technical
Report SRS-16

An Old-Growth Definition for Western and Mixed Mesophytic Forests

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A Section of the Old-Growth Definition Series

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Preface

Old growth is widely acknowledged today as an essential part of managed forests, particularly on public lands. However, this concept is relatively new, evolving since the 1970's when a grassroots movement in the Pacific Northwest began in earnest to define old growth. In response to changes in public attitude, the U.S. Department of Agriculture, Forest Service, began reevaluating its policy regarding old-growth forests in the 1980's. Indeed, the ecological significance of old growth and its contribution to biodiversity were apparent. It was also evident that definitions were needed to adequately assess and manage the old-growth resource. However, definitions of old growth varied widely among scientists. To address this discrepancy and other old-growth issues, the National Old-Growth Task Group was formed in 1988. At the recommendation of this committee, old growth was officially recognized as a distinct resource by the Forest Service, greatly enhancing its status in forest management planning. The committee devised "The Generic Definition and Description of Old-Growth Forests" to serve as a basis for further work and to ensure uniformity among Forest Service Stations and Regions. Emphasis was placed on the quantification of old-growth attributes.

At the urging of the Chief of the Forest Service, all Forest Service Stations and Regions began developing old-growth definitions for specific forest types. Because the Southern and Eastern Regions share many forest communities (together they encompass the entire Eastern United States), their efforts were combined, and a cooperative agreement was established with The Nature Conservancy for technical support. The resulting project represents the first large-scale effort to define old growth for all forests in the Eastern United States. This project helped bring the old-growth issue to public attention in the East.

Definitions will first be developed for broad forest types and based mainly on published information and so must be viewed accordingly. Refinements will be made by the Forest Service as new information becomes available. This document represents 1 of 35 forest types for which old-growth definitions will be drafted.

In preparing individual old-growth definitions, authors followed National Old-Growth Task Group guidelines, which differ from the standard General Technical Report format in two ways—the abstract (missing in this report) and the literature citations (listed in Southern Journal of Applied Forestry style). Allowing for these deviations will ensure consistency across organizational and geographic boundaries.

September 1997

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Introduction

Mesophytic forests can be segregated into two subgroups based on species richness and composition—western and mixed mesophytic forests. Western mesophytic forests occur primarily in the Interior Low Plateau, southern Central Lowland, Ozark Plateaus and Ouachita physiographic provinces, and the northern Coastal Plain along the Mississippi River. Typically oak (*Quercus* spp.)-dominated, this type occurs in a wide range of topographic positions, including drier sites than the more mesic, mixed mesophytic forests.

Mixed mesophytic forests occur in the Appalachian Plateau, Ridge and Valley, and Blue Ridge physiographic provinces. In the mountains, this forest type occurs on lower north- and east-facing slopes and mesic coves up to about 5,000 feet [1524 meters (m)] in elevation (McLeod 1988). In less mountainous terrain, mixed mesophytic forest may cover the entire landscape where conditions are suitable.

Mixed mesophytic forest types are among the most biologically diverse ecosystems of the United States and perhaps of temperate regions worldwide (Hinkle et al. 1993). The most common of the 25 to 30 characteristic tree species are sugar maple (*Acer saccharum* Marsh.), beech (*Fagus grandifolia* Ehrh.), hemlock [*Tsuga canadensis* (L.) Carr.], silverbell (*Halesia carolina* L.), yellow-poplar (*Liriodendron tulipifera* L.), red maple (*A. rubrum* L.), white ash (*Fraxinus americana* L.), white oak (*Q. alba* L.), northern red oak (*Q. rubra* L.) and yellow birch (*Betula alleghaniensis* Britton), yellow buckeye (*Aesculus octandra* Marsh.) and basswood (*Tilia heterophylla* Vent.) (Braun 1935, 1938, 1940, 1942, 1950; Whittaker 1956; Core 1966; Quarterman et al. 1972; Winstead and Nicely 1976; Dickison 1980) (appendix A). The latter two are indicator species for the mixed mesophytic forest type but are absent from western mesophytic forests (Braun 1938).

Species dominance patterns, or "association-segregates," may vary with geographic or physiographic region and site conditions (Braun 1950). Topographic features, including slope, aspect, elevation, and geomorphic form, and associated differences in soils, moisture, insolation, and microclimate contribute to subcommunity distributions within the mixed mesophytic forest (Caplenor 1965, Martin 1975, Dickison 1980, Muller 1982, Crownover 1988, McLeod 1988, Hinkle 1989). Many of the characteristic mixed mesophytic forest tree species are associated with high pH, and with cation exchange capacity, percent base saturation, and some nutrient contents (Muller 1982, McLeod 1988). Depth of organic soil averages 3.0 ± 0.4 inches [7.5 + 1.1 centimeters (cm)][1] in nonrocky areas.

Society of American Foresters forest cover types included within the definition of mixed mesophytic and western mesophytic forests are

25—sugar maple-beech-yellow birch (in part)
27—sugar maple
52—white oak-black oak-northern red oak
57—yellow-poplar-eastern hemlock
59—yellow-poplar-white oak-northern red oak

Human influence on eastern forests has a long history (Guffey 1977). Native Americans cleared large areas of forest and commonly set fire to woodlands to increase game populations (Eller 1982). Later, European settlers accelerated the clearing of forests for farmland. Woodlands were often heavily grazed by free-ranging hogs and livestock (Eller 1982). With the development of a logging industry capable of cutting and milling large volumes of timber, coupled with newly completed railroad access, eastern forests were extensively logged around the turn of the century (Shands 1992). Mixed mesophytic forests were clearcut or high-graded with little thought for future land condition. By the late 19th and early 20th centuries, all but the most inaccessible stands of old-growth forests were eliminated (Buttrick 1923, Westveld 1933).

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[1] McLeod, Donald E. December 3, 1996. Unpublished raw data. On file with: U.S. Department of Agriculture, Forest Service, Southern Research Station, Bent Creek Research and Demonstration Forest, 1577 Brevard Road, Asheville, NC 28806.

Introduction of exotic plants, animals, and pathogens has also dramatically affected forest dynamics. The American chestnut blight (*Cryphonectria parasitica*), introduced in the early 20th century, caused widespread death of this previously dominant tree species by 1930 and greatly changed forest species composition and regeneration patterns (Ashe 1911, Woods and Shanks 1959). Similarly, Dutch elm disease *(Ceratocystis ulmi)* dramatically affected forest dynamics and species composition where Dutch elm was dominant (Boggess and Bailey 1964). Introductions of the European wild hog (*Sus scrofa*), dogwood anthracnose (*Discula destructiva*), and gypsy moth (*Porthetria dispar*) have also significantly altered forest dynamics.

Structure and Composition of Old-Growth Forests

Government surveyors described the coves below Mount Mitchell, near Asheville, North Carolina, as "a forest of oaks, hickories, maples, (American) chestnuts [(*Castanea dentata* (Marsh.) Borkh.)], and tulip poplars, some of them large enough to be suggestive of the giant trees on the Pacific Coast."[2]

While no single attribute defines old-growth forests, a combination of several factors may serve as important indicators. Pertinent structural attributes of the living component of old-growth forests include species composition, richness and diversity of canopy, and understory and herbaceous strata; plant and animal species potentially dependent upon old growth (Martin 1992); age, diameter, density, and basal area of canopy trees; vertical stand structure; and stand age and size structure including apportionment of small and large stems (Schmelz and Lindsey 1965, Weaver and Ashby 1971, Martin 1992). Important nonliving structural features include the volume and distribution of coarse woody debris (CWD) and standing snags and their apportionment among size and decay classes; tree-fall gaps of various size and age; undisturbed soil and soil macropores; and little evidence of disturbance by humans (Martin 1992). Below, we discuss specific characteristics of structured categories that may assist in defining and identifying old-growth western and mixed mesophytic forests.

[2] Southern Appalachian Center, Mars Hill College. 1979. A socioeconomic overview of western Carolina for Nantahala-Pisgah Forests. 73 p. Unpublished report. On file with: Mars Hill College, College Library, Southern Appalachian Room, Mars Hill, NC 28754.

Vertical Structure

Numerous factors contribute to a complex vertical structure in old-growth, mixed mesophytic forests. Different size and age distributions of canopy tree species create a wide spread in heights. Understory trees, shrubs, and herb layers form distinct forest strata. Continual creation and closure of gaps create a temporally and spatially "shifting mosaic" of age and size-class patches.

Canopy height of eastern old-growth forests ranges from 98.4 to 131.2 feet (30 to 40 m) (Whittaker 1966, McLeod 1988). Clebsch and Busing (1989) described old-growth canopy as having overlapping and spreading crowns. Such canopy structure allows only 0.3 to 2 percent of incident light penetration to the herb stratum (Whittaker 1966, Canham 1989). The subcanopy and shrub layer tend to be sparse (5 to 30 percent cover) where they are deciduous (McLeod 1988) but can be thick where dominated by ericaceous shrubs. Likewise, a multistructural herbaceous layer may be present under a deciduous canopy but sparse to nonexistent beneath dense evergreen shrubs or in excessive shade (Caplenor 1965, McLeod 1988). McLeod (1988) reported a thick (about 100 percent cover), species-rich herbaceous cover in old-growth stands of the Black and Craggy Mountains of North Carolina.

Whittaker (1966) estimated aboveground biomass of 223 to 272 tons per acre [500 to 610 metric tons per hectare (ha)] and net productions of 3.3 to 3.9 ounces per square foot [1000 to 1200 grams per square meter (grams per m^2)] annually in mature climax mesic forests. Of total aboveground production, about 95.8 percent were trees, 0.1 percent shrubs, 3.4 percent summer herbs, and 0.7 percent vernal herbs.

Many old, living trees are hollow or severely decayed. McLeod (see footnote 1) found an average of 4.9 ± 2.4 decadent trees per acre (12 ± 6 decadent trees per ha), or 3 percent of living trees in six old-growth stands in the Southern Appalachians (table 1). Of decadent trees, 21 percent were Florida dogwood and 26 percent were beech. Most decadent trees (59 percent) were small [<7.9 inches (20 cm) in diameter at breast height (d.b.h.)] or midsize [26 percent were from 7.9 to 15.4 inches (20 to 39 cm)]. Only 15 percent were larger than 15.7 inches (40 cm) d.b.h. Hardt and Swank (in press) found 5.1 and 8.7 decadent trees ≥11.8 inches d.b.h. per acre (12.5 and 21.5 decadent trees ≥30 cm d.b.h. per ha) in two old-growth Southern Appalachian stands, respectively. They suggest that species composition has an important influence on tree decadence, since some species (such as red maple, beech, and

Table 1 (English units)—Standardized table of old-growth attributes for western and mixed mesophytic forests

Quantifiable attribute	Value Range	Value Mean	Number of stands	References
Stand density (no./acre)				
—trees ≥4 in. d.b.h.	68–184	130±34	14	Bryant 1987
				Muller 1982
				Palmer 1987[a]
				McLeod[b]
Stand basal area (ft^2/acre)				
—trees ≥4 in. d.b.h.	113–296	165±48	14	Bryant 1987
				Muller 1982
				Palmer 1987[a]
				McLeod[b]
Age of large trees (yrs) (maximum)				
Liriodendron tulipifera L.	226			in Runkle 1982
Tilia heterophylla Vent.	198			in Runkle 1982
Acer saccharum Marsh.	372			Tubbs 1977
Aesculus octandra Marsh.	431			in Runkle 1982
Fagus grandifolia Ehrh.	412			Morey 1936
Tsuga canadensis (L.) Carr.	607			Morey 1936
Number of 4-in size classes				
—trees ≥4 in. d.b.h.	1–22	17	6	McLeod[b]
Maximum d.b.h. (in)				
L. tulipifera L.	65		6	McLeod[b]
Tilia heterophylla Vent.	77			
Acer saccharum Marsh.	46			
Aesculus octandra Marsh.	41			
F. grandifolia Ehrh.	43			
Tsuga canadensis (L.) Carr.	45			
Standing snags (no./acre)				
—snags ≥4 in. d.b.h.	4–28	13±8	8	McComb and Muller 1983
				Muller 1982[c]
				McLeod[b]
Downed logs (ft^3/acre)	943–5859	2,215±1,615	9	Muller and Liu 1991[d]
				McLeod[b]
				Hardt and Swank, in press
Decadent trees (no./acre)				
—trees ≥4 in. d.b.h.	2–8	5±2	6	McLeod[b e]
Percent of canopy in gaps	3–24	9.5	14	Runkle 1982

[a] See also Whittaker 1966, Weaver and Ashby 1971, Martin 1975, Winstead and Nicely 1976, Dickison 1980, McGee 1984, Lorimer 1985, and Clebsch and Busing 1989.
[b] McLeod, Donald E. December 3, 1996. Unpublished raw data. On file with: U.S. Department of Agriculture, Forest Service, Southern Research Station, Bent Creek Research and Demonstration Forest, 1577 Brevard Road, Asheville, NC 28806.
[c] See also Schmelz and Lindsey 1965, McGee 1984, Rosenberg et al. 1988, Poulson and Platt 1989, and Martin 1992.
[d] See also Thompson 1980; and MacMillan 1981, 1988.
[e] See also Hardt and Swank, in press.

Table 1 (metric units)—Standardized table of old-growth attributes for western and mixed mesophytic forests

Quantifiable attribute	Value		Number of stands	References
	Range	Mean		
Stand density (no./ha) —trees ≥ 10 cm d.b.h.	168–455	322±85	14	Bryant 1987 Muller 1982 Palmer 1987[a] McLeod[b]
Stand basal area (m^2/ha) —trees ≥ 10 cm d.b.h.	26–68	38±11	14	Bryant 1987 Muller 1982 Palmer 1987[a] McLeod[b]
Age of large trees (yrs) (maximum)				
Liriodendron tulipifera L.	226			in Runkle 1982
Tilia heterophylla Vent.	198			in Runkle 1982
Acer saccharum Marsh.	372			Tubbs 1977
Aesculus octandra Marsh.	431			in Runkle 1982
Fagus grandifolia Ehrh.	412			Morey 1936
Tsuga canadensis (L.) Carr.	607			Morey 1936
Number of 10-cm size classes —trees ≥ 10 cm d.b.h.	1–22	17	6	McLeod[b]
Maximum d.b.h. (cm)				
L. tulipifera L.	166		6	McLeod[b]
Tilia heterophylla Vent.	195			
Acer saccharum Marsh.	118			
Aesculus octandra Marsh.	104			
F. grandifolia Ehrh.	108			
Tsuga canadensis (L.) Carr.	115			
Standing snags (no./ha) —snags ≥ 10 cm d.b.h.	10–70	31±19	8	McComb and Muller 1983 Muller 1982[c] McLeod[b]
Downed logs (m^3/ha)	66–410	155±113	9	Muller and Liu 1991[d] McLeod[b] Hardt and Swank, in press
Decadent trees (no./ha) —trees ≥ 10 cm d.b.h.	4–20	12±6	6	McLeod[b e]
Percent of canopy in gaps	3–24	9.5	14	Runkle 1982

[a] See also Whittaker 1966, Weaver and Ashby 1971, Martin 1975, Winstead and Nicely 1976, Dickison 1980, McGee 1984, Lorimer 1985, and Clebsch and Busing 1989.
[b] McLeod, Donald E. December 3, 1996. Unpublished raw data. On file with: U.S. Department of Agriculture, Forest Service, Southern Research Station, Bent Creek Research and Demonstration Forest, 1577 Brevard Road, Asheville, NC 28806.
[c] See also Schmelz and Lindsey 1965, McGee 1984, Rosenberg et al. 1988, Poulson and Platt 1989, and Martin 1992.
[d] See also Thompson 1980; and MacMillan 1981, 1988.
[e] See also Hardt and Swank, in press.

basswood) are more susceptible to heart rot and cavity formation. Stillwell (1955) reported that 67 percent of old yellow birch were highly decayed. Williams (1936) reported that nearly all large beech trees in an Ohio climax forest were hollow, at least at the base, because of various fungal infections. Norden (1954) found that 91 percent of old sugar maples were highly decayed.

Diversity

Old-growth forests tend to have fewer tree species overall, but they have more canopy species than younger stands (<63 years) (Clebsch and Busing 1989). Gap-phase regeneration permits regeneration of both tolerant and intolerant species, which contributes to the maintenance of great canopy-species diversity in old growth. Conversely, younger stands may be dominated by yellow-poplar and other less shade-tolerant species (Clebsch and Busing 1989; Hardt and Swank, in press). Martin (1992) reported 43 tree species in 7 mixed mesophytic communities within the Lilley Cornett Woods in Kentucky. Appendix A presents tree species characteristic of old-growth, mixed mesophytic forests.

Diversity [Shannon-Weiner Index (H')] based on tree density is more variable in old-growth forests than in younger tracts. However, H' based on biomass tends to be higher in older stands than in younger stands because biomass is more evenly distributed among canopy species.

High species diversity, richness and equitability, and low dominance of canopy tree species appear to characterize old-growth, mixed mesophytic forests (Martin 1992). Martin (1992) suggests quantitative criteria for defining the canopy community composition of old-growth, mixed mesophytic forests: (1) $\geq$20 species, (2) H' >3.0, (3) evenness >0.50, and (4) Simpson's dominance values <0.30.

Shrub, tree seedling, and herbaceous species richness also tends to be high. McLeod (1988) reported an average of 51.1 vascular plant species per 0.25 acre (0.1 ha), with herbs contributing 72.2 percent of the total flora. Species richness generally increases with soil pH (McLeod 1988). Seedling density is significantly lower under ericaceous shrubs, suggesting that such shrubs may prevent seedlings from becoming established. This could be due to soil acidification, other chemical modifications, or decreased moisture or light levels beneath heath (Palmer 1987).

Although several plants are associated with old growth, no plant species is currently known to be restricted to old-growth, mixed mesophytic forests (Meier et al. 1996). Candidate species include Fraser's sedge [*Cymophyllus fraseri* (Andr.) Mackenzie] and spotted mandarin [*Disporum maculatum* (Buckley) Britt.] (Martin 1992). It is likely that if old-growth-dependent plants exist, mycorrhizal fungus species limit their distribution (Martin 1992).

Mixed mesophytic forests support rich mammalian, avifaunal, and herpetofaunal communities, several of which are rarely found in other forest types (appendix B) (Hinkle et al. 1993). No species is known to be restricted to old-growth forests, but several require the structural features (Hardt and Swank, in press) and microclimate of mature mesophytic forests (Haney and Schaadt 1996, Meier et al. 1996, Pelton 1996). Hence, moisture gradients affect the distribution of several species within the mixed mesophytic forest type (Hudson 1972, Hinkle et al. 1993).

Basal Area and Density

Basal area of old-growth, mixed mesophytic forest trees $\geq$3.9 inches (10 cm) d.b.h. ranges from 113.0 to 296.0 square feet per acre (26 to 68 m^2 per ha) (table 1). Clebsch and Busing (1989) found that basal area in second-growth forests approached that of old growth by age 63, but species composition differed. Muller (1982) reported that basal area did not significantly differ between an old-growth stand and an adjacent 35-year-old, second-growth stand in southeastern Kentucky [average 126.3 square feet per acre (29 m^2 per ha)]. However, fewer large diameter individuals comprised more basal area in old growth, while more smaller diameter individuals were present in younger growth.

Canopy trees are usually widely spaced. Reported numbers range from 68.0 to 349.0 stems per acre (168 to 863 stems per ha), but values depend on count method (table 1). Martin (1992) suggests that an average of 101.1 trees per acre (250 trees per ha) $\geq$3.9 inches (10 cm) d.b.h. may be an indicator, although not a defining attribute, of old-growth, mixed mesophytic forests.

Density of large trees may be more useful in defining old-growth mesic forests. Density of trees $\geq$29.5 inches (75 cm) ranged from 3.4 to 17.9 per acre (8.5 to 44.3 per ha) and averaged 11.3 ($\pm$ 4.9) per acre (27.8 $\pm$ 12.0 per ha) in five old-growth mixed mesophytic stands in the Southern Appalachians (see footnote 1). Martin (1992) suggests at least 2.8 trees per acre (7 trees per ha) $\geq$29.5 inches (75 cm) d.b.h. indicate old growth.

Species composition, site factors, such as soil type and moisture, and disturbance history, affect tree density (Martin 1992).

Snags

Standing dead trees, or snags, are important foraging and nesting resources for many cavity-nesting birds (Runkle 1991, Haney and Schaadt 1996). Numerous other animal species use standing snags for cover, denning, and foraging (Carmichael and Guynn 1983, Pelton 1996). Animal use may depend on the stage of decomposition (Cline and Phillips 1983). The number of snags depend on their formation rate and longevity, which vary by size, species, and cause of death (Bull 1983, McComb and Muller 1983, Raphael 1983, MacMillan 1988).

Annual snag formation rates vary from 0.7 to 9.3 per acre (1.6 to 23 per ha) (Lindsey and Schmelz 1965, Runkle 1991). Density estimates of snags ≥3.9 inches (10 cm) in old-growth, mixed mesophytic forests range from 4.0 to 28.3 per acre (10 to 70 per ha) [McComb and Muller 1983, Martin 1992, McLeod (see footnote 1)] (table 1). McComb and Muller (1983) reported that snag densities were the same or greater in a 35-year-old forest than in an old-growth, mixed mesophytic forest for all size classes. The younger forests had more than twice as many small snags than the older forests [1.0 to 3.9 inches (2.5 to 9.9 cm) d.b.h.]; both stands had 0.8 large snags 9.8 to 35.4 inches d.b.h. per acre [1.9 large snags (25 to 90 cm) d.b.h. per ha]. Martin (1992) reported ≥1.2 snags per acre (3 snags per ha) ≥23.6 inches (60 cm) d.b.h. Hardt and Swank (in press) found about 6.9 snags ≥9.8 inches d.b.h. per acre (17.0 snags ≥25 cm d.b.h. per ha) in two old-growth stands in the Southern Appalachians. They suggest that because species differ in their modes of mortality and decay rates, species composition influences snag density in old-growth stands. Muller and Liu (1991) reported that snags made up 24 percent of total CWD mass and 18 percent of total CWD volume in an old-growth forest in Kentucky.

Coarse Woody Debris

Coarse woody debris provides important microhabitat and "safe sites" for bryophytes, liverworts, fungi, and tree seedlings (Martin 1992). Many animal species use CWD for hiding, egg-laying and development, foraging for arthropods, and other functions. Thompson (1980) reported that fallen logs and pits created by tip-up mounds were important colonization sites for numerous herbaceous species. Coarse woody debris is also an important nutrient reserve, slowly releasing them as the wood decays.

Gap-phase disturbance (Barden 1980, Runkle 1981, Romme and Martin 1982) creates an uneven distribution of downed, dead logs in mixed mesophytic forests. Muller and Liu (1991) reported that 39.2 percent of CWD >7.9 inches (20 cm) d.b.h. occurred in only 12.5 percent of plots, primarily because of recent tree falls or standing snags. Estimates of the number of logs range from 7.7 to 61.1 logs ≥7.9 inches d.b.h. per acre (19.0 to 151.0 logs ≥20 cm d.b.h. per ha). Because log accumulations vary widely depending on disturbance type and history, and past and present species composition, they are poor indicators of the old-growth condition (Thompson 1980; MacMillan 1981; Martin 1992; Hardt and Swank, in press). Muller and Liu (1991) found only a weak inverse relationship between plot basal area and CWD. Species composition of CWD is largely dictated by forest species composition (Muller and Liu 1991).

Estimates of CWD volume range from 943.1 to 5,858.9 cubic feet per acre (66 to 410 m^3 per ha) [average 2,215.0 ± 1,615.0 cubic feet per acre (155.0 ± 113 m^3 per ha)] [Muller and Liu 1991; McLeod (see footnote 1); Hardt and Swank, in press] (table 1). Although McLeod (see footnote 1) recorded 98 percent of the total volume of CWD as moderately to highly decayed, Muller and Liu (1991) reported only 49 percent as moderately to highly decayed. Hardt and Swank (in press) found logs in two old-growth stands to be well distributed among decay classes, suggesting regular inputs to the forest floor.

Site conditions influence CWD volume because decomposition rates increase with increasing temperature and moisture. Hence, dry, exposed sites tend to have more CWD than moist, protected sites (Muller and Liu 1991). For similar reasons, more CWD occurs in cool deciduous forests than in warm temperate deciduous forests (Muller and Liu 1991).

Wood-decomposition rate varies among species. MacMillan (1988) reported that maple decays faster than beech, which decays faster than oak and hickory (*Carya* spp.). Fragmentation of CWD and subsequent accelerated decay varies among species. Beech, oak, and hickory fragment rapidly (MacMillan 1988). Muller and Liu (1991) reported that although American chestnut has not reached tree size [≥3.9 inches (10 cm) d.b.h.] since the mid-1940's because of the chestnut blight, it contributed 11 percent to the total CWD mass in their 1991 study. MacMillan (1988) found that the diameter of CWD affects decay rate only slightly, with large-diameter wood decaying somewhat faster than smaller-diameter debris. Such differences may affect size-class distribution of CWD.

Silsbee and Larson (1983) found 4 times more woody debris volume and 10 times more material in debris dams in streams of watersheds that were never logged than in those that were logged 45 years ago. Large, rotten wood was more than four times more common in streams of unlogged watersheds than of logged watersheds. Most of the woody debris in never-logged streams was concentrated in debris dams.

Soil

Soils of undisturbed forest stands have well developed organic horizons with no compaction (Martin 1992). Constant plant turnover maintains a thick, nutrient-rich O and A horizon that retains moisture. Old root channels and animal burrows create soil macropores in sites with undisturbed soils. These macropores may influence water availability, soil mixing, root distribution (Martin 1992), and underground use by animals.

Old-Growth Dynamics

Disturbance

Lorimer (1980) suggests that climax forests be defined as "those capable of self-perpetuation in the absence of severe disturbance." For forest types not mediated by high intensity disturbance, this definition may be suitable. Although the perpetuation of climax, mixed mesophytic forests may not depend on severe disturbance, several types of disturbance act at variable scales and frequencies to influence forest dynamics.

Wind damage, including windthrow (Lorimer 1980), tornadoes (Runkle 1982), hurricanes, and microbursts may create forest openings of various sizes (Greenberg and McNab, in press; Martin 1992). Ice storms, insect damage, and fungal infections, floods, and landslides (Runkle 1982, Shands 1992) are other disturbances that variously influence forest structure and composition.

The existence of association segregates dominated by shade-intolerant species, such as yellow-poplar, suggests that large-scale disturbance influences tree regeneration and species composition. Lorimer (1980) suggested that a heavy wind created the old-growth poplar cove at Joyce Kilmer Memorial Forest near Robbinsville, NC, over 300 years ago. McGee (1984) reported heavy mortality of old trees at Dick Cove, apparently from a combination of drought, heat, and defoliation by insects. Approximately 17 percent of northern red oak, 13 percent of white oak, and 19 percent of hickories died within a 3-year period.

The prevalence of mixed mesophytic forest across its geographic range, and the susceptibility of species to fire-induced damage or death suggest that large-scale, high intensity fire was infrequent (Harmon et al. 1983). Minimum fire-return interval was greater than a canopy generation (Runkle 1990). Fires within the mixed mesophytic region were probably small and/or restricted to specific topographic positions, such as xeric ridges (Harmon et al. 1983). Infrequent fire may have been the primary large-scale disturbance type, but frequency has decreased even further since fire suppression was begun by State and Federal agencies in the 1930's (Eller 1982, Runkle 1985, McLeod 1988).

Gap Dynamics

The creation of small canopy gaps by the death of a portion, entire, or group of trees accounts for the nearly constant tree turnover and species composition of old-growth, mixed mesophytic forests (Runkle and Yetter 1987, Barden 1989). Actual gap size may range from 10.8 to 16,032.4 square feet (1 to 1490 m^2) but commonly does not exceed 4,304.0 square feet (400 m^2) (Barden 1980; Lorimer 1980, 1989; Runkle 1981, 1982, 1985; Romme and Martin 1982; Runkle and Yetter 1987; Clebsch and Busing 1989). However, "expanded" or effective gaps, where more light reaches the forest floor, may exceed 21,520.0 square feet (2000 m^2).

Estimates of background tree mortality for all species range from 5 to 10 percent per decade in old-growth, mixed mesophytic forests (Christensen 1977; Lorimer 1980, 1989; Buchman 1983; Smith and Shifley 1984; Runkle 1991). Estimates of canopy turnover rates vary from <0.4 percent to 1 percent annually (Runkle 1982, 1985; Barden 1989). Gaps may close from above by lateral-branch extension of surrounding canopy trees or infill from below by sapling growth (Runkle 1982, 1990). The proportion of land area in gaps ranges from 3.2 to 24.2 percent (average 9.5 percent) (Runkle 1982) (table 1). The size and orientation of gaps may influence canopy recruitment patterns. For example, Poulson and Platt (1989) report more light in small, north-south gaps than in east-west gaps. Time required for lateral gap infilling also is greater for north-south than east-west-oriented gaps.

Tree Regeneration and Canopy Recruitment

Many characteristic, mixed mesophytic forest canopy tree species are shade tolerant; their seeds are able to germinate and persist for years as saplings beneath a tree canopy. Because light beneath a closed canopy forest can be as little as 0.3 to 2 percent, even small gaps can more than double understory radiation (Whittaker 1966, Canham 1989).

While shade-tolerant species, such as beech and sugar maple may be released by small gaps (Canham 1988), shade-intolerant species may require larger gaps that permit more light, longer daily periods of light, and greater gap longevity (the length of time for the canopy to close laterally before saplings reach canopy height). Species also vary in importance as a function of gap size and age (Runkle and Yetter 1987, Runkle 1990). Runkle (1990) reported that sugar maple was most important in small gaps of all ages; beech in all sizes of old gaps; white ash in large, young gaps; and yellow-poplar in large gaps of all ages. Barden (1981) reported that shade-tolerant species replaced most single- and multiple-tree gaps in the Great Smoky Mountains, but four species of low shade tolerance (yellow-poplar, black cherry (*Prunus serotina* Ehrhart), American ash, and northern red oak) maintained their presence in 3 percent of the canopy by infrequent captures of multiple-tree gaps.

Recruitment patterns and old-growth stand dynamics affecting future stand composition depend upon a combination of disturbance type and pattern, current species composition, and regeneration mode (Forcier 1975). For example, sugar maple produces many seeds with good dispersal ability (Fowells 1965). Hence, abundant, shade-tolerant seedlings can exploit canopy gaps as they occur (Dickison 1980). Conversely, beech seeds have poor dispersal ability (Fowells 1965). Hence, its distribution depends upon advance regeneration in gaps formed by or near parent trees or by root suckers (Williams 1936, Dickison 1980). Buckeye also has poorly dispersed seeds and low seed production (Fowells 1965). Basswood is highly clonal, so it recolonizes gaps rapidly if present (Dickison 1980, Barden 1981, Runkle 1989). Dickison (1980) reported that intolerant and two tolerant species (basswood and buckeye) regenerated periodically, while shade-tolerant species, including sugar maple, beech, and hophornbeam [*Ostrya virginiana* (Mill.) K. Koch] regenerated continuously in Walker Cove.

Interspecific differences in seed germination and seedling and sapling survival (competitive ability) also affect forest dynamics. Williams (1936) noted poorer survival of beech than sugar maple seedlings but a high mortality of sugar maple saplings. Red maple produced abundant seed, but germination was low and young trees were poor competitors with forest dominants. Variation in moisture and climate may affect germination and survival differently from year to year (Schmelz et al. 1975).

Age Structure and Diameter Distributions

Old-growth, mixed mesophytic forests are broadly uneven-aged or all aged (Lorimer 1980). The diameter distribution of uneven-aged forests is commonly negatively exponential, with many more small- than large-diameter trees (Lorimer 1980, 1985; Palmer 1987). Old-growth stands differ from younger, uneven-aged forests in having greater range of tree sizes, maximum tree age, and more large-diameter trees (table 1). Hardt and Swank (in press) reported an average of 2.4 and 2.5 trees ≥30.0 inches per acre (5.9 and 6.3 trees ≥75.0 cm d.b.h. per ha) in two old-growth stands in the Southern Appalachians. Longevity varies with species (Morey 1936, Tubbs 1977, Runkle 1982). However, few studies cite age exceeding 250 years for trees in old-growth, mixed mesophytic forests, although occasional trees much older than 250 years have been reported (table 1).

Irregular age distributions are common in old-growth stands and reflect severe natural disturbance or irregularities in seed production (Lorimer 1980). Breaks in slope or peaks in curves may indicate disturbance as it affects recruitment and mortality (Schmelz and Lindsey 1965, Schmelz et al. 1975, Lorimer 1980). Estimates of background tree mortality for all species range from 5 to 10 percent per decade in old-growth, mixed mesophytic forests. An additional 6 to 8 percent mortality caused by disturbance within a given decade is sufficient to create peaks in diameter distributions as more seedlings and saplings survive and grow into the canopy stratum (Lorimer 1980).

The diameter distributions of species within stands probably reflect their frequency of recruitment into the canopy (Palmer 1987). Palmer (1987) noted that Fraser's magnolia (*Magnolia fraseri* Walt.), a prolific basal sprouter, had a negatively exponential diameter distribution, whereas two other species that reproduce by seed did not.

Old-Growth Forests and Change

Clearly, old-growth forests are not static in species composition or structural attributes. Increases in basal area and density, and shifts in species composition have been reported for numerous old-growth stands (Weaver and Ashby 1971, Schmelz et al. 1975, MacMillan 1981, Busing 1989). Gap-model projections by Clebsch and Busing (1989) predicted a shift in species composition from yellow-poplar to sugar maple over 250 years, after which changes would stabilize, with some increase in biomass of several subdominant species. Williams (1936) noted more red oak stumps than live red oaks in a beech-maple climax in Ohio. The elimination of canopy-sized American chestnut by the chestnut blight dramatically altered canopy-species composition of old-growth stands.

Whittaker (1966) reported basal-area growth of 1.3 to 2.6 square feet per acre per year (0.3 to 0.6 m^2 per ha per year) in mature climax mesic forests of the Great Smoky Mountains. Busing (1989) reported a 52-year increase in basal area from 173.7 to 195.5 square feet per acre (39.9 to 44.9 m^2 per ha) and from 118.0 to 167.7 square feet per acre (27.1 to 38.5 m^2 per ha) in two old-growth stands in the Great Smoky Mountains National Park (Busing 1989). Increases were mainly in sugar maple and hemlock or silverbell, primarily in response to American chestnut mortality.

Conclusion

Defining old growth is enigmatic and problematic. The assignment of specific values to a host of attributes disregards the tremendous variability among and combination of features exhibited in old-growth forests. Viewed as the sum of a series of rigid criteria, a given stand may not "add up," whereas in fact, viewed as a whole it is indeed old growth. The species composition and structural attributes of old-growth western and mixed mesophytic forest stands are widely variable and depend upon the history of the specific stand. Species composition depends upon stand origin. An old-growth forest may be dominated by "pioneer" species, such as yellow-poplar, if the stand originated following a catastrophic disturbance (such as the Joyce Kilmer Memorial Forest), or of shade-tolerant species if gap dynamics has been the dominant process driving regeneration for several tree generations. Similarly, the number of snags, decadent trees, and logs depends upon tree mortality rates and mode, which in turn, depend upon disturbance history (including less dramatic disturbance such as drought), species composition and specific vulnerability to disease, heart rot, and blow down. Even-age and diameter distribution depend upon stand history and, if too rigidly defined, may exclude some stands that would otherwise be recognized as old growth. Nonetheless, assimilation of studies in which old-growth characteristics have been studied, and the drafting of general guidelines provide a starting point in defining and identifying old growth. Further work is needed to distinguish features that are unique to old growth.

Acknowledgments

We thank C. Ross Hinkle, Chief Scientist, Dynamac Corporation, Kennedy Space Center, FL; Paul Schmalzer, Senior Field Ecologist, Dynamac Corporation, Kennedy Space Center, FL; and Chris Ulrey, doctoral student, North Carolina State University, Raleigh, NC, for reviewing an earlier version of this manuscript.

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Appendix A

Tree, shrub, and select vascular herbaceous species that are characteristic of mature western mixed mesophytic forests:[a,b]

Canopy and understory trees

Acer pensylvanicum L.
A. rubrum L.
A. saccharum Marsh.
Aesculus flava Solander
Amelanchier arborea (Michx. f.) Fern.
Betula lenta L.
B. alleghaniensis Britt.
Carpinus caroliniana Walt.
Carya cordiformis (Wang.) K. Koch
C. glabra (Mill.)
C. ovata (Mill.) K. Koch
C. tomentosa (Poir.) Nutt.
Cercis canadensis L.
Cladrastis kentukea (Dum.-Cours.) Rudd
Cornus florida L.
Fagus grandifolia Ehrh.
Fraxinus americana L.
Halesia carolina L.
Ilex opaca Ait.
Juglans nigra L.
J. cinerea L.
Liquidambar styraciflua L.
Liriodendron tulipifera L.
Magnolia acuminata L.
M. fraseri Walt.
M. macrophylla Michx.
M. tripetela L.
Morus rubra L.
Nyssa sylvatica Marsh.
Ostrya virginiana (Mill.) K. Koch
Oxydendrum arboreum (L.) DC.
Pinus echinata Mill.
P. rigida Mill.
P. virgiana Mill.
Prunus serotina Ehrhart
Quercus alba L.
Q. coccinea Muenchh.
Q. muhlenbergii Engelm.
Q. montana Willd.
Q. rubra L.
Q. velutina Lam.
Robinia pseudoacacia L.
Sassafras albidum (Nutt.) Nees
Tilia heterophylla Vent.
Tsuga canadensis L. (Carr.)
T. caroliniana Engelm.
Ulmus americana L.
U. alata Michx.

Shrubs

Aralia spinosa L.
Asimina triloba (L.) Dunal
Clethra acuminata Michx.
Cornus alternifolia L. f.
Euonymus americanus L.
E. atropurpureus Jacq.
Hamamelis virginiana L.
Hydrangea arborescens L.
Kalmia latifolia L.
Lindera benzoin (L.) Blume
Pyrularia pubera Michx.
Rhododendron maximum L.
Ribes cynosbati L.
Sambucus canadensis L.
Stewartia ovata (Cav.) Weatherby
Viburnum acerifolium L.

Woody vines

Aristolochia macrophylla Lam.
Bignonia capreolata L.
Celastrus scandens L.
Parthenocissus quinquefolia (L.) Planch.
Smilax tamnoides L.
Vitus spp.

Herbaceous species

Anemone lancifolia Pursh
A. quinquefolia L.
Thalictrum thalictroides (L.) Eames & Boivin
Actaea pachypoda Ell.
Aster spp.
Caulophyllum thalictroides (L.) Michx.
Claytonia caroliniana Michx.
C. virginica L.
Cypripedium calceolus L.
Delphinium tricorne Michx.
Dicentra canadensis (Goldie) Walp.
D. cucullaria (L.) Bernh.
Dioscorea villosa L.
Disporum lanuginosum (Michx.) Nicholson
Erythronium americanum Ker-Gawl.
Eupatorium rugosum Houttuyn
Hydrophyllum spp.
Phlox divaricata L.
Sanguinaria canadensis L.
Sedum ternatum Michx.
Solidago spp.
Stylophorum diphyllum (Michx.) Nutt.
Synandra hispidula (Michx.) Baill.
Tiarella cordifolia L.

Appendix A (continued)

Herbaceous species (continued)
Trillium grandiflorum (Michx.) Salisb.
T. erectum L.
Viola spp.

Ferns
Adiantum pedatum L.
Athyrium filix-femina (L.) Roth
Dryopteris carthusiana (Villars) H.P. Fuchs
D. goldiana (Hooker) A. Gray
Osmunda claytoniana L.
Thelypteris hexagonoptera (Michx.) Weath.
Polystichum acrostichoides (Michx.) Schott

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[a] Nomenclature from Wofford 1989.
[b] Compiled from Braun 1938, McLeod 1988, and Hinkle et al. 1993.

Appendix B

Common birds, mammals, and herpetofauna of mature mixed mesophytic forest:[a]

Birds
Cerulean warbler *(Dendroica cerulea)*
Black-throated green warbler (*D. virens*)
Acadian flycatcher *(Empidonax virescens)*
Black-and-white warbler *(Mniotilta varia)*
Kentucky warbler *(Oporornis formosus)*
Parula warber *(Parula americana)*
Summer tanager (*Piranga rubra*)
Ovenbird *(Seiurus aurocapillus)*
Yellow-throated vireo *(Vireo flavifrons)*

Mammals
Short-tailed shrew *(Blarina brevicauda)*
Opossum *(Didelphis virginiana)*
Big brown bat *(Eptisicus fuscus)*
Southern flying squirrel *(Glaucomys volans)*
Red bat *(Lasiurus borealis)*
Striped skunk *(Mephitis mephitis)*
Little brown bat *(Myotis lucifugus)*
Eastern woodrat *(Neotoma floridana)*
White-tailed deer *(Odocoileus virginianus)*
Hairy-tailed mole (*Parascalops breweri*)
White-footed mouse *(Peromyscus leucopus)*
Eastern pipistrelle *(Pipistrellus subflavus)*
Raccoon *(Procyon lotor)*
Gray squirrel *(Sciurus niger)*
Smoky shrew *(Sorex fumeus)*
Eastern chipmunk *(Tamias striatus)*
Gray fox *(Urocyon cinereoargenteus)*
Black bear (*Ursus americanus*)

Herpetofauna
Copperhead *(Agkistrodon contortrix)*
Green salamander *(Aneides aeneus)*
American toad *(Bufo americanus)*
Fowler's toad *(B. woodhousei)*
Black racer *(Coluber constrictor)*
Worm snake *(Corphophis amoenus)*
Mountain salamander *(Desmognathus monticola)*
Ring-necked snake*(Diadophis punctatus)*
Black rat snake *(Elaphe obsoleta)*
Coal skink *(Eumeces anthracinus)*
Five-lined skink *(Eumeces fasciatus)*
Cave salamander *(Eurycea lucifuga)*
Spring peeper *(Hyla crucifer)*
Gray treefrog *(H. versicolor)*
Red-spotted newt *(Notophthalmus viridescens)*
Slimy salamander *(Plethodon glutinosus)*
Mountain chorus frog (*Pseudacris brachyphona*)
Eastern box turtle *(Terrapene carolina)*
Garter snake *(Thamnophis sirtalis)*
Wood frog *(Rana sylvatica)*

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[a] Adapted from Hinkle et al. 1993.

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United States
Department of
Agriculture

Forest Service

Southern
Research Station

General Technical
Report SRS-19

An Interim Old-Growth Definition for Cypress-Tupelo Communities in the Southeast

Margaret S. Devall

A Section of the Old-Growth Definition Series

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Preface

Old growth is widely acknowledged today as an essential part of managed forests, particularly on public lands. However, this concept is relatively new, evolving since the 1970's when a grassroots movement in the Pacific Northwest began in earnest to define old growth. In response to changes in public attitude, the U.S. Department of Agriculture, Forest Service, began reevaluating its policy regarding old-growth forests in the 1980's. Indeed, the ecological significance of old growth and its contribution to biodiversity were apparent. It was also evident that definitions were needed to adequately assess and manage the old-growth resource. However, definitions of old growth varied widely among scientists. To address this discrepancy and other old-growth issues, the National Old-Growth Task Group was formed in 1988. At the recommendation of this committee, old growth was officially recognized as a distinct resource by the Forest Service, greatly enhancing its status in forest management planning. The committee devised "The Generic Definition and Description of Old-Growth Forests" to serve as a basis for further work and to ensure uniformity among Forest Service Stations and Regions. Emphasis was placed on the quantification of old-growth attributes.

At the urging of the Chief of the Forest Service, all Forest Service Stations and Regions began developing old-growth definitions for specific forest types. Because the Southern and Eastern Regions share many forest communities (together they encompass the entire Eastern United States), their efforts were combined, and a cooperative agreement was established with The Nature Conservancy for technical support. The resulting project represents the first large-scale effort to define old growth for all forests in the Eastern United States. This project helped bring the old-growth issue to public attention in the East.

Definitions will first be developed for broad forest types and based mainly on published information and so must be viewed accordingly. Refinements will be made by the Forest Service as new information becomes available. This document represents 1 of 35 forest types for which old-growth definitions will be drafted.

In preparing individual old-growth definitions, authors followed National Old-Growth Task Group guidelines, which differ from the standard General Technical Report format in two ways—the abstract (missing in this report) and the literature citations (listed in Southern Journal of Applied Forestry style). Allowing for these deviations will ensure consistency across organizational and geographic boundaries.

June 1998

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An Interim Old-Growth Definition for Cypress-Tupelo Communities in the Southeast

Margaret S. Devall

Introduction

Forested wetlands [cypress-tupelo (*Taxodium* spp.-*Nyssa* spp.)] as well as some bottomland hardwood forests, are of increasing interest in the South. They are important in water management, wildlife conservation, habitat diversity, and high quality timber (Ewel and Odom 1984). The acreage of such forests in the region has declined dramatically; for example, at the time of European colonization, Louisiana had an estimated 11 to 12 million acres [4.4 to 4.8 million hectares (ha)] of forested wetlands. At that time, wetlands were considered useful only after they had been drained. The Swamp Land Acts of 1849-50 granted Federally owned swamp lands to the States to be reclaimed and disposed of, and, by 1974, only about 49 percent of the original acreage remained (Turner and Craig 1980).

Virgin cypress swamps were an important source of timber for early settlers. Cutting of cypress began as soon as the French and Spanish arrived in the gulf coastal area, and, by 1723, they were exporting some cypress lumber. However, logging in swamps was difficult, and, although cypress lumbering slowly increased during the colonial period, only the best trees in the most accessible locations were cut. Industrial logging of cypress began around 1890; the dwindling northern lumber industry, availability of cheap land, and development of new logging and milling techniques caused a dramatic increase in the utilization of cypress. However, industrial exploitation of cypress was short-lived, and, by 1925, only a few stands of commercial importance remained (Mancil 1972). By the late 1930's, virgin cypress was extremely scarce. A memorandum written in 1939 by L. Cook, Chief of Forestry of the National Park Service, states: "In Louisiana, cypress logs that have been lying on the ground for many years are now being salvaged due to the growing scarcity of standing timber of large size."

Description

Cypress-tupelo forests occur mainly in the Coastal Plain physiographic province (after Fenneman 1938) from southern Delaware through southern Florida to southeastern Texas and extend northward along the Mississippi River and its major tributaries to southern Illinois. Most cypress is within 98.4 feet [30 meters (m)] above sea level (Harlow and Harrar 1969). This forest type is found almost exclusively in low areas prone to frequent flooding such as swamps, deep sloughs, alluvial flats of major river floodplains, swamps of tidal estuaries, margins of coastal marshes, and isolated depressions of the Coastal Plain. Fine-textured mineral soils predominate in alluvial bottoms, whereas nonalluvial swamps and depressions have surfaces of muck or shallow peat. Most soils are poorly aerated due to saturated conditions.

Principal tree species include baldcypress [*Taxodium distichum* (L.) Rich.], pondcypress (*T. ascendens* Brong.), water tupelo (*N. aquatica* L.), and swamp tupelo (*N. biflora* Walt.). Swamps may be composed of any of these species (Hall and Penfound 1939b). Baldcypress grows larger and faster than pondcypress and is usually associated with flowing water. Pondcypress ordinarily dominates shallow ponds, edges of strands, and other locations where water collects and stands for part of the year (Ewel and Odom 1984). Hall and Penfound (1939b) mention that pondcypress and slash pine (*Pinus elliottii* Engelm.) may be major components of the pine flatwoods of the lower Coastal Plain. Baldcypress is an important component of bottomland hardwood communities, but those forest types are not considered here.

Tree species associated with baldcypress include red maple (*Acer rubrum* L.), sweetbay (*Magnolia virginiana* L.), southern magnolia (*M. grandiflora* L.), sweetgum (*Liquidambar styraciflua* L.), and various oaks (*Quercus* spp.), ashes (*Fraxinus* spp.), and pines (*Pinus* spp). Small trees and shrubs include buttonbush (*Cephalanthus occidentalis* L.), poison-ivy [*Toxicodendron radicans* (L.) Kuntze—S], muscadine grape (*Vitis rotundifolia* Michaux), Spanish moss (*Tillandsia usneioides* L.), cattail (*Typa latifolia* L.), lizardtail (*Saururus cernuus* L.), and various hollies (*Ilex* spp.), viburnums (*Viburnum* spp.), lyonias (*Lyonia* spp.), sedges, grasses, and ferns (Wilhite and Toliver 1990).

Species associated with water tupelo are black willow (*Salix nigra* Marshall), swamp cottonwood (*Populus heterophylla* L.), red maple, waterlocust (*Gleditsia aquatica* Marshall), water-elm (*Planera aquatica* Walter ex J.F. Gmelin.), overcup oak (*Q. lyrata* Walter), water oak (*Q. nigra* L.), water hickory [*Carya aquatica* (Michaux f.)] green and pumpkin ash (*F. pennsylvanica* Marshall and *F. profunda* Bush—S), sweetgum, and redbay [*Persea borbonia* (L.) Sprengel.]. Small trees and shrubs associated with water tupelo include swamp-privet [*Forestiera acuminata* (Michaux) Poiret], buttonbush, sweetbay, Carolina ash (*F. caroliniana* Miller), poison sumac [*T. vernix* (L.) Kuntze—S], southern bayberry (*Myrica cerifera* L.), and dahoon (*Ilex cassine* L.) (Johnson 1990).

Swamp tupelo often occurs in pure stands, although cypress and water tupelo may be associated with it. The species is confined to ponds and sloughs and to the deltas of streams (Hall and Penfound 1939b). Other common associates of swamp tupelo are red maple, buttonbush, buckwheat tree [*Cliftonia monophylla* (Lam.) Britton ex Sarg.], dogwood (*Cornus* spp.), swamp cyrilla (*Cyrilla racemiflora* L.), swamp-privet, Carolina ash, loblolly-bay [*Gordonia lasianthus* (L.) Ellis], dahoon, inkberry [I. *glabra* (L.) Gray], yaupon (I. *vomitoria* Aiton), fetterbush lyonia [*Lyonia lucida* (Lam.) K. Koch], and bayberry (Outcalt 1990).

Pondcypress is commonly found in shallow ponds of the Coastal Plain associated with swamp tupelo. Other species found along the margins and on slightly elevated positions in the ponds are pines, red maple, sweetbay, and loblolly-bay. Small trees and shrubs found in this habitat include buttonbush, yaupon, swamp cyrilla, viburnums, swamp-privet, bayberry, inkberry, ferns, and vines. Pondcypress is also found in some swamps along black-water rivers and creeks, in Carolina bays, in the Okefenokee Swamp, and in pondcypress savannahs. On these sites, it may be associated with the species listed above and many others (Wilhite and Toliver 1990).

Although these species are not considered shade tolerant, the forest type as a whole is considered successional stable (climax) on most sites because prolonged periods of deep flooding prevent seed germination and curtail invasion by more shade-tolerant species. However, where either sediment accumulates or the frequency of flooding diminishes, or both, this forest type may be replaced by others (e.g., bottomland hardwoods). Historically, low intensity, small-scale disturbances were probably most common in these forests, although proximity to the coast ensured occasional large-scale disturbance from storms.

Due to hydric conditions, fire is unusual in these forests except during periods of drought. The principal tree species typically have long life spans; baldcypress, for instance, can live longer than 1,600 years (Earley 1990). Wide age distribution was probably characteristic of original old-growth stands, including trees 200 to 800 years old (Ewel and Odom 1984).

Associated Cover Types

Following are the Society of American Foresters (SAF) forest cover types (Eyre 1980) and Region 8 and Southern Research Station forest types that correspond to the cypress-tupelo community:

Crosswalk with SAF forest cover types:

100—pondcypress
101—baldcypress
102—baldcypress-tupelo
103—water tupelo-swamp tupelo

USDA Forest Service Region 8 forest types:

23—pondcypress
24—baldcypress
67—baldcypress-water tupelo

Southern Research Station forest type:

67—cypress-water tupelo

Old-Growth Conditions

Living Tree Component

Botanists and foresters have been interested in the size of old-growth trees (Brown 1984) (table 1). Mattoon (1915) found baldcypress trees with diameters up to 12 feet (3.6 m) above the swollen buttress and heights of 118 to 128 feet (36 to 39 m). Moore (1967) mentions that Andrew Brown purchased logs for his sawmill in Natchez, MS, that were 4 to 12 feet (1.2 to 3.6 m) in diameter with clear boles as long as 69 feet (21 m). In the early days of cypress logging, the largest trees were left in the forest because they were impossible to cut with the equipment available (Brown 1984). Later, only defective trees were left.

Pondcypress is a much smaller tree than baldcypress; it has a slender bole, usually not over 3 feet (1 m) in diameter, with rounded to flat-topped crowns (Brown 1984). Water tupelo is also much smaller than baldcypress. It is a

Table 1 (English units)—Standardized table of old-growth attributes for cypress-tupelo communities in the Southeast

Quantifiable attribute	Data	No. of stands[a]	References
	Live trees in main canopy		
Stand density	***(No./acre)***		
Taxodium distichum >1 in. d.b.h.	240	1	Hall and Penfound 1939a[b]
T. distichum ≥1 in. d.b.h.	36–252	1	Hall and Penfound 1939b[c]
Nyssa aquatica ≥4 in. d.b.h.	5	1	Martin and Smith 1991[d]
N. aquatica ≥20 in. d.b.h.	3	1	Martin and Smith 1991[d]
N. aquatica >1 in. d.b.h.	300	1	Hall and Penfound 1939a
	48–342	1	Hall and Penfound 1939b
N. biflora >1 in. d.b.h.	840	1	Hall and Penfound 1939a
	0–216	1	Hall and Penfound 1939b
	302	1	Hall and Penfound 1943[e]
T. ascendens >1.6 in. d.b.h.	1,447–7,702	1	Schlesinger 1978
Mixed species >4 in. d.b.h.	1,618	4	Gresham, personal communication[f]
	1,495	4	Gresham, personal communication[g]
	551	1	Gresham, personal communication[h]
Mixed species >50 in. d.b.h.	445	4	Gresham, personal communication[f]
	138	4	Gresham, personal communication[g]
	74	1	Gresham, personal communication[h]
Stand basal area	***(Ft²/acre)***		
T. distichum >1 in. d.b.h.	203	1	Hall and Penfound 1939a
N. biflora >1 in. d.b.h.	139.5[i]	1	Hall and Penfound 1939a
	1,095[j]	1	Hall and Penfound 1939b
T. ascendens	202.5–443.4[k]	1	Schlesinger 1978
Mixed species >4 in. d.b.h.	493.9	4	Gresham, personal communication[f]
	240.9	4	Gresham, personal communication[g]
	81.0	1	Gresham, personal communication[h]
Mixed species >50 in. d.b.h.	384.1	4	Gresham, personal communication[f]
	321.0	4	Gresham, personal communication[g]
	47.9	1	Gresham, personal communication[h]
Average age of large trees[l]	***(Years)***		
T. distichum	500–1,000 max.		Lynch 1991
	700–800		Porcher 1981
	400–600 (up to 1,200)		Harlow and Harrar 1969
	200–800		Ewel and Odum 1984
N. aquatica	93		Martin and Smith 1991
T. ascendens	120–200 (up to 900)		Schlesinger 1978
N. biflora	200		Hall and Penfound 1939b
	Variation in tree diameter		
D.b.h. of largest trees	***(Inches)***		
T. distichum	36–60		Harlow and Harrar 1969
	72 d.n.[m]		Lynch et al. 1991[n]
	48–60, rarely 144		Sargent 1965
	108–120		Lindsey et al. 1961
	63.8		Gresham, personal communication[f]
	30.2		Gresham, personal communication[g]
	33.8		Gresham, personal communication[h]
N. aquatica	36–48		Harlow and Harrar 1969
	25–30		Martin and Smith 1991
	36–48		Lynch et al. 1991[n]
	36–48		Sargent 1965
	46, 23.9		Gresham, personal communication[g]
N. biflora	24–36		Harlow and Harrar 1969
	26.9		Gresham, personal communication[g]
T. ascendens	8–27.5 d.n., 78		Schlesinger 1978

Table 1 (English units)—Standardized table of old-growth attributes for cypress-tupelo communities in the Southeast (continued)

Quantifiable attribute	Data					No. of stands[a]	References
	Dead trees—coarse woody debris						
Standing snags	***(No./acre)***						
T. distichum	Several/3ac						Martin and Smith 1991
N. aquatica	Several/3 ac						Martin and Smith 1991
T. ascendens >1.6 in. d.b.h.	667						Schlesinger 1978
N. biflora >1 in	34						Hall and Penfound 1943
Mixed species, all sizes	321						Gresham, personal communication[f]
	156						Gresham, personal communication[g]
	287						Gresham, personal communication[h]
Downed logs	***(Ft²/acre)***						
T. distichum	Several/3 ac						Martin and Smith 1991
N. aquatica	Several/3 ac						Martin and Smith 1991
Mixed species, all sizes	489						Gresham, personal communication[f]
	178						Gresham, personal communication[g]
	830						Gresham, personal communication[h]
	Tree canopy structure						
Layers	Main canopy/subcanopy/shrub						Hall and Penfound 1939a
	Main canopy/shrub						Schlesinger 1978
	Main canopy/minimal shrub & herb						Hall and Penfound 1943
Percent canopy in gaps[o] (Percent cover)[p]	0–19	20–39	40–59	60–79	80–100		
	5[q]	5	6	35	47		Gresham, personal communication[f]
	0	2	3	9	86		Gresham, personal communication[g]
	23	11	11	19	35		Gresham, personal communication[h]
	Other important features						
Height	***(Feet)***						
T. distichum	100–120						Harlow and Harrar 1969
N. aquatica	80–90						
N. biflora	50–60						

[a] Number of stands may not equal number of citations.
[b] No evidence of cutting or drainage.
[c] Little human influence on stand.
[d] Virgin stand not subject to drainage or cutting.
[e] No evidence of cutting or burning.
[f] Personal communication. February 16, 1995. Charles A. Gresham, Associate Professor, College of Forest and Recreation Resources, The Belle W. Baruch Forest Science Institute, Clemson University, Georgetown, SC 29442. Data from four stands in Beidler Forest.
[g] Personal communication. February 16, 1995. Charles A. Gresham, Associate Professor, College of Forest and Recreation Resources, The Belle W. Baruch Forest Science Institute, Clemson University, Georgetown, SC 29442. Data from four stands in Congaree Swamp National Monument.
[h] Personal communication. February 16, 1995. Charles A. Gresham, Associate Professor, College of Forest and Recreation Resources, The Belle W. Baruch Forest Science Institute, Clemson University, Georgetown, SC 29442. Data from a stand in Santee Experimental Forest, Francis Marion National Forest.
[i] Measured at head height.
[j] Measured above swell.
[k] Measured 3 feet above swell.
[l] Dominant and codominant overstory trees.
[m] d.n. = diameter normal (18" above butt swell).
[n] Lynch, Baker, T. Foti, and L. Peacock. 1991. The White River—Lower Arkansas River megasite: A preserve design project. 95 p. Draft unpublished report. On file with: Arkansas Nature Conservancy, 601 N. University, Little Rock, AR 72205.
[o] 100 measurements per stand.
[p] Percent of upward vertical view of canopy that was leaves and branches.
[q] Five out of 100 measurement points had 0–19% of canopy occupied by leaves and branches.

Table 1 (metric units)—Standardized table of old-growth attributes for cypress-tupelo communities in the Southeast

Quantifiable attribute	Data	No. of stands[a]	References
	Live trees in main canopy		
Stand density	*(No./ha)*		
Taxodium distichum >2.5 cm d.b.h.	240	1	Hall and Penfound 1939a[b]
T. distichum ≥2.5 cm d.b.h.	36–252	1	Hall and Penfound 1939b[c]
Nyssa aquatica ≥10 cm d.b.h.	5	1	Martin and Smith 1991[d]
N. aquatica ≥50 cm d.b.h.	3	1	Martin and Smith 1991[d]
N. aquatica >2.5 cm d.b.h.	300	1	Hall and Penfound 1939a
	48–342	1	Hall and Penfound 1939b
N. biflora >2.5 cm d.b.h.	840	1	Hall and Penfound 1939a
	0–216	1	Hall and Penfound 1939b
	302	1	Hall and Penfound 1943[e]
T. ascendens >4 cm d.b.h.	586–3,117	1	Schlesinger 1978
Mixed species >10 cm d.b.h.	655	4	Gresham, personal communication[f]
	605	4	Gresham, personal communication[g]
	223	1	Gresham, personal communication[h]
Mixed species >50 cm d.b.h.	180	4	Gresham, personal communication[f]
	56	4	Gresham, personal communication[g]
	30	1	Gresham, personal communication[h]
Stand basal area	*(m^2/ha)*		
T. distichum >2.5 cm d.b.h.	46.6	1	Hall and Penfound 1939a
N. biflora >2.5 cm d.b.h.	32[i]	1	Hall and Penfound 1939a
	77.6, 251.4[j]	1	Hall and Penfound 1939b
T. ascendens	46.5–101.8[k]	1	Schlesinger 1978
Mixed species >10 cm d.b.h.	113.4	4	Gresham, personal communication[f]
	55.3	4	Gresham, personal communication[g]
	18.6	1	Gresham, personal communication[h]
Mixed species >50 cm d.b.h.	88.2	4	Gresham, personal communication[f]
	73.7	4	Gresham, personal communication[g]
	11.0	1	Gresham, personal communication[h]
Average age of large trees[l]	*(Years)*		
T. distichum	500–1,000 max.		Lynch 1991
	700–800		Porcher 1981
	400–600 (up to 1,200)		Harlow and Harrar 1969
	200–800		Ewel and Odum 1984
N. aquatica	93		Martin and Smith 1991
T. ascendens	120–200 (up to 900)		Schlesinger 1978
N. biflora	200		Hall and Penfound 1939b
	Variation in tree diameter		
D.b.h. of largest trees	*(cm)*		
T. distichum	91-152		Harlow and Harrar 1969
	183 d.n.[m]		Lynch et al. 1991[n]
	122–152, rarely 366		Sargent 1965
	275–305		Lindsey et al. 1961
	162		Gresham, personal communication[f]
	76.7		Gresham, personal communication[g]
	85.9		Gresham, personal communication[h]
N. aquatica	91–122		Harlow and Harrar 1969
	64–76		Martin and Smith 1991
	91–122		Lynch et al. 1991[n]
	91–122		Sargent 1965
	117		Gresham, personal communication[g]
N. biflora	61–92		Harlow and Harrar 1969
	68.4		Gresham, personal communication[g]
T. ascendens	20–70 d.n., 2 m		Schlesinger 1978

Table 1 (Metric units)—Standardized table of old-growth attributes for cypress-tupelo communities in the Southeast (continued)

Quantifiable attribute	Data	No. of stands[a]	References
	Dead trees—coarse woody debris		
Standing snags	*(No./ha)*		
T. distichum	Several		Martin and Smith 1991
N. aquatica	Several		Martin and Smith 1991
T. ascendens >4 cm d.b.h.	270		Schlesinger 1978
N. biflora >2.5 cm d.b.h.	34		Hall and Penfound 1943
Mixed species, all sizes	130		Gresham, personal communication[f]
	63		Gresham, personal communication[g]
	116		Gresham, personal communication[h]
Downed logs	*(m^3/ha)*		
T. distichum	Several		Martin and Smith 1991
N. aquatica	Several		Martin and Smith 1991
Mixed species, all sizes	198		Gresham, personal communication[f]
	72		Gresham, personal communication[g]
	336		Gresham, personal communication[h]
	Tree canopy structure		
Layers	Main canopy/subcanopy/shrub		Hall and Penfound 1939a
	Main canopy/shrub		Schlesinger 1978
	Main canopy/minimal shrub & herb		Hall and Penfound 1943
Percent canopy in gaps[o] (Percent cover)[p]	0–19 / 20–39 / 40–59 / 60–79 / 80–100		
	5[q] / 5 / 6 / 35 / 47		Gresham, personal communication[f]
	0 / 2 / 3 / 9 / 86		Gresham, personal communication[g]
	23 / 11 / 11 / 19 / 35		Gresham, personal communication[h]
	Other important features		
Height	*(m)*		
T. distichum	30.5–36.6		Harlow and Harrar 1969
N. aquatica	24.4–27.4		
N. biflora	15.2–18.3		

[a] Number of stands may not equal number of citations.
[b] No evidence of cutting or drainage.
[c] Little human influence on stand.
[d] Virgin stand not subject to drainage or cutting.
[e] No evidence of cutting or burning.
[f] Personal communication. February 16, 1995. Charles A. Gresham, Associate Professor, College of Forest and Recreation Resources, The Belle W. Baruch Forest Science Institute, Clemson University, Georgetown, SC 29442. Data from four stands in Beidler Forest.
[g] Personal communication. February 16, 1995. Charles A. Gresham, Associate Professor, College of Forest and Recreation Resources, The Belle W. Baruch Forest Science Institute, Clemson University, Georgetown, SC 29442. Data from four stands in Congaree Swamp National Monument.
[h] Personal communication. February 16, 1995. Charles A. Gresham, Associate Professor, College of Forest and Recreation Resources, The Belle W. Baruch Forest Science Institute, Clemson University, Georgetown, SC 29442. Data from a stand in Santee Experimental Forest, Francis Marion National Forest.
[i] Measured at head height.
[j] Measured above swell.
[k] Measured 3 feet above swell.
[l] Dominant and codominant overstory trees.
[m] d.n. = diameter normal (18 inches above butt swell).
[n] Lynch, Baker, T. Foti, and L. Peacock. 1991. The White River—Lower Arkansas River megasite: A preserve design project. 95 p. Draft unpublished report. On file with: Arkansas Nature Conservancy, 601 N. University, Little Rock, AR 72205.
[o] 100 measurements per stand.
[p] Percent of upward vertical view of canopy that was leaves and branches.
[q] Five out of 100 measurement points had 0 to 19% of canopy occupied by leaves and branches.

medium-to-large tree 79 to 92 feet high (24 to 28 m) and 3 to 4 feet [100 to 122 centimeters (cm)] in diameter at breast height (d.b.h.) The maximum in height is 110 feet (33.5 m) and 6 feet (183 cm) in d.b.h. Water tupelo is found on sites that are periodically under water (Harlow and Harrar 1969). Swamp tupelo is a small-to-medium-sized tree that inhabits swampy lake shores (Brown 1965). Both species have swollen buttresses and looping roots.

Many early botanists visited cypress swamps, and numerous descriptions of the community type have been published. However, little quantitative data exist. In 1876, Ridgway (Lindsey et al. 1961) described Little Cypress Swamp across the Wabash River from Mt. Carmel, IN. He stated that the swamp covered 20,000 acres (8094 ha), timbered mostly with baldcypress. The largest trees [9 to 10 feet (2.7 to 3 m) in diameter] had been cut usually at the beginning of the cylindrical portion of the tree. Ridgway wrote that the swollen buttresses of the trees were "growing so near together that the intervening spaces are entirely taken up by the knees, the whole surface thus being an irregular wooden one, with soil or water only in the depressions." Lindsey et al. (1961) published a photograph of a huge baldcypress tree, taken near the mouth of the White River by Ridgway in 1888, and labeled "average size mature *Taxodium*."

Williams, Inc. harvested several stands of virgin baldcypress from swamps in south Louisiana around 1919. The number of board feet per tree harvested ranged from 555 to 2,841 (1.31 to 6.70 m^3) for live baldcypress, 288 to 1,458 (0.68 to 3.42 m^3) for dead baldcypress, and 407 to 729 (0.96 to 1.72 m^3) for water tupelo. During 1903 to 1907, an average volume of 38,926 board feet per acre (226.76 m^3 per ha) was harvested from 3,800 acres (1537 ha) of cypress-tupelo swamp in the Bay Wallace area.[1]

Hall and Penfound (1939b) studied a 200-year-old virgin swamp tupelo (*N. biflora*) swamp at the edge of the Pearl River Valley in southeastern Louisiana. The trees, 82 feet (25 m) high, were slender above the conspicuous swollen buttresses; they had numerous looping roots. The d.b.h. averaged 25.7 inches (65.3 cm), whereas diameter above the buttresses [10 feet (3 m)] averaged 14.5 inches (36.8 cm). Swamp tupelo was the only important tree component.

Hall and Penfound (1939a) also investigated a virgin baldcypress-tupelo swamp that had invaded marshlands along the Pearl River. The authors measured trees >1 inch (>2.5 cm) at head height, just above the swollen buttress, so that better comparisons could be made with other forest types (diameter at the bottleneck). They state that although Indian Village swamp was considered a baldcypress-gum swamp, it was really a *Nyssa biflora* consocies, with swamp tupelo the dominant species (55 percent of trees per acre and 65 percent of crown cover). The authors note that the basal area of the community 203 square feet per acre (46.6 m^2 per ha) was approximately equal to that of a mature virgin longleaf pine community 205 square feet per acre (47 m^2 per ha). Swamp tupelo had a basal area of 139.5 square feet per acre (32 m^2 per ha) and occupied 69 percent of the basal area; baldcypress, 16 percent; water tupelo, 14 percent; and red maple, 1 percent. Average age of baldcypress was 85 years. The understory included individuals of the canopy species as well as pumpkin ash and buttonbush.

Age Characteristics

Harlow and Harrar (1969) reported that baldcypress trees in virgin stands averaged 400 to 600 years old with some up to 1,200 years old. Other authors also describe baldcypress trees 500 to 1,000 years old (table 1). Although few baldcypress trees of that age are living today, Van Deusen et al. (1993) cored living baldcypress trees up to 1,270 years of age in swamps in Louisiana and Mississippi.

Canopy Characteristics

Old baldcypress trees have broad, low, rounded crowns often 98 feet (30 m) across. Usually baldcypress makes up the canopy in this community, whereas water tupelo or swamp tupelo make up the subcanopy. However, other combinations may also be found.

Beidler Swamp is a 799–acre (728.5–ha) original growth tract with three climax bottom-land forests: swamp forest, hardwood bottom, and ridge bottom. The canopy baldcypress trees are 120 feet (36.6 m) tall, whereas the water tupelo subcanopy is approximately 80 feet (24.4 m) tall. The largest baldcypress trees are 5 to 6 feet (150 to 180 cm) in diameter and 700 to 800 years old (Porcher 1981).[2] Baldcypress and tupelo occur in pure stands in the lowest parts of the swamp, but, in the higher parts, other tree species occur. Carolina ash forms a subcanopy below the tupelo in some areas, usually growing from the bases of the baldcypress or water tupelo trees. Swamp tupelo is scattered

[1] Personal communication. 1992. Rudy Sparks, Vice President, Williams, Inc., 107 McGee Drive, Patterson, LA 70392.

[2] Dennis, J.V. 1970. Four Holes Swamp, Berkeley and Dorchester Counties, SC: Study of the natural history and matters pertaining to acquisition of one of the last large virgin bottomland swamps in the South. 55 p. Unpublished report. On file with: The Nature Conservancy, 1815 N. Lynn Street, Arlington, VA 22209.

throughout the forest and occasionally reaches the canopy (Porcher 1981).

In Indian Village Swamp (Hall and Penfound 1939a), total crown cover just as buds were opening was 20 percent. Swamp tupelo made up approximately 65 percent of the cover, whereas the rest was formed by other canopy species. When the trees were fully leafed out, crown cover was 60 percent.

Schlesinger (1978) studied 17 stands in the Okefenokee Swamp in Georgia. The forests were along the middle fork of the Suwannee River and are thought to be undisturbed remnants of the former extensive forest. Canopy trees were 8 to 28 inches (20 to 70 cm) in d.b.h. and 66 feet (20 m) tall. Water depth ranged from 6 inches to 3 feet (15 cm to 1 m). Pondcypress was by far the dominant species in the overstory, although density and basal area of cypress varied among sites by 1,448 to 7,702 stems per acre (586 to 3,119 stems per ha) and 202 to 444 square feet per acre (46.5 to 101.8 m^2 per ha), diameter was measured above the swell—about 3 feet (1 m) above the water level.

Dead Tree Component

Standing Snags—Little data are available on the dead tree component of the cypress-tupelo community. Hall and Penfound (1939b) state that 302 living trees and 34 dead trees per acre (122 and 14 per ha) occurred in a swamp near Pearl River in southeastern Louisiana. Several of the early workers in swamps mentioned that herbaceous vegetation germinates and grows on logs and stumps because the swamp floor is too wet or flooded.

Down Woody Debris—Very little data have been collected on large woody debris, but some studies of litterfall have been carried out. Annual litterfall in Okefenokee Swamp (Schlesinger 1978) was 0.067 pounds per square foot [328 grams (g) per m^2], with 68 percent falling between October and December. Of the total, 0.046 pounds per square foot (222 g per m^2) (68 percent) was cypress needles, 0.0021 pounds per square foot (10.23 g per m^2) was cypress twigs, and 0.0089 pounds per square foot (43.37 g per m^2) was bark.

Understory Characteristics

Cypress seeds do not germinate in water (Mattoon 1916, Demaree 1932), so dense stands of cypress seedlings are established during periodic drought when large areas of unoccupied soil are exposed. Distinct cohorts of equal-sized individuals are present as young trees. The cohorts reaching the canopy converge in size to form a canopy 11 to 16 inches (28 to 40 cm) in diameter. As these trees age, separate groups merge, and old stands are dominated by a number of large individuals. Schlesinger (1978) found that the size of the average tree at a site grew sixfold as density was reduced, but forest biomass per ha remained the same.

The large tupelo seeds are distributed by water. They become stranded in the mud as the water recedes, and many germinate. Seedlings on poorly drained sites grow slowly but are not as likely to be suppressed by other species as those that germinate in better drained sites (Harlow and Harrar 1969). Shade-tolerant seedlings generally cannot invade cypress-tupelo swamps because of prolonged flooding. The shrub and herbaceous layers are often sparse, also because of flooding, whereas woody vines and epiphytes, especially Spanish moss, are common. Schlesinger (1978) reported that the biomass of Spanish moss in Okefenokee Swamp equaled the total biomass of herbaceous plants in most upland temperate forests. In deep water cypress-tupelo swamps, logs and stumps may support distinctive vegetation, and floating mats of litter or peat may serve the same purpose (Huenneke and Sharitz 1986).

Woody species found in Indian Village Swamp (Hall and Penfound 1939a) include swamp tupelo, water tupelo, baldcypress, red maple, pumpkin ash, Virginia willow, and buttonbush, which the authors considered true swamp species. Border species that occurred on elevated portions of the swamp floor, around the bases of trees and on knees, as well as vines that climbed on the dominant swamp species were: yellow jessamine [*Gelsemium sempervirens* (L.) Aiton f.], poison ivy, bayberry, greenbrier (*Smilax walteri* Pursh.), wisteria [*Wisteria frutescens* var. *macrostachya* (Nutt.) T.& G.], storax (*Styrax americana* Lam.), pepper-vine [*Ampelopsis arborea* (L.) Koehne], greenbrier (*Smilax laurifolia* L.), Carolina ash, Virginia creeper [*Parthenocissus quinquefolia* (L.) Planchon], dogwood (*Cornus* spp.), sweet pepperbush (*Clethra alnifolia* L.), possum haw (*Ilex decidua* Walter), blackberry *Rubus* spp., and holly (*Ilex opaca* Aiton).

Small individuals of waterlocust and water-elm occur throughout the Beidler Swamp, sometimes growing from the bases of baldcypress or tupelo and sometimes rooted in the soil. Four other tree species occur in the forest rooted on fallen logs, large cypress knees, and buttresses: laurel oak (*Q. laurifolia* Michaux), red maple, and American elm (*Ulmus americana* L.). The shrub layer in the Beidler Swamp is well developed on the high portion of the swamp forest, with the plants growing in the soil and on buttresses, knees, fallen logs, and stumps. Species include: Virginia willow, storax, fetterbush [*Leucothoe racemosa* (L.) Gray], fetterbush lyonia, swamp dogwood (*C. stricta* Lam.), buttonbush, viburnum, and possum haw, as well as vines and occasional canopy and subcanopy species. Where standing water occurs most of the year, the shrub layer is sparse, with Virginia willow, storax, buttonbush, fetterbush, and fetterbush lyonia growing from buttresses (Porcher 1981).

Density of shrubs >3 feet high (1 m) ranged from 36,818 to 105,759 stems per acre (14,900 to 42,800 stems per ha) in the Okefenokee Swamp. Four species accounted for 71 percent of the importance value: Virginia willow, fetterbush lyonia, fetterbush, and sweet pepperbush. There was little relation between the character of the shrub layer and the overstory.

The herbaceous flora of the Beidler Swamp forest is particularly rich and varied. In the deep areas of the swamp, herbs are confined to floating logs, stumps, knees, and buttresses. Three species found only in this portion of the swamp are: skullcap (*Scutellaria latiflora* L.), lycopus (*Lycopus rubellus* Moench.), and St. John's wort (*Hypericum virginicum* L.). Other species that occur here as well as in higher areas of the swamp and adjacent communities include: netted chain-fern [*Woodwardia aerolata* (L.) Moore], false nettle [*Boehmeria cylindrica* (L.) Swartz], butterweed (*Senecio glabellus* Poiret), sensitive fern (*Onoclea sensiblis* L.), cardinal flower (*Lobelia cardinalis* L.), diodia (*Diodia virginiana* L.), and St. John's wort. Pokeweed (*Phytolacca americana* L.) and dog-fennel (*Eupatorium compositifolium* Walter), two weed species, are occasionally found here. Where high areas occur, the following herbs are found: obedient plant [*Dracocephalum purpureum* (Walter) McClintock], water pimpernell (*Samolus parviflorus* Raf.), milkweed (*Asclepias perennis* Walter), golden club (*Orontium aquaticum* L.), peltandra [*Peltandra virginica* (L.) Kunth.], bulrush (*Scirpus divaricatus* Ell.), bulrush (*S. fontinalis* Harper), proserpinaca (*Proserpinaca palustris* L.), and cardinal flower. An occasional spruce pine (*P. glabra* Walter) sapling occurs here. It is apparent that this is a mature, climax forest because of the great size variation among dominant trees and the numerous fire-scarred stumps and trunks of live trees (Porcher 1981).

Only a few herbaceous species were found in Indian Village Swamp (Hall and Penfound 1939a) due to the low light intensity and long hydroperiod. The most common species were proserpinaca, spider lily [*Hymenocallis occidentalis* (Le Conte) Kunth.], micranthemum [*Globifera umbrosa* (Walter) J.F. Gmelin—S], and bladderwort [*Utricularia macrorhiza* (Le Conte)—S]. Species occurring rarely included pumpkin ash (seedlings), buttonbush (young), bacopa [*Hydrotrida caroliniana* (Walter) Small—S], justicia [*Justicia ovata* var. *lanceolata* (Chapm.) R.W. Long], and greenbrier (*S. walteri* Pursh). Resurrection fern [*Polypodium polypodiodies* (L.) Watt] occasionally grew on the trunks of the trees and Spanish moss was conspicuous on the trees, especially on the mature trees. Little shrub or herbaceous cover was found (<2 percent, four species) in the nearby tupelo swamp (Hall and Penfound 1939b); this was attributed to the long hydroperiod, a great range in water level of 0 to 12 feet (0 to 3.7 m), and dense shade. The authors state that this is common in primeval swamps. Three conspicuous epiphytes were present: resurrection fern, green fly orchid [*Amphiglottis conopsea* (Aiton) Small—S], and Spanish moss.

Soils

Baldcypress grows best on deep, fine, sandy loam with moderately good drainage, but, because of competition, it is usually found in permanent swamps. The species extends into the coastal region of brackish tidewater but grows poorly there (Harlow and Harrar 1969).

Baldcypress sites are distinguished by frequent, prolonged flooding with water of up to 10 feet (3 m) or more and flow rates of up to 4 miles [6 kilometers (km)] per hour (although occasionally stagnant). The species is found on intermittently flooded and poorly drained phases of Spodosols, Ultisols, Inceptisols, Alfisols, and Entisols. It occurs in the thermic and hyperthermic soil temperature regimes (Wilhite and Toliver 1990).

Pondcypress occurs on the impoverished and poorly drained phases of Spodosols and Ultisols of the thermic and hyperthermic soil temperature regimes. Soils range from sands to clays to mucks to peats. Pondcypress grows in shallow ponds and poorly drained sites on the Coastal Plain, seldom in the swamps of rivers and streams. Pondcypress grows on soils with a pH of 6.8 or lower, and baldcypress occurs on soils with a pH of 5.5 or higher. Usually pondcypress sites are much less fertile than baldcypress sites and are flat or with slight depressions called domes (Wilhite and Toliver 1990).

Water tupelo grows in low, wet flats or sloughs and in deep swamps. It grows best in the sloughs and swamps of Coastal Plain rivers and in the large swamps of southwestern Louisiana and southeastern Texas. Water may reach a depth of 20 feet (6 m) and may remain as high as 13 feet (4 m) for long periods. Soils that support water tupelo range from mucks and clays to silts and sands and are in the orders Alfisols, Entisols, Histisols, and Inceptisols. Most are moderately to strongly acidic; subsoil often is rather permeable (Johnson 1990).

Swamp tupelo grows on an assortment of wet, bottom-land soils, including organic mucks, heavy clays, and wet sands, mainly on soils of the orders Ultisols, Inceptisols, and Entisols. It thrives under flooded conditions and is seldom found on sites that are not inundated most of the growing season. The species occurs in headwater swamps, strands, ponds, river bottoms, bays, estuaries, and low coves. It does not usually occur in the deep parts of swamps. The water regime is more important than soil type for good growth of swamp tupelo; it grows best on soil that is continuously saturated, with shallow moving water (Outcalt 1990).

Hall and Penfound (1939a) examined the water content of the soil in Indian Village Swamp. At the end of a long hydroperiod, the water content was 197 percent, 505 percent, 343 percent, and 289 percent in the first, second, third, and fourth foot of the soil. The amount of material driven off by combustion (for the same samples) was 22 percent, 44 percent, 39 percent, and 38 percent, respectively. Soil pH values ranged from 6.1 to 6.7.

In the nearby tupelo area at times of flood, the amount of water at the 1-foot (0.3-m) level (as based on the dry weight of the soil) was 4.67 times the oven-dry weight of the soil, but this decreased to 1.22 at the 4-foot (1.2-m) level because little organic matter was present (Hall and Penfound 1939b). There was more sand at the 4-foot (1.2-m) level. The loss by combustion was approximately 11 percent at the 1- to 3-foot (0.3 to 0.9 m) levels and 9 percent at the 4-foot (1.2-m) level. The soil was strongly acidic (pH 5.1 to 5.3).

Associated Flora and Fauna

The cypress-tupelo community is an important habitat for numerous animals and birds including neotropical migrant birds. Bird censuses were carried out from 1979 to 1989 in the Francis Beidler Forest (a national Audubon sanctuary in Four Holes Swamp, SC). This is a virgin hardwood swamp forest with the largest stand of original growth cypress and water tupelo in the United States (Brunswig and Winton 1978, Porcher 1981). Species present in the swamp included: northern parula warbler (*Parula americana*), blue-gray gnatcatcher (*Polioptila caerulea*), great crested flycatcher (*Myiarchis crinitus*), tufted titmouse (*Parus bicolor*), red-eyed vireo (*Vireo olivaceous*), yellow-billed cuckoo (*Coccyzus americanus*), prothonotary warbler (*Protonotaria citrea*), cardinal (*Cardinalis cardinalis*), Acadian flycatcher (*Empidonax virescens*), white-breasted nuthatch (*Sitta carolinensis*), hooded warbler (*Wilsonia citrina*), yellow-throated warbler (*Dendroica dominica*), Carolina chickadee (*Parus carolinensis*), Carolina wren (*Thryothorus ludovicianus*), white-eyed vireo (*Vireo griseus*), brownheaded cowbird (*Molothrus ater*), wood thrush (*Hylocichla mustelina*), pine warbler (*Dendroica pinus*), red-bellied woodpecker (*Centurus carolinus*), downy woodpecker (*Picoides pubescens*), wood duck (*Aix sponsa*), chimney swift (*Chaetura pelagica*), ruby-throated hummingbird (*Archilochus colubris*), eastern wood peewee (*Contopus virens*), Swainson's warbler (*Limnothlypis swainsonii*), summer tanager (*Piranga rubra*), barred owl (*Strix varia*), and pileated woodpecker (*Dryocopus pileatus*). Visitors included: the red-shouldered hawk (*Buteo lineatus*), yellow-crowned night heron (*Nycticorax violacea*), white ibis (*Eudocimus albus*), mourning dove (*Zenaida macroura*), blue jay (*Cyanocitta cristata*), common crow (*Corvus brachyrynchos*), and fish crow (*Corvus ossifragus*).

Although the old-growth cypress-tupelo community is an excellent habitat for fungi and mosses, little data are recorded on their occurrence in this community. Epiphytes were abundant in Indian Village Swamp (Hall and Penfound 1939a); bryophytes grew on the lower 40 feet (12.2 m) of tree trunks. A community of *Pallavicinia lyelli*, sometimes with *Odontoschisma* spp., occurred on the edges of the swamp on slight elevations, on knees, and around the bases of trees. *Riccardia latifrons* and *R. pinguis* occurred on decaying logs. *Fontinalis sullivanti* inhabited the submerged bases of baldcypress and gum trees, and above that was a community dominated by *Porella pinnata*. From the part of the trunks that were rarely submerged to about 30 feet (9 m) above the ground, there existed a community of *Leucolejeunea clypeata*, *Leocolejeunea unciloba*, *Radula sullivanti*, and other less numerous species. The upper portion of the trunks and some branches were colonized with a sparse xeric community of *Frullania* spp. In the swamp tupelo swamp studied by Hall and Penfound (1939b), mosses and liverworts were common in the trunks of trees.

Other Important Features

Water quality is important to the old-growth baldcypress-tupelo community, but little data on it are available. Michael Dawson provided water quality data for the Francis Beidler

Forest.[3] Mean turbidity (1978–92) for quarterly samples taken from two sites in the swamp ranged from 12.5 to 23.5 at Canoe Lake and from 13.7 to 22.7 for Goodson Lake; pH ranged from 7.0 to 7.1 and 6.8 to 7.0; dissolved oxygen ranged from 5.0 to 9.5 and 4.3 to 9.1; hardness ranged from 4.6 to 6.0 and 4.4 to 4.7; phosphates ranged from 0.27 to 1.01 and 1.56 to 2.03, respectively.

Forest Dynamics and Ecosystem Function

Swamps such as red river cypress-tupelo swamps, with high nutrient input during flooding and alternating periods of decomposition, are among the most productive of ecosystems; however, swamps with little intra- or intersystem nutrient circulation, such as headwater swamps and cypress ponds, can be low in productivity. If permanent water inhibits decomposition and nutrient input via drainage is negligible, as in the Okefenokee system, tree growth will be slow and ultimate tree size will be small. In the Okefenokee system, the net effect of geological processes is to remove nutrients from circulation. The deepest peats in Okefenokee are 6,500 years old, so nutrients have been accumulating for some time (Schlesinger 1978).

Disturbance Regime—Ewel and Mitsch (1978) stated that dominance of cypress in some swamps is maintained partly by occasional fires that damage scarcer species. Schlesinger (1978) noted that numerous charcoal deposits, some at great depth, suggest that fire played an important role in the Okefenokee Swamp. Large fires occurred during droughts in 1844, 1910, 1932, and 1954–55. Fire scars on the large pondcypress trees suggest that the understory must have been severely burned in 1954–55. Comparison of burned and unburned stands suggests that fire increases the dominance of cypress by reducing the number of species and the relative importance of broadleaf species.

Hurricanes and other major disruptions strongly influence the structure and composition of many forests and also affect succession (Lugo et al. 1983). However, the cypress-tupelo community seems better able to withstand hurricanes and severe storms than other community types. Hurricane Hugo (September 21, 1989) seriously damaged only 19 percent of trees in sloughs of Congaree Swamp, SC, and few trees were uprooted. Hugo reduced canopy diversity by uprooting many species other than baldcypress and water tupelo, especially trees rooted on fallen logs, etc. Storms such as Hurricane Hugo can cause changes in composition for some time after they occur. The heavy fuel loads increase the likelihood of fire, and resprouted trees will be more susceptible to wood-rotting organisms and further mechanical damage (Putz and Sharitz 1991).

Current Conditions—The current forest community differs from that of presettlement time in several ways. Changes have occurred in the abundance of plants and animals that inhabit the cypress-tupelo community, and introduced plants and animals are causing problems. Although fires occurring in swamps during droughts can be difficult to put out, suppression of fires originating outside of swamps no doubt leads to less burning within. Large predators, such as the black bear and the Florida panther, are scarce everywhere, and thus are less likely to occur now in swamps than they were formerly. Partly due to the absence of large predators, animal herbivore populations are increasing and can influence the vegetative composition of the community. Introduced animals, such as the nutria (*Myocastor coypu*), are impeding baldcypress regeneration as they often destroy seedlings by eating the root collar. Introduced tree species, such as Chinese tallow [*Sapium sebiferum* (L.) Roxb.] and Brazilian pepper (*Schinus terebinthifolia* Raddi), are changing the composition of some cypress-tupelo communities.

On most sites, the cypress-tupelo forest is considered a climax community because extended periods of flooding restrict invasion by shade-tolerant species. Disturbances such as hurricanes and fires also help to restrict entry of other tree species into swamps. However, if flooding is reduced or eliminated, the forest type may be replaced by shade-tolerant species.

Representative Old-Growth Stands

Areas where representative old-growth stands may appear include:

- Grassy Lake Natural National Landmark, Hempstead County, AR
- Moro Creek Bottoms Preserve, Cleveland and Calhoun Counties, AR
- Big Cypress Bend, inside or near Fakahatchee Strand State Preserve, FL
- Big Cypress Nature Preserve, Collier County, FL
- Bayou DeView Bald Cypress Stand, Monroe County, AR

[3] Dawson, Michael. 1995. Bird data and water chemistry. 16 p. Unpublished report. On file with: Francis Beidler Forest, 336 Sanctuary Road, Harleyville, SC 29448.

- Corkscrew Swamp Sanctuary, Collier County, FL
- Gum Swamp Research Natural Area, Osceola National Forest, FL
- Heather Island, Marion County, FL
- Jim Creek Cypress Swamp, Tosohatchee State Reserve, FL
- Orange Lake Cypress, Marion County, FL
- Strand West of Cow Bone Island, Seminole Indian Reservation, FL
- Pond Cypress Swamps, Apalachicola National Forest, FL
- Tate's Hell Swamp, Franklin County, FL
- Ebenezer Creek Swamp, east of Springfield, GA
- Lewis Island Natural Area, northwest of Darien, GA
- Heron Pond, Johnson County, IL
- Little Black Slough, Johnson County, IL
- Lower Cache River State Natural Area, southern Illinois
- Bayou Sale Swamp, LA
- Big Cypress, Bienville Parish, LA
- Black Bayou Swamp, Tangipahoa Parish, LA
- Coochie Brake, southwest of Winnfield, LA
- Cunningham Brake, southwest of Cypress, LA
- Jim Reed Bayou Swamp/Black Bayou Swamp, Tangipahoa Parish, LA
- White Kitchen Preserve, near Slidell, LA
- Allred Lake Natural Area, Butler County, MO
- Big Oak Tree Natural Area, Big Oak Tree State Park, MO
- Cash Swamp Natural Area, Dunklin County, MO
- Black River Site, NC
- Beidler Sanctuary, Dorchester County, SC
- Congaree Swamp National Monument, south of Columbia, SC
- Four Holes Swamp, SC
- Guilliard Lake Scenic and Research Natural Area, Berkley County, SC

Acknowledgment

Thanks to Michael Dawson for data on Beidler Forest, to Rudy Sparks for data on old-growth cypress on Williams, Inc. lands, and to Charles Gresham for data on old-growth cypress in Beidler Forest, Congaree Swamp National Monument, and Francis Marion National Forest. We appreciate the helpful information provided by John Toliver and Latimore Smith. Greg Nowacki provided some of the references and information on the cypress-tupelo community, and the names of representative old-growth stands.

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